9478 H2 PHYSICS

JC 1 PROMO EXAM PAST YEAR PAPERS (SOLUTION)

MEASUREMENTS

KINEMATICS

DYNAMICS

FORCES

WORK, ENERGY POWER

CIRCULAR MOTION

GRAVITATIONAL FIELD

OSCILLATIONS

TEMPERATURE & IDEAL GASES

FIRST LAW OF THERMODYNAMICS

WAVE MOTION

NANYANG JUNIOR COLLEGE
JC1 PHYSICS TEAM
SCIENCE DEPARTMENT
2025

H

NANYANG JUNIOR COLLEGE
JC 1 END OF YEAR EXAMINATION
Higher 2

CANDIDATE NAME	Solution

CLASS		TUTOR'S NAME	
CENTRE NUMBER	S	INDEX NUMBER	

PHYSICS 9749/01

Paper 1 Multiple Choice

1 October 2024

40 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

There are **twenty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

1	2	3	4	5	6	7	8	9	10
C	D	C	B	D	D	C	D	C	B
11	12	13	14	15	16	17	18	19	20
A	C	A	B	C	A	B	D	C	B

This document consists of **12** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Which of the following is the best estimate of the weight of a basketball?

A 5000 mg

B 0.500 kg

C 5.0×10^{-6} MN

D 5.0×10^{11} nN

Ans: C
Option A and B are masses, not weights.
Option C: $5.0 \times 10^{-6} \times 10^{6} = 5.0$ N (≈ 0.5 kg equivalent)
Option D: $5.0 \times 10^{11} \times 10^{-9} = 500$ N (≈ 50 kg equivalent)

2 In an experiment, the external diameter d_1 and internal diameter d_2 of a glass tube are found to be 82 ± 2 mm and 53 ± 1 mm respectively.

What is the percentage uncertainty of the term $(d_1 - d_2)$?

A 0.7% **B** 3% **C** 4% **D** 10%

Ans: D

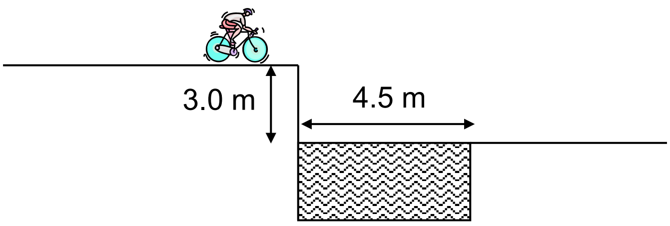
$$\Delta(d_1 - d_2) = \Delta d_1 + \Delta d_2 = 2 + 1 = 3\text{ mm}$$

$$\text{Percentage uncertainty} = \frac{\Delta(d_1 - d_2)}{(d_1 - d_2)} \times 100\%$$

$$= \frac{3}{82 - 53} \times 100\%$$

$$= 10\%\ (2\text{ sig. fig.})$$

3 A cyclist moving horizontally takes off from a point 3.0 m above the river surface, landing 4.5 m away as shown.



cross-section of river channel

What was the speed at take-off?

A 3.1 m s^{-1} **B** 3.2 m s^{-1} **C** 5.8 m s^{-1} **D** 7.4 m s^{-1}

Ans: C

Use vertical component to determine time of flight:

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$3.0 = \frac{1}{2} \times 9.81 \times t^2$$

$$t \approx 0.782\ \text{s}$$

Use horizontal component to determine speed at take off

$$s_x = u_x t$$

$$4.5 = u_x \times 0.782$$

$$u_x \approx 5.75\ \text{m s}^{-1}$$

Option D looks possible, but question mentioned that cyclist landed 4.5m as shown. The question is NOT asking what are the possible speeds that the cyclist can have to clear the channel.

4 A trolley moves down a slope with a constant acceleration *a*. The mass of the trolley is now doubled and the trolley is allowed to move down the same slope. In both cases, effects of friction and air resistance are negligible.

Which statement is correct for the second experiment?

A The acceleration is $\frac{1}{2}a$.

B The acceleration is *a*.

C The acceleration is 2*a*.

D The resultant force is the same.

Ans: B

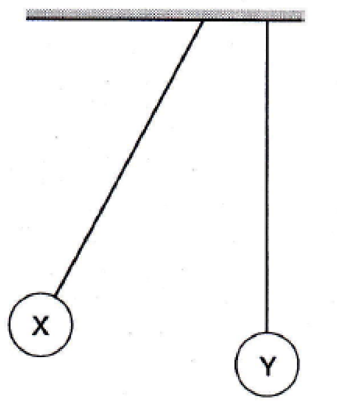
$\Sigma F = ma$

$mg\sin\theta = ma$

$a = g\sin\theta$

Acceleration is independent of mass.

5 Two steel balls X and Y are suspended on strings. Ball X is pulled to one side as shown.



After ball X is released, the balls collide.

Which quantities must be conserved in the collision?

A kinetic energy, total energy and momentum

B kinetic energy and momentum only

C kinetic energy and total energy only

D total energy and momentum only

Ans: D

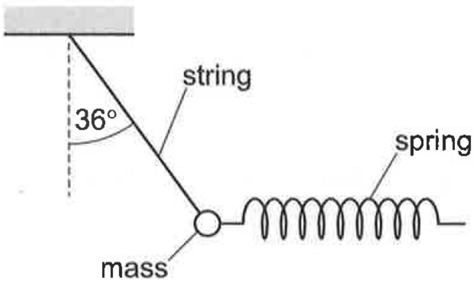
Some kinetic energy may be converted to other forms of energy such as sound energy. However, by conservation of energy, total energy MUST be conserved.

Momentum is also conserved since there is no net external force acting on the system.

Take note that the question is only concern IN THE COLLISION, hence we do not need to look at the processes before and after the collision.

6 A mass is tied to the end of a string. The mass is pulled horizontally to one side by a spring of spring constant 25 N m^{-1}.

The mass is in equilibrium and the extension of the spring is 0.060 m. The string is at an angle of 36° to the vertical, as shown.

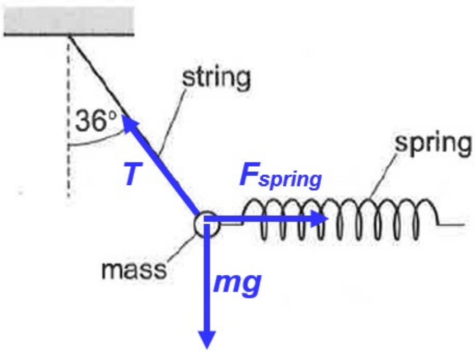


What is the weight of the mass?

A 1.1 N **B** 1.5 N **C** 1.9 N **D** 2.1 N

Ans: D

With reference to the FBD of the mass,



$\sum F_x = 0$

$F_{spring} = T \sin\theta$

$kx = T \sin\theta$ --- (1)

$\sum F_y = 0$

$W = T \cos\theta$ --- (2)

(1)/(2): $\dfrac{kx}{W} = \tan\theta$

$W = \dfrac{kx}{\tan\theta} = \dfrac{(25)(0.06)}{\tan 36} = 2.1\text{ N}$

7 As a gun fires a shot horizontally, a constant force F is exerted on the bullet of mass m over a time interval t. During this period, the bullet accelerates from rest to a speed v in the gun's barrel with an acceleration a. The length of the gun's barrel is L.

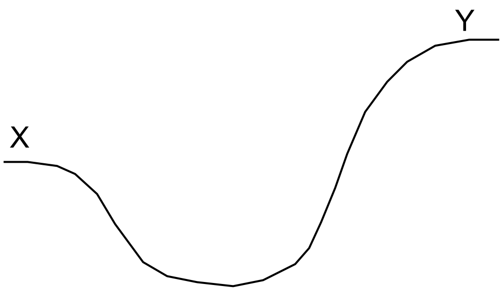
Which of the following gives the expression for the average power of the bullet in the described motion?

A Fv **B** $\frac{2maL}{t}$ **C** $\frac{mv^2}{2t}$ **D** $\frac{mv^2}{t}$

Ans: C

Average power = $\frac{\text{energy gained}}{\text{time taken}} = \frac{\frac{1}{2}mv^2}{t}$

8 A body moves from X to Y along a track. At point Y, its kinetic energy is 25 kJ and its potential energy is 30 kJ more than that at point X.



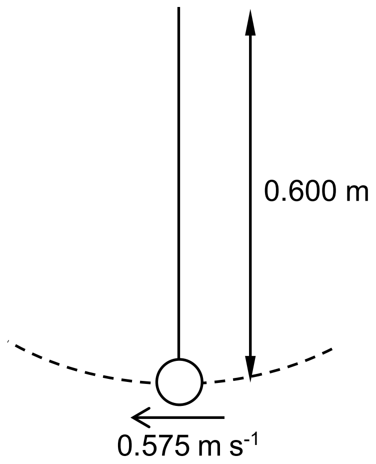
If the work done against friction along XY is 10 kJ, what is the kinetic energy of the body at X?

A 35 kJ **B** 45 kJ **C** 55 kJ **D** 65 KJ

Ans: D
By Principle of conservation of energy,

$$KE_X + GPE_X + W_{by friction} = KE_Y + GPE_Y$$
$$KE_X - 10 = KE_Y + \Delta GPE$$
$$= 25 + 30$$
$$KE_X = 25 + 30 + 10 = 65 \text{ kJ}$$

9 A pendulum bob of mass 1.27 kg is supported by a string so that the radius of its path is 0.600 m. It is moving with velocity 0.575 m s^{-1} horizontally at the lowest point of its motion when the string is vertical.



What is the tension in the string at this instant?

A 11.8 N **B** 12.5 N **C** 13.2 N **D** 13.7 N

Ans: C

$\Sigma F_c = ma_c$

$T - mg = \dfrac{mv^2}{r}$

$T = \dfrac{mv^2}{r} + mg = \dfrac{1.27(0.575)^2}{0.600} + 1.27(9.81) = 13.2\text{ N}$

10 An Earth satellite is moved from one stable circular orbit to another stable circular orbit at a greater distance from the Earth.

Which one of the following quantities increases for the satellite as a result of the change?

A Gravitational force

B Gravitational potential energy

C Angular velocity

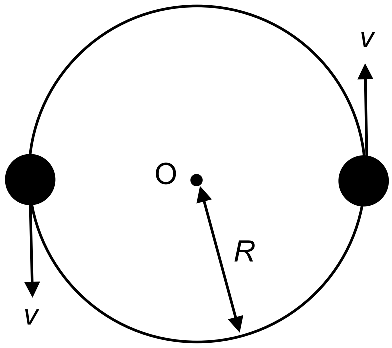
D Tangential velocity

Ans: B

Since $U = -\dfrac{GMm}{r}$, when r increases, U becomes less negative.

As U is a scalar, being less negative means that it increases.

11 Two stars of equal mass M move with constant speed v in a circular orbit of radius R about their common centre of mass O as shown.



What is the magnitude of the centripetal force on each star?

A $\dfrac{GM^2}{4R^2}$ **B** $\dfrac{GM^2}{R^2}$ **C** $\dfrac{2Mv^2}{R}$ **D** $\dfrac{Mv^2}{2R}$

Ans: A

Using Newton's law of gravitation, $F = \dfrac{Gm_1m_2}{r^2}$ where m_1 and m_2 are the respective masses and r is the distance between the 2 masses:

$$F = \frac{GMM}{(2R)^2} = \frac{GM^2}{4R^2}$$

12 A fixed mass of an ideal gas is at a pressure of 1.0×10^5 Pa. It has a temperature of 300 K and a volume of 0.010 m^3.

What is the total kinetic energy of the gas molecules after the volume is changed to 0.0050 m^3 at constant temperature?

A 500 J **B** 1000 J **C** 1500 J **D** 2000 J

Ans: C

The internal energy of an ideal gas is the sum of the kinetic energy due to the distribution of random motion of the gas particles.

$$\langle E_k \rangle = \frac{3}{2}kT$$

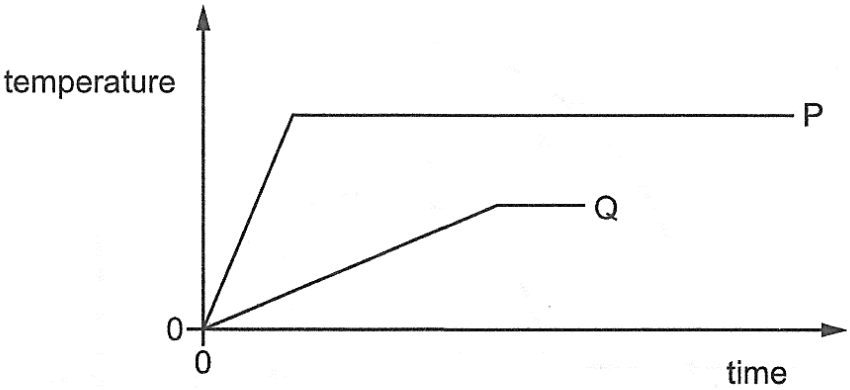
$$\sum E_k = \frac{3}{2}NkT$$

Since it was proven that $= \dfrac{3}{2}pV$ (Using $pV = NkT$ and since $\Delta T = 0$)

$$= \frac{3}{2}\left(1.0 \times 10^5\right)(0.01)$$

$$= 1500 \text{ J}$$

13 Thermal energy is supplied at the same rate to equal masses of two different solids, P and Q. The graphs show how the temperatures of the solids change with time. Each line finishes when the solid it represents has completely changed to liquid.



How do the values for the specific heat capacities and specific latent heat of fusion compare with each other?

	specific heat capacity of P	specific latent heat of fusion of P
A	smaller than Q	larger than Q
B	smaller than Q	smaller than Q
C	larger than Q	larger than Q
D	larger than Q	smaller than Q

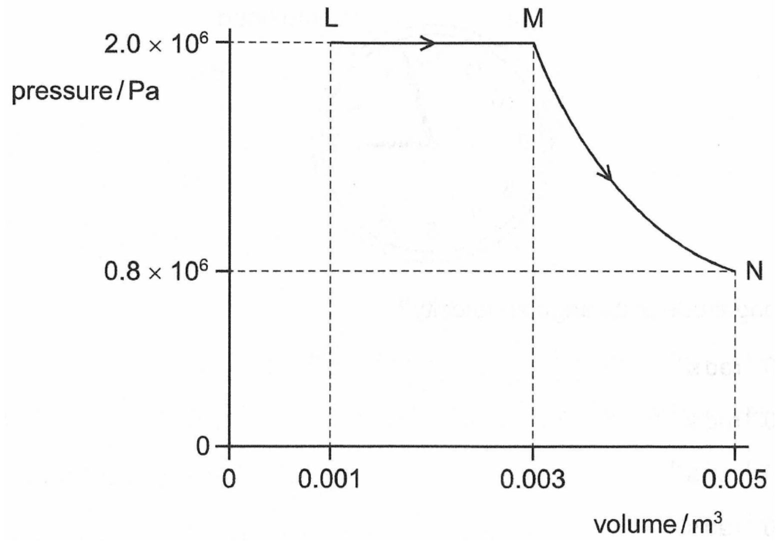
Ans: A

Since thermal energy is being supplied at the same rate to both masses, this suggests that the amount of energy supplied to each mass is proportional to the duration where thermal energy is being supplied.

The temperature of P increase at a rate faster than Q (steeper gradient) shows that for the same amount of thermal energy supplied, the temperature rises more significantly for P. This implies that less thermal energy is needed to raise a unit temperature of P compared to Q which suggests that P has a smaller specific heat capacity compared to Q.

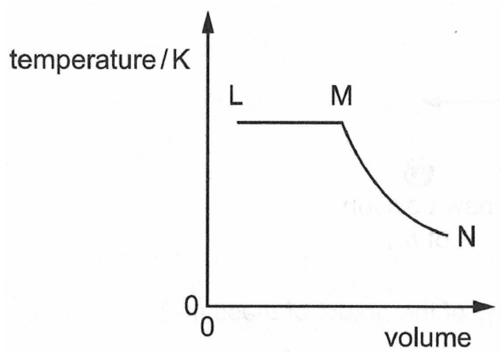
Melting of both solids takes place when temperature remains constant. As P takes a longer duration to melt compared to Q, it implies that more thermal energy is needed to completely melt P compared to Q (for same masses). This suggests that P has a larger specific latent heat of fusion compared to Q.

14 A fixed mass of ideal gas undergoes changes of pressure and volume starting at L, as shown.

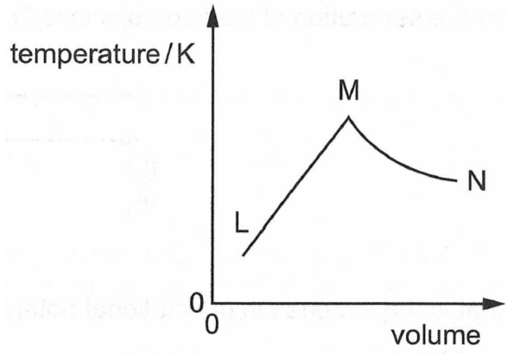


Which graph shows how temperature (measured in kelvin) changes with volume?

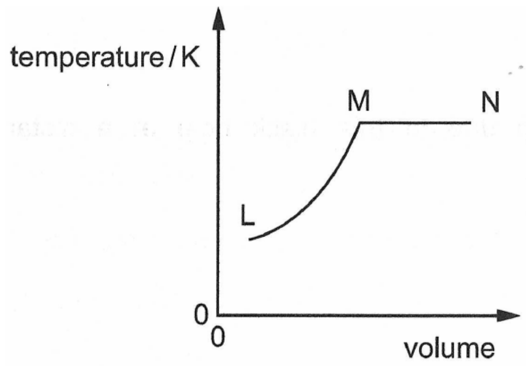
A



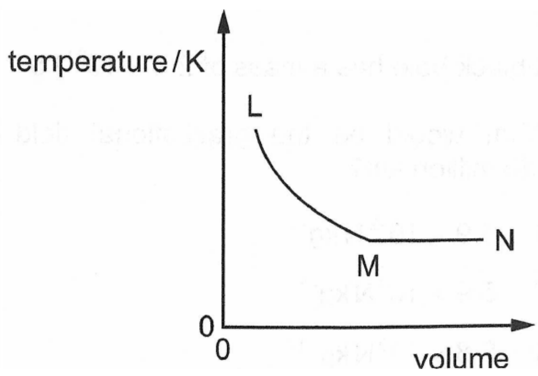
B



C



D



Ans: B

Note: question said "for a fixed mass of…" implies no. of mol *n* is constant

Process LM: constant pressure process, so $V \propto T \Rightarrow V = kT$. When plotted as *T* against *V*, should get a straight line with positive gradient (incidentally, option B already shows this!). For learning purposes, note that $T_M > T_L$.

Process MN: Warning, do not assume isothermal process just because curve looks like an isotherm! Use the given values to check:

$$\frac{P_M V_M}{T_M} = \frac{P_N V_N}{T_N}$$

$$\frac{T_N}{T_M} = \frac{0.8 \times 10^6 \times 0.005}{2.0 \times 10^6 \times 0.003} = \frac{4000}{6000} = \frac{2}{3}$$

$$T_N = \frac{2}{3} T_M \quad \therefore T_M > T_N$$

Here, we can clearly see MN is not an isothermal process, in fact $T_M > T_N$.

15 An object placed on a horizontal platform is vibrating vertically in simple harmonic motion with a frequency of 1.9 Hz.

What is the amplitude of oscillation which will allow the object to just lose contact with the platform throughout the motion?

A 2.5 cm **B** 5.1 cm **C** 6.9 cm **D** 8.2 cm

Ans: C
When the platform is above the equilibrium position, acceleration of object on platform will be downwards.

$F_{net} = ma$

$mg - N = m\omega^2 x_0$

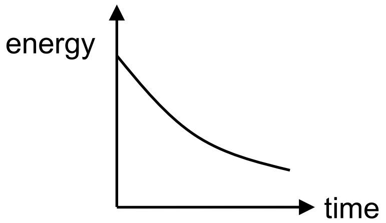
For max amplitude to reamin in contact, $N = 0$

$m(9.81) - 0 = m\left[2\pi(1.9)^2\right]x_0$

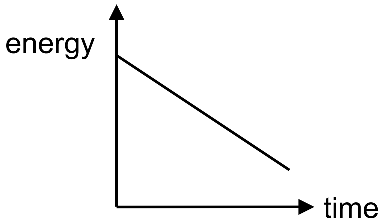
$x_0 = 0.069\,\text{m} = 6.9\,\text{cm}$

16 Which of the following graphs shows the variation with time of the total energy of an object subjected to light damping?

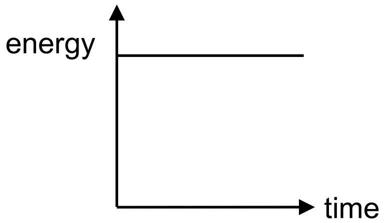
A



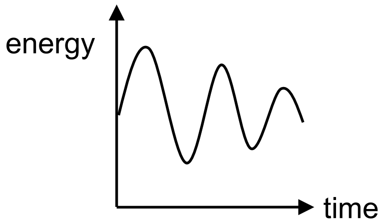
B



C

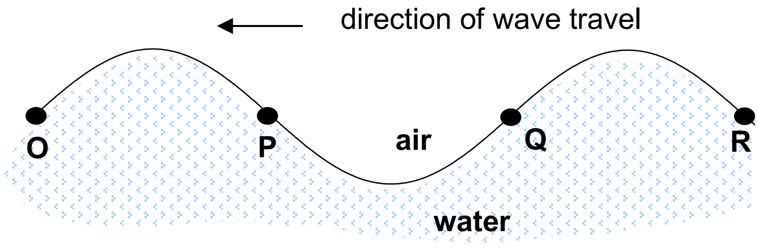


D

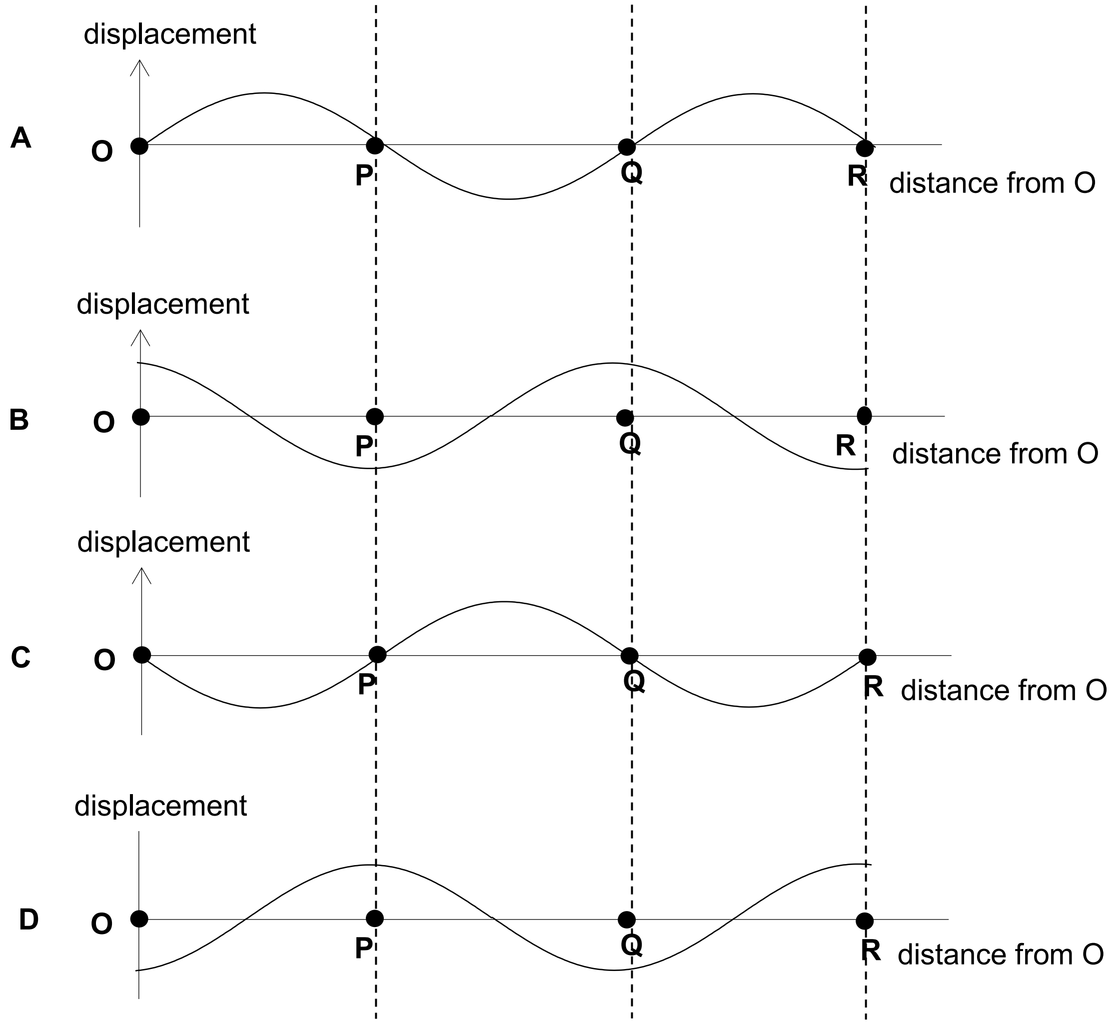


Ans: A
Amplitude of oscillation decreases exponentially, causing the shape of the graph to be a curve.

17 The wave profile of a surface wave on water at a particular instant is shown in the diagram below.

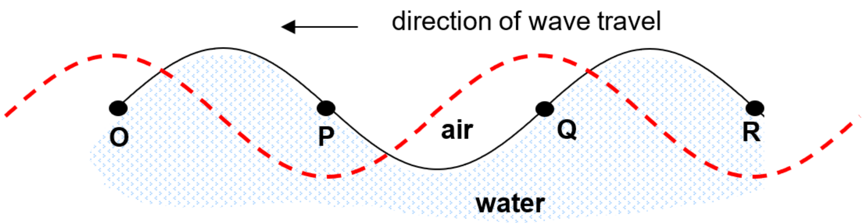


Which one of the graphs below best represents the wave profile a quarter period later, taking upward displacement as positive?

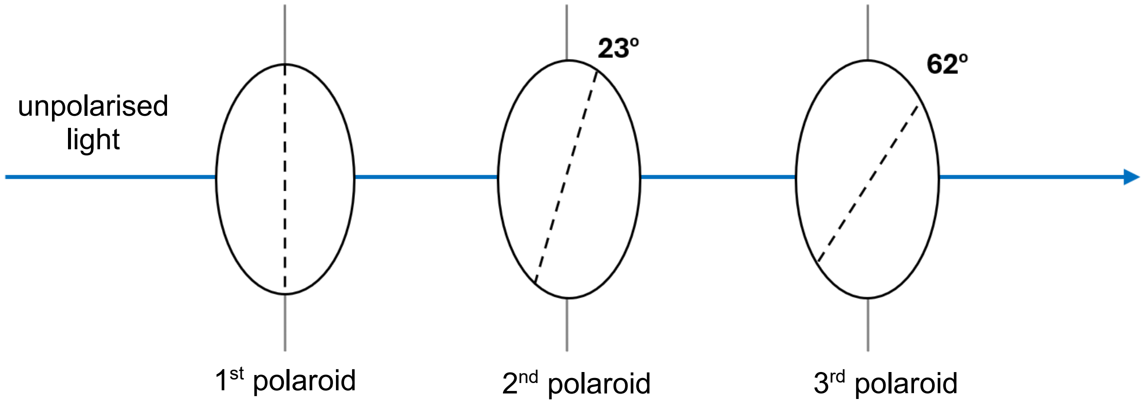


Ans: B

The best way to visualise is to draw, the crest before P will move to the left to be just above O.



18 Light is polarised when it passes through a sheet material known as a polaroid. Three polaroids are stacked, with the polarising axis of the second and third polaroids at 23˚ and 62˚ respectively to that of the first polaroid, as shown in the diagram below.



When an unpolarised light is incident on the stack of polaroids, its amplitude after passing through the first polaroid is A_1, and becomes A_2 after it passes through the second polaroid, and subsequently A_3 after it passes through the third polaroid.

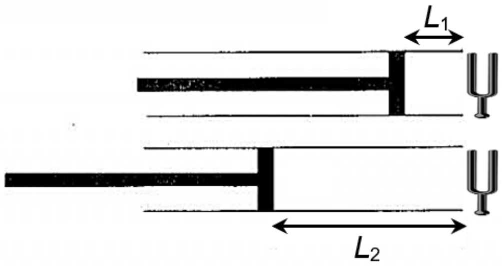
What is the value of $\dfrac{A_3}{A_1}$?

A 0.25 **B** 0.31 **C** 0.43 **D** 0.72

Ans: D
Since the amplitude after 1st polariser is A_1, to obtain the amplitude after the second polariser will be $A_2 = A_1 \cos(23^\circ)$ and after third polariser will be $A_3 = A_2 \cos(62^\circ - 23^\circ)$

Thus, $A_3 = A_1 \cos(23^\circ)\cos(39^\circ) = 0.72\,A_1$

19 A tuning fork of frequency f is held near the open end of a tube which is closed at the other end.



The length of the tube is adjusted until resonance occurs. The two shortest lengths of the tube that produce resonance are L_1 and L_2, where $L_1 < L_2$.

Which of the following expressions represents the speed of the sound?

A $\dfrac{1}{2} f(L_2 - L_1)$ **B** $f(L_2 - L_1)$ **C** $2f(L_2 - L_1)$ **D** $2f(L_2 + L_1)$

Ans: C
For the shortest length, $1/4\ \lambda = L_1$ and $¾\ \lambda = L_2$, $\lambda = 2(L_2 - L_1)$

Speed = $f\lambda = 2f(L_2 - L_1)$

20 A space shuttle orbits at a height of 330 km above the surface of the Earth. It carries two light sources separated by a distance of 24 m. The light sources emit light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the light sources with a telescope that has an aperture diameter of 85 mm. Assuming that the light sources can be treated as point sources of light for the observer.

Which of the following is correct?

	Will the two light sources seen by the observer be resolved?	Angular separation of two light sources as measured from aperture / rad
A	Yes	5.9×10^{-6}
B	Yes	7.3×10^{-5}
C	No	5.9×10^{-6}
D	No	7.3×10^{-5}

Ans: B

For the two sources, $\sin\alpha = \dfrac{12}{330000} \quad \Rightarrow \quad \alpha = 3.64\times10^{-5}\,\text{rad}$

Thus, the angular separation is $2\alpha = 7.27\times10^{-5}\,\text{rad}$

For the telescope, for the object to be just resolved, $\theta_{res} = \dfrac{500\times10^{-9}}{85\times10^{-3}} = 5.88\times10^{-6}$ rad

Since the actual angular separation is larger than θ_{res}, image is resolved.

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: Solution

CLASS:

TUTOR'S NAME:

PHYSICS 9749/02

Paper 2 Structured Questions

1 October 2024

1 hour 50 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 7**
2	**/ 6**
3	**/ 6**
4	**/ 11**
5	**/ 9**
6	**/ 7**
7	**/ 6**
8	**/ 10**
9	**/ 12**
Total	**/ 74**

This document consists of **20** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Fig. 1.1 shows the cross section of a smooth long ramp inclined at 20° to the horizontal. P and Q are 50.0 cm apart. A ball at point P moves up the ramp with a speed of 30.0 cm s^{-1}.

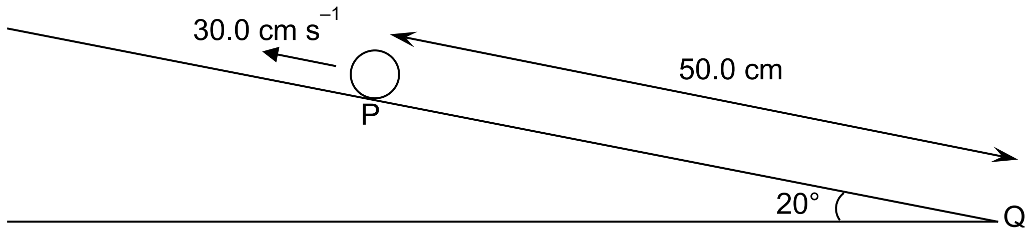


Fig. 1.1

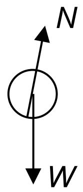
(a) **(i)** Using Newton's second law of motion, show that the deceleration of the ball is 3.4 m s^{-2}. [1]

Taking downslope as positive,

Fnet = *ma*

mgsin 20° = ma [M1]

Acceleration = 9.81sin 20° = 3.3552 m s^{-2} = 3.4 m s^{-2} [A0] (downslope)



(ii) Calculate the time taken for the ball to reach point Q at the bottom of the ramp.

Taking downslope as +ve,

$s = ut + \frac{1}{2}at^2$

$0.500 = -0.300t + \frac{1}{2}(3.4)t^2$ [M1]

$t = 0.63769 = 0.64$ s [A1]

https://www.youtube.com/watch?v=HuqJW1iZ6vI

time taken = ... s [2]

(b) The ball at point P is now given an initial velocity of 60.0 cm s^{-1} *in the plane of the slope*. The initial velocity is in a direction 30° to PS as shown in Fig. 1.2a. This causes the ball to travel upslope and then downslope without leaving the ramp, as shown in the side view in Fig. 1.2b.

PS is parallel to QR and perpendicular to PQ. The ball reaches the bottom of the ramp at point R.

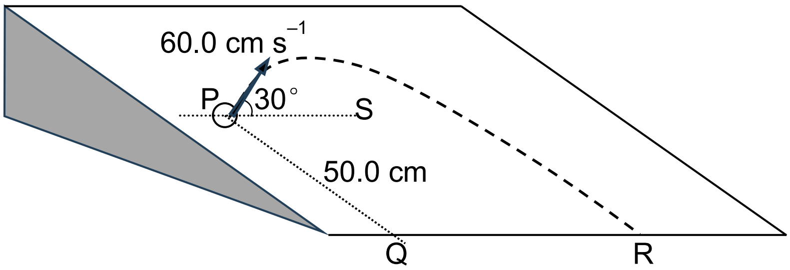


Fig. 1.2a (3-D view)

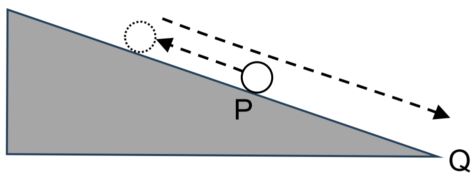


Fig. 1.2b (2-D side view)

(i) Explain why the path of the ball is parabolic.

The resultant acceleration of the ball is constant and directed parallel down the ramp. Thus, it only causes the velocity directed parallel down the ramp to change [B1], but the velocity component perpendicular to the slope of the ramp does not change [B1] This causes a parabolic path.

....[2]

(ii) Calculate the distance QR.

u_x = 0.60 cos 30°

x = 0.60 cos 30° × 0.64 [M1]

= 0.33 m [A1]

distance QR = ... m [2]

2 **(a)** Explain what is meant by *upthrust*.

- **Upthrust** is the net upwards force exerted by a fluid on a submerged or floating object.
- It arises due to the difference in pressure between the upper and lower surfaces of the object.

Both points above to be present before B1 mark is given.

(b) Before a small balloon is inflated, its mass recorded on an electronic mass balance is 1.30 g. The balloon is inflated with air and becomes spherical in shape with a diameter of 22.0 cm.

(i) The density of air is 1.21 kg m^{-3}. Determine the mass of air displaced by the balloon.

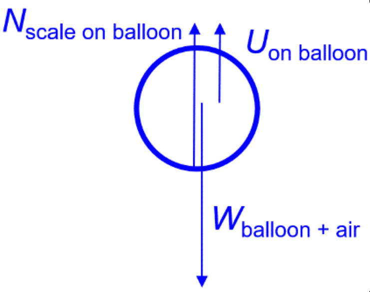
$$M = \rho V$$
$$= \rho\left(\frac{4}{3}\pi r^3\right)$$
$$= (1.21)\left(\frac{4}{3}\pi(11.0\times10^{-2})^3\right) \quad \text{[C1]}$$
$$= 0.00675\ \text{kg}$$
$$= 6.75\ \text{g} \quad \text{[A1]}$$

mass of air displaced = ... g [2]

(ii) The inflated balloon gives reading of 1.55 g when placed on the balance. Calculate the mass of air in the balloon.

From FBD, since the balloon is in equilibirum,

$$\sum F_{net} = 0$$
$$U_{\text{on balloon}} + N_{\text{scale on balloon}} = W_{\text{balloon + air}}$$
$$W_{\text{air displaced}} + N_{\text{scale on balloon}} = W_{\text{balloon + air}} \quad (\because U = \text{weight of fluid displaced})$$
$$(6.75\times10^{-3})(9.81) + (1.55\times10^{-3})(9.81) = (m_{\text{air in balloon}} + m_{\text{balloon}})(9.81)$$
$$(8.30\times10^{-3})(9.81) = (m_{\text{air in balloon}} + 1.30\times10^{-3})(9.81) \quad \text{[M1]}$$
$$m_{\text{air in balloon}} = 7.00\times10^{-3}\ \text{kg}$$
$$= 7.00\ \text{g} \quad \text{[A1]}$$



mass of air in balloon = ... g [2]

(iii) Explain why the value in **(b)(ii)** is larger than the value in **(b)(i).**

The air is being compressed by the elastic balloon material so is at a higher pressure and hence denser. Hence, it has a greater mass in the same volume. [B1]

....[1]

3 Fig. 3.1 shows a horizontal table where surface TU is smooth and UV is rough. Block A, with a mass of 1.5 kg, is at rest. An inextensible string attached to block A passes over a smooth pulley and supports block B of mass 0.50 kg at its other end.

Block B is released from rest and block A just reaches point U as block B hits the floor.

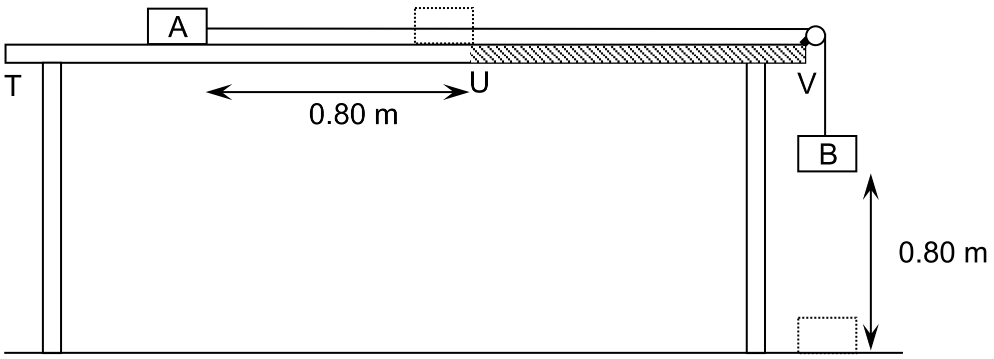


Fig. 3.1

(a) Using energy considerations, show the maximum kinetic energy of block A is 2.9 J.

Gain in K.E. by the whole system

= loss in G.P.E. by B

= mgh = (0.5)(9.81)(0.80) = 3.924 J [C1]

Maximum K.E. of A occurs just before B hits the floor (and they both have the same speed) [M1]

$$= \frac{m_A}{m_A + m_B} \times 3.924$$

$$= \frac{1.5}{2.0} \times 3.924 = 2.943 \approx 2.9 \text{ J}$$ [A0]

[2]

(b) Block A continues to slide along the rough surface from U to V until it comes to rest in 0.60 s. Assuming that the frictional force on block A by the rough table is constant, determine the distance moved by block A in the 0.60 s.

As the string is now **not** taut, the only (horizontal) force acting on Block A is the frictional force, f, by the table; $F_{net} = f$ (directed to the left)

Initial velocity of block A at U $= \sqrt{\frac{2 \times E_k}{m_A}} = \sqrt{\frac{2 \times 2.9}{1.5}} = 1.966 \text{ ms}^{-1}$

acceleration = $= \frac{v-u}{t} = \frac{0-1.966}{0.60} = -3.27667 \text{ ms}^{-2}$ [B1]

F_{net} = 1.5 x -3.27667 = - 4.915 N [C1]

by PCOE,

$$W_{net} = \Delta E_k$$
$$-F_{net}s = 0 - 2.9$$
$$-(4.915)s = -2.9$$
$$s = 0.5900 \text{ m} \approx 0.59 \text{ m}$$ [A1]

2nd method: use v^2 = u^2 + 2as / 3rd method: <v> = 1.966/2. Then d=<v>*t

(c) State and explain how your answer to **(a)** will change if the mass of the pulley is not negligible.

The maximum KE of block A will decrease. The loss in GPE of block B will be converted to gain in the KE of both block A and the rotational KE of the pulley.

....[1]

4 The Earth and the Moon may be considered to be spheres that are isolated in space with their masses concentrated at their centres.

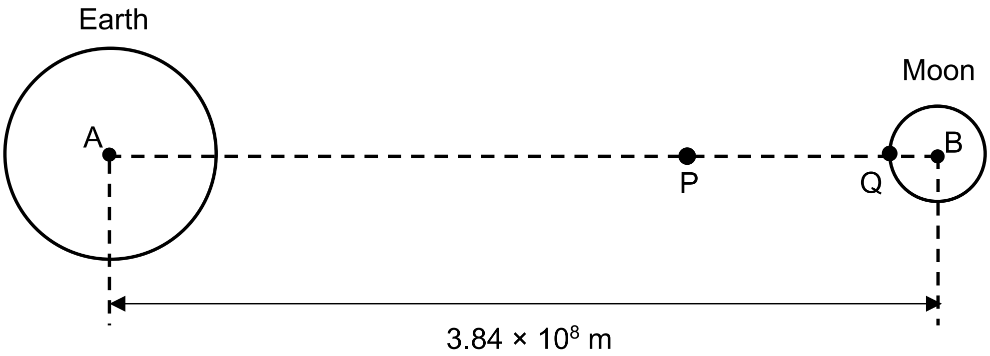


Fig. 4.1

Fig. 4.2 provides some astronomical data for the Earth and the Moon.

Mass of the Earth	5.98×10^{24} kg
Mass of the Moon	7.35×10^{22} kg
Radius of the Earth	6.38×10^{6} m
Radius of the Moon	1.74×10^{6} m
Distance from the centre of Earth to the centre of Moon	3.84×10^{8} m

Fig. 4.2

(a) Define *gravitational potential* at a point.

The gravitational potential at a point in a gravitational field is defined as the work done per unit mass by an external agent [B1] in bringing a small test mass from infinity to that point [B1].

....[2]

(b) Show that the resultant gravitational potential at point Q on the surface of the Moon due to both the Earth and the Moon is -3.86×10^{6} J kg^{-1}.

$$\Phi = \left(-\frac{GM_{Earth}}{r_{Earth}}\right) + \left(-\frac{GM_{Moon}}{r_{Moon}}\right)$$

$$\Phi = \left(-\frac{6.67\times10^{-11}\times5.98\times10^{24}}{3.84\times10^{8}-1.74\times10^{6}\ ^{[B1]}}\right) + \left(-\frac{6.67\times10^{-11}\times7.35\times10^{22}}{1.74\times10^{6}}\right)\ ^{[B1]}$$

$$= -3.86\times10^{6}\ \text{J kg}^{-1}\ ^{[A0]}$$

[2]

(c) The table in Fig. 4.3 shows the values of the gravitational potential along the line AB. The distances are measured from the surface of the Earth.

Distance from surface of Earth / 10^8 m	Gravitational potential / 10^6 J kg^{-1}	Remarks
0.00	-62.5	At the surface of the Earth
1.99	-1.97	[redacted]
2.00	-1.96	Point P
2.01	-1.95	[redacted]
3.40	-1.28	Neutral point (zero resultant gravitational force)
3.76	-3.86	Point Q on the surface of the Moon

Fig. 4.3

(i) Using data from Fig. 4.3, estimate the magnitude of the gravitational field strength at point P, at a distance of 2.00 × 10^8 m from the surface of the Earth.

$$\text{gravitational field strength} = \frac{\left(-1.95-(-1.97)\times 10^6\right)}{\left(2.01-1.99\right)\times 10^8} \quad \text{[M1]}$$

$$= 0.010 \text{ N kg}^{-1} \quad \text{[A1]}$$

magnitude of gravitational field strength = ... N kg^{-1} [2]

(ii) Using your answer in **(c)(i)**, calculate the linear speed of an object which is in circular orbit around the Earth at point P.

The net gravitational force due to the Earth and the Moon provides the centripetal force for the object to move in circular motion.

$$\Sigma F_c = ma_c$$

$$mg_{net} = \frac{mv^2}{r}$$

$$v = \sqrt{g_{net} r}$$

$$= \sqrt{(0.010)(2.00\times 10^8 + 6.38\times 10^6)} \quad \text{[M1]}$$

$$= 1440 = 1400 \text{ m s}^{-1} \quad \text{[A1]}$$

speed = ... m s^{-1} [2]

(d) An object is projected from the Earth to the Moon.

Using the data in Fig. 4.3 and ignoring any energy losses due to air resistance, estimate the minimum kinetic energy with which this object of mass 10.0 kg would need to be projected in order to reach the surface of the Moon. Explain your working.

The object must have enough kinetic energy to cross the neutral point (> 3.400×10^8 m), after which the resultant force acts toward the Moon. [B1]

$$KE_1 + PE_1 = KE_2 + PE_2$$

$$KE + m\Phi_1 = 0 + m\Phi_2$$

$$KE = 10.0(-1.28-(-62.5))\times 10^6 \quad \text{[M1]}$$

$$= 6.12\times 10^8 \text{ J} \quad \text{[A1]}$$

minimum kinetic energy = ... J [3]

[Total: 11]

5 **(a)** State what is meant by the internal energy of a system.

The internal energy of a system is the sum of the random distribution of kinetic energy and potential energy of all the molecules.

KE+PE of molecules [B1]
Random motion/distribution [B1]

(b) A balloon contains a fixed mass of air that expands on heating, as illustrated in Fig. 5.1.

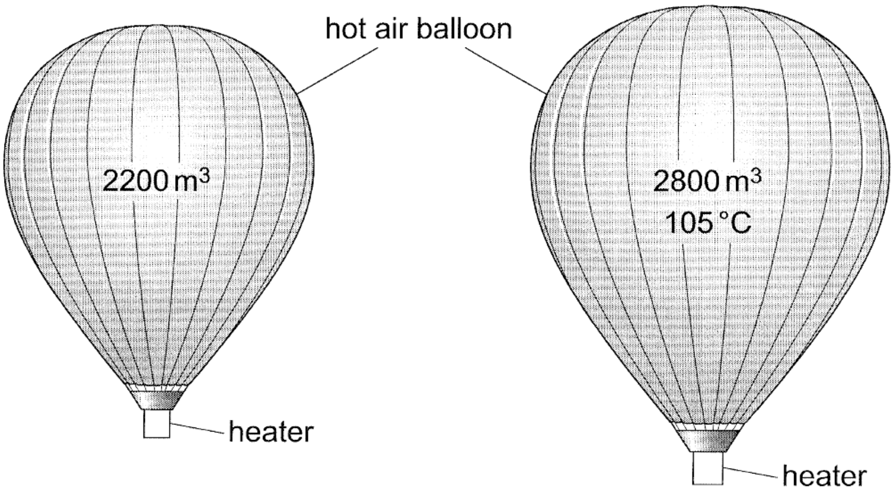


Fig. 5.1

The air is heated to a final temperature of 105 °C and the balloon expands at atmospheric pressure from 2200 m^3 to 2800 m^3, when it is fully inflated.

The air inside the balloon may be assumed to be an ideal gas.

Atmospheric pressure is 1.01×10^5 Pa.

(i) Calculate the work done by the expanding balloon on the atmosphere.

$$\begin{aligned} W_{\text{by gas}} &= p\Delta V \\ &= p(V_{\text{final}} - V_{\text{final}}) \\ &= (1.01\times10^5)(2800-2200) \\ &= 6.06\times10^7\,\text{J} \end{aligned}$$
[A1]

work done = ... J [1]

(ii) Explain, using simple kinetic model, why the internal energy of the air in the balloon

When temperature increases, the average KE and hence the sum of KE increases. [B1]

No/negligible change in PE. [B1]

Hence, the internal energy increases.
Do not accept answers using 1st law of thermodynamics as amount of heat provided

....[2]

(iii) The propane used in the heater produces 50 MJ of thermal energy for each kilogram of fuel that is burned. The air inside the balloon gains 116 MJ of internal energy during the expansion.

Calculate the minimum mass of propane which must be burned to fully inflate the balloon.

Using First Law of thermodynamics,

$\Delta U = Q + W_{\text{on gas}}$

$Q = \Delta U - W_{\text{on gas}}$

$Q = 116 \times 10^6 + 6.06 \times 10^7$

$= 177 \times 10^6 \text{ J}$ [M1]

Mass of propane needed $= \dfrac{177 \times 10^6}{50 \times 10^6}$

$= 3.52 \text{ kg}$ [A1]

(iv) Calculate the initial temperature, in °C, of the air.

fixed mass so Nk constant

isobaric so p constant

Using $pV = NkT$

$\dfrac{T_i}{V_i} = \dfrac{T_f}{V_f}$

$T_i = \dfrac{V_i}{V_f} T_f$

$= \dfrac{2200}{2800}(105 + 273.15)$ [M1]

$= 297 \text{ K}$

$= 24 °\text{C}$ [A1]

6 A spring stretches when a mass is attached to its lower end. The spring is then stretched a further distance of 4.0 cm from the equilibrium position, and the mass is released, performing a simple harmonic motion of period 0.44 s.

The variation with time of the vertical displacement of the mass is shown in Fig. 6.1.

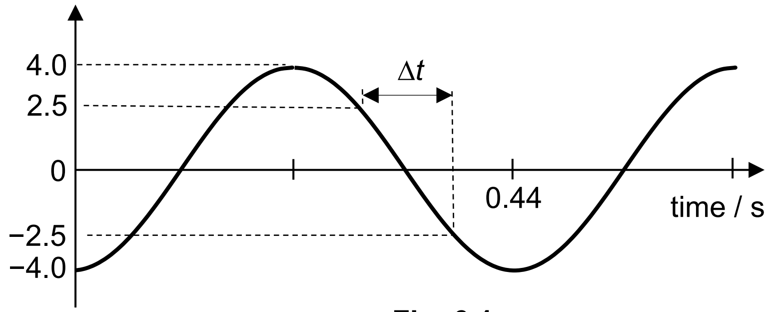


Fig. 6.1

(a) State what is meant by *simple harmonic motion*.

The acceleration of the mass is opposite to the direction of displacement from equilibrium position [B1]
and is directly proportional to its displacement from the equilibrium position [B1]

[2]

(b) Determine the shortest time taken for the mass to move from x = +2.5 cm to x = –2.5 cm, labelled Δt on Fig. 6.1.

From Fig. 6.1, the equation for displacement is

$x = -x_0 \cos(\omega t)$

$x = -x_0 \cos(\frac{2\pi}{T} t)$

$x = -0.040 \cos(\frac{2\pi}{0.44} t)$ [C1]

$0.025 = -0.040 \cos(\frac{2\pi}{0.44} t)$

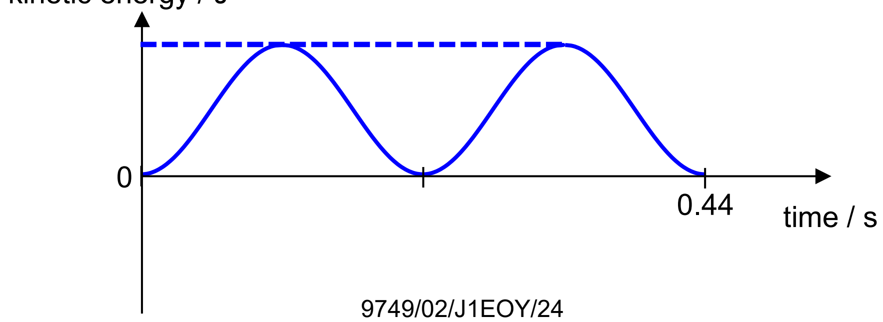
$t_{+2.5} = 0.157$ s, 0.283 s, ... (Calculator in radian mode)

$-0.025 = -0.040 \cos(\frac{2\pi}{0.44} t)$

$t_{-2.5} = 0.0627$ s, 0.377 s, ... [C1] (Calculator in radian mode)

$\Delta t = 0.377 - 0.283 = 0.094$ s [A1]

(c) On the axes of Fig. 6.2, sketch the variation with time of kinetic energy of the mass for the first period T.



[2]

[Total: 7]

7 **(a)** The figure below shows the variation with time *t* of *p*, the excess pressure at a point in a progressive sound wave in air. The speed of the wave is 340 m s^{-1}.

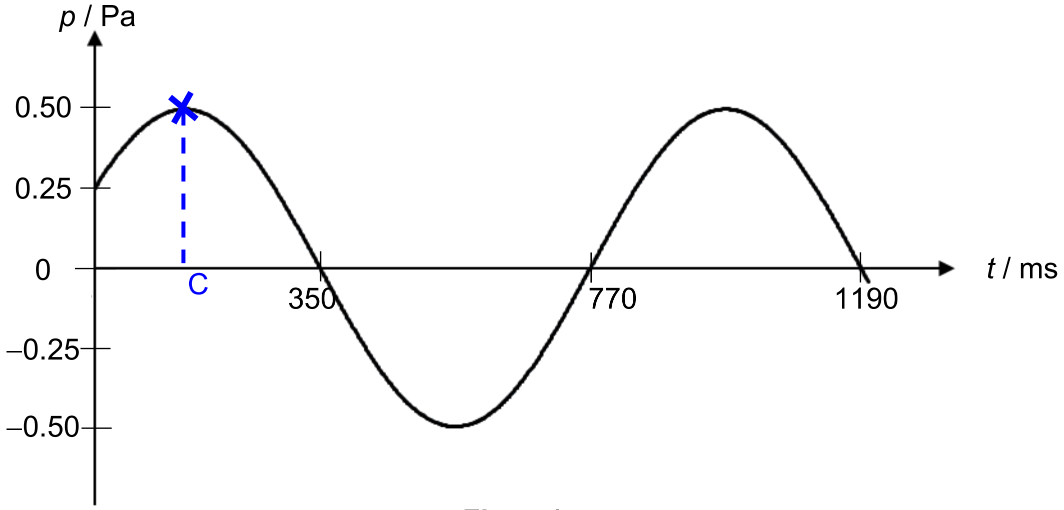


Fig. 7.1

(i) On Fig. 7.1, mark with a letter C a time at which a compression occurs. [1]

(ii) Explain your answer to **(a)(i)** in molecular terms.

Compression occurs when molecules are closest together, thus pressure is the highest.

....[1]

(iii) Using Fig. 7.1 to determine the wavelength of the wave.

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{340}{\frac{1}{(1.190 - 0.350)^{[B1]}}} = 286 \text{ m}^{[A1]}$$

wavelength = ... m [2]

(b) The intensity of a wave is defined as the rate of transfer of energy per unit area normal to the direction of propagation of the wave. At a distance of 10 m from a point source of waves, the amplitude of a wave is 1.6 mm and its intensity is 4.4 × 10^{-3} W m^{-2}. At a distance 5.0 m from the source, determine the amplitude of the wave.

$$\text{Since } I \propto \frac{1}{r^2} \text{ and } I \propto a^2, a \propto \frac{1}{r}$$

$$a_{5.0m} = \frac{r_{10m}}{r_{5.0m}} \times a_{10m} = \frac{10}{5} \times 1.6 \times 10^{-3\,[M1]} = 3.2 \times 10^{-3}\ ^{[A1]}$$

amplitude = ... m [2]

[Total: 6]

8 A laser light of wavelength 633 nm is incident on a single slit of width *b*. A diffraction pattern is formed on a vertical screen 4.2 m away from the single slit.

A photograph of the single slit diffraction pattern is shown in Fig. 8.1.

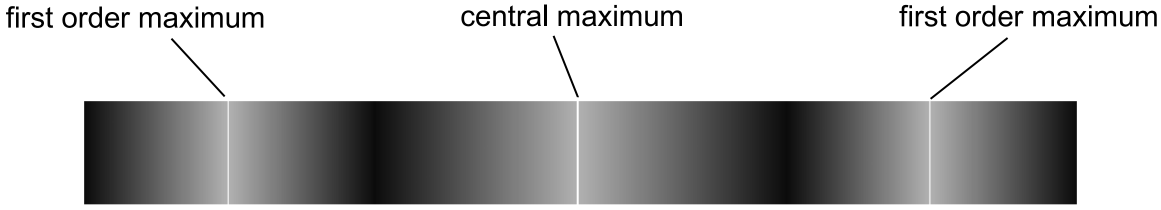


Fig. 8.1 (drawn to scale)

(a) **(i)** With reference to the positions of the maxima in Fig. 8.1, show that the separation between the central maximum and the *first order minimum* is 3.1 cm.

By measurement, distance between central max and 1st order max $= 4.7$ cm

Hence separation between central max and 1st order min $= \frac{2}{3} \times 4.7$ [B1]

$= 3.1$ cm

[1]

(ii) Determine *b*.

$$\tan\theta = \frac{3.1\times10^{-2}}{4.2}$$

$$\theta = 0.423°$$

$$\sin 0.423° = \frac{633\times10^{-9}}{b} \quad \text{[C1]}$$

$$= 8.6\times10^{-5}\text{ m} \quad \text{[A1]}$$

b = ... m [2]

(b) A second identical single slit is then placed beside the first slit such that the slit separation between the two slits is 0.320 mm as shown in Fig. 8.2. An interference pattern is then observed.

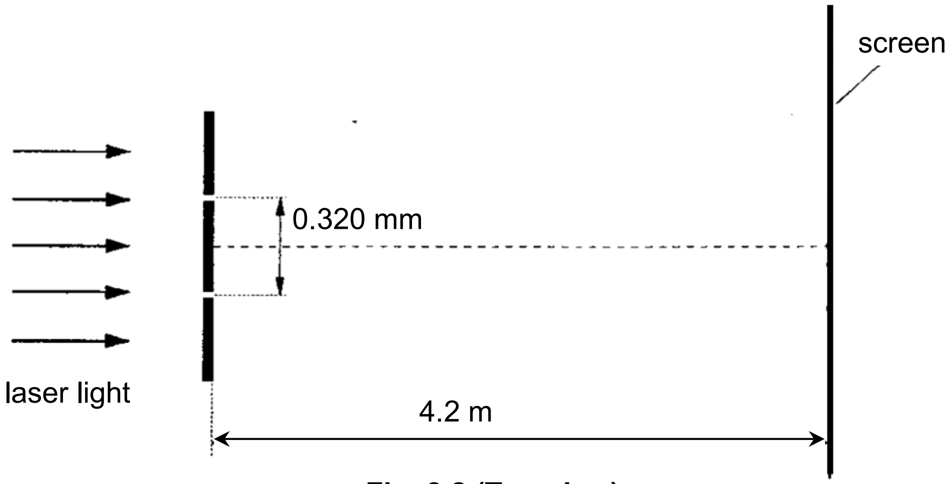


Fig. 8.2 (Top view)

(i) Explain why an interference pattern is observed on the screen.

As laser light which is cohorent[B1a], passes through the double slits, the light undergoes diffraction[B1b] and formed a region of overlapping of the 2 light waves from the 2 slits. When the 2 light waves meet in phase and reinforce each other, they will form bright fringes due to constructive interference. [B1]
When the 2 light waves meet in antiphase and cancel each other, they will form dark fringes due to destructive interference. [B1]
....[3]

(ii) Calculate the fringe separation of the interference pattern.

$$\lambda = \frac{ax}{D}$$

$$x = \frac{\lambda D}{a} = \frac{(633 \times 10^{-9})(4.2)^{[A1]}}{0.320 \times 10^{-3}} = 8.3 \times 10^{-3}\,\mathrm{m}^{[A1]}$$

fringe separation = ... m [2]

(iii) In an attempt to produce brighter fringes, the width of both slits is widened, keeping their separation constant. Fringes are no longer observed. Suggest why the fringes are no longer observed.

When the width of the slits is widened, the light ray will be not be diffracted[B1], resulting in no overlapping region of the 2 light rays. They travel in straight path and do not meet at the same point[B1]. Thus, no interference occurs, and no fringes are formed.
....[2]

[Total: 10]

9 When a structural engineer is designing a building there will be occasion when a beam must be used to bridge a gap. The width of the gap is called the span. The engineer makes calculations to ensure that there is not too much sag in the beam. Generally, a beam should not be allowed to sag beyond 1/360 of the gap it is spanning.

Sometimes, when the loading is small, a plain wooden beam is sufficient, as shown in Fig. 9.1.

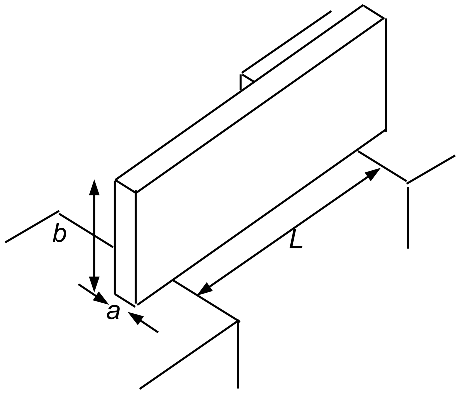


Fig. 9.1

A wooden beam, loaded at its centre, will undergo a depression x given by the expression

$$x = \frac{WL^3}{kab^3},$$

where W is the total load,
L is the span,
a is the width of the wooden beam,
b is the depth of the wooden beam and
k is a constant.

However, when greater loads or greater spans are required, a steel beam may be used. To minimize the amount of steel required, the shape of the beam used is as shown in Fig. 9.2.

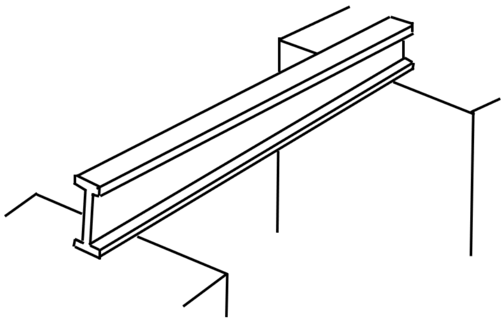


Fig. 9.2

The distribution of the load on a steel beam can be uneven, as shown in Fig. 9.3, where the moments of the forces must be calculated to ensure the sag does not exceed the acceptable allowance.

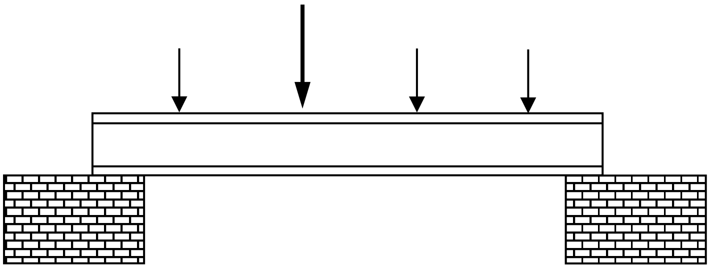


Fig. 9.3

The loading of the steel beam can also be uniform along its length, as shown in Fig. 9.4.

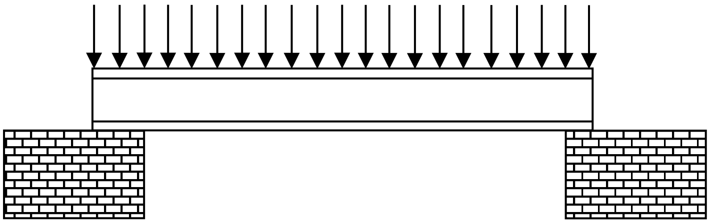


Fig. 9.4

The bending moment B for this uniform loading pattern on a steel beam is given by the expression

$$B = \frac{WL}{8},$$

and the depression x at the centre of the steel beam is given by the expression

$$x = \frac{BL^3}{c},$$

where c is a constant with a value of 3.35×10^8 N m^3.

One measure of the strength of a steel beam is its allowable bending stress. Two dimensionless constants P and Q are determined from the dimensions of the beam and the gap it is spanning. The allowable bending stress is then determined using a table of values shown in Fig. 9.5. For example, when P = 15 and Q = 160, the allowable bending stress is 111 MPa.

allowable bending stress / MPa					
		P			
		15	20	25	30
Q	160	111	96	88	82
	170	106	93	83	77
	180	102	89	80	73

Fig. 9.5

The final check on the suitability of the steel beam is to calculate the ratio between the bending moment B it is subjected to and its allowable bending stress. The beam is safe to use if the ratio is less than 2.0×10^{-4} m^3.

(a) **(i)** An engineer is given a choice of two wooden beams, D and E, to span across a gap. Their cross sections are being shown in Fig. 9.6. The cross-sectional area of the wooden beams are equal.

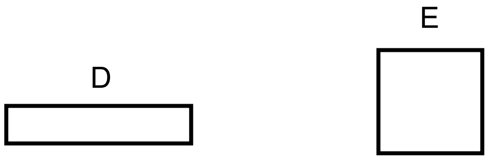


Fig. 9.6

Given that the beams are used in the orientation shown in Fig. 9.6, with reference to the equation given for depression x, suggest and explain which beam would sag more.

From the equation $x = \dfrac{WL^3}{kab^3}$, the amount of depression is inversely proportional to the width a and inversely proportionally to the cube of the depth b, for the same load and length. [M1]

Since beam D has a greater width a but a smaller depth b compared to beam E, [M1]

hence beam D will sag more than beam E. [A1]

(ii) Wooden beam D has width 0.50 m, depth 0.10 m and spans 3.0 m.

Calculate the maximum load it can support at its centre for a maximum depression x = 0.010 m. Take k to be 3.6×10^{10} Pa for this wood.

$$x = \frac{WL^3}{kab^3}$$

$$0.010 = \frac{W \times 3.0^3}{3.6 \times 10^{10} \times 0.50 \times 0.10^3}$$

$W = 6670$ N [A1]

maximum load = ... N [1]

(b) A steel beam across a gap is shown in Fig. 9.7, together with values of the forces acting and their distances from point X.

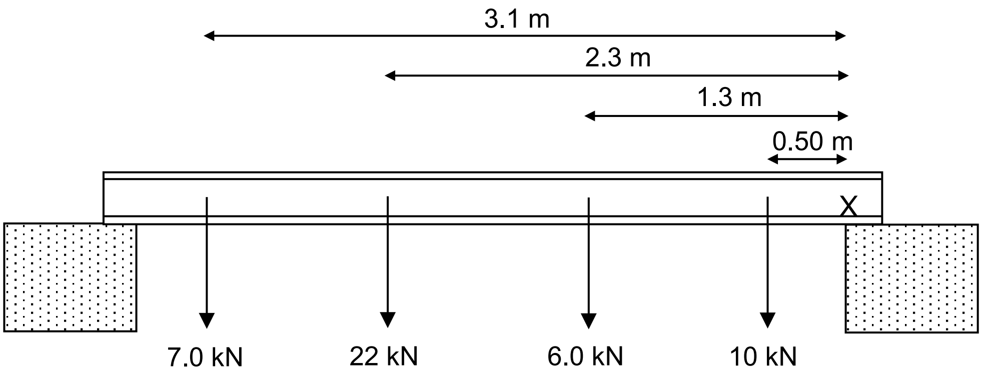


Fig. 9.7

Determine the net moment about point X.

Net moment

$=(10000)(0.50)+(6000)(1.3)+(22000)(2.3)+(7000)(3.1)$ [C1]

$=8.51\times10^4$ N m [A1]

moment = ... N m [2]

(c) A uniformly loaded steel beam is used to carry a total load of 33 000 N and span a gap of 4.20 m.

(i) Calculate the bending moment *B* of the steel beam.

$$B=\frac{WL}{8}$$

$$=\frac{33000\times4.20}{8}=1.7325\times10^4\approx1.73\times10^4 \text{ N m}$$ [A1]

B = ... N m [1]

(ii) Calculate the depression *x* at the centre of the steel beam.

$$x=\frac{BL^3}{c}$$

$$=\frac{(1.7325\times10^4)(4.20)^3}{3.35\times10^8}$$

$=0.00383$ m [A1]

x = ... m [1]

(iii) Given that P = 21 and Q = 170 for the dimensions of this steel beam and span of the gap, estimate the allowable bending stress.

From Fig. 9.5, stress is between 93 to 83 MPa. [C1]
Assuming the relationship between these points is linear,

$$\text{Stress} = \frac{83-93}{25-20}(21-20)+93$$
$$= 91 \text{ MPa} \quad [A1]$$

Accept : $89 \geq \text{stress} \geq 92$

allowable bending stress = ... MPa [2]

(iv) Determine whether this steel beam is safe under these conditions.

$$\frac{\text{Bending moment}}{\text{allowable bending stress}} = \frac{1.7325\times10^{4}}{91\times10^{6}}$$
$$= 1.90\times10^{-4} \text{ m}^{3} \quad [M1]$$

Since the ratio is less than 2.0×10^{-4} m^{3}, the beam is safe. [A1]

....[2]

[Total: 12]

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: **SOLUTIONS**

CLASS:

TUTOR'S NAME:

PHYSICS 9749/01

Paper 1 Multiple Choice **27 September 2023**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}}$
	$(1 / (36\pi)) \times 10^{-9}\ \mathrm{F\ m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\ s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant	$R = 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \mathrm{N\ m^{2}\ kg^{-2}}$
acceleration of free fall	$g = 9.81\ \mathrm{m\ s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / {}^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 What could **not** be a measurement of a physical quantity?

A 10 K **B** 11 J $N^{-1}m^{-1}$ **C** 17 Pa m^3 N^{-1} **D** 25 Tm

Ans: B

Option A:
10 K is a measurement of temperature with Kelvin as a unit

Option B:
11 J $N^{-1}m^{-1}$ is not a measurement of a physical quantity because the SI base units of J $N^{-1}m^{-1}$ is actually dimensionless as shown below.

$$\text{J N}^{-1}\text{m}^{-1} = (\text{N m})\,\text{N}^{-1}\text{m}^{-1} = 1$$

Option C:
17 Pa m^3 N^{-1} = 17 m is a measurement of length with metre as a unit.

Option D:
25 Tm means 25 Tera metre = 25 × 10^{12} m

2 A cyclist has a speed of 5 m s^{-1} and a small car has a speed of 12 m s^{-1}.

Which statement does **not** give a reasonable estimate?

A The kinetic energy of the cyclist is 1 × 10^3 J.

B The kinetic energy of the car is 7 × 10^4 J.

C The momentum of the cyclist is 4 × 10^2 kg m s^{-1}.

D The momentum of the car is 2 × 10^5 kg m s^{-1}.

Ans: D

Mass of cyclist = 80 kg (reasonable)

Mass of car = 1000 kg (reasonable)

KE of cyclist = ½ (80)$(5)^2$ = 1000 J

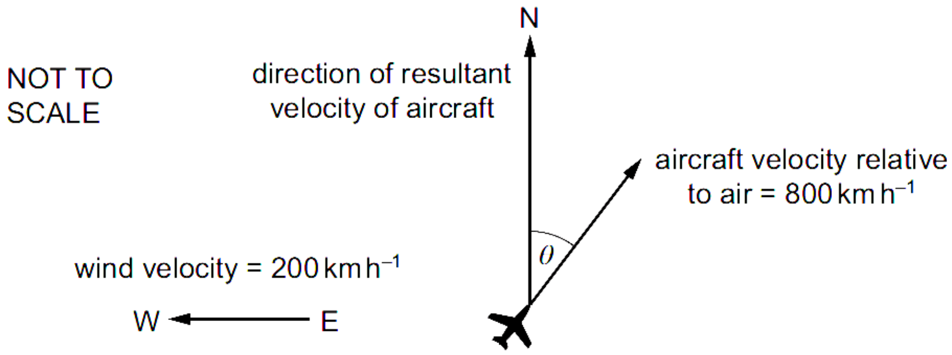
KE of car = ½ (1000)$(12)^2$ = 72000 J

$p_{cyclist}$ = (80)(5) = 400 kg m s^{-1}

p_{car} = (1000)(12) = 12000 kg m s^{-1}

From option D: Mass of car = 16700 kg (unreasonable this is like 3 times that of a bus)

3 An aircraft heads in a direction at an angle θ east of north with a horizontal velocity relative to the air of 800 km h^{-1}. The wind blows with a horizontal velocity of 200 km h^{-1} from east to west, as shown.

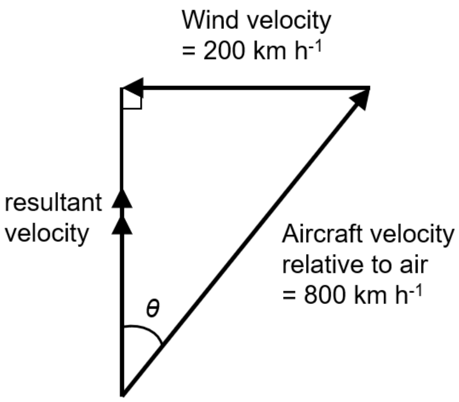


The resultant velocity of the aircraft is in a direction due north.

What is angle θ and what is the magnitude of the resultant velocity?

	θ / °	resultant velocity / km h^{-1}
A	14	770
B	14	820
C	76	770
D	76	820

Ans: A



Using Pythagoras Theorem,

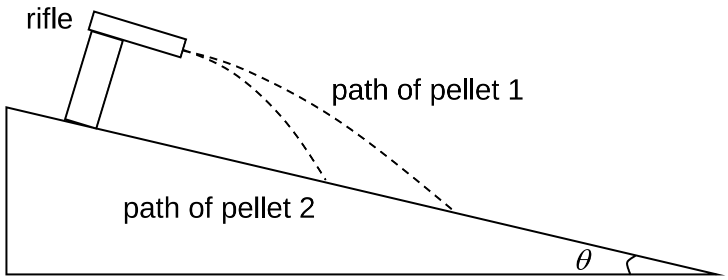
resultant velocity, v $= \sqrt{800^2 - 200^2} = 770$ km h^{-1}

Using

$\tan\theta = \left(\dfrac{200}{800}\right)$

$\theta = 14°$

4 Two identical pellets are projected simultaneously from a rifle, parallel to an inclined plane. Pellet 1 is projected at a higher initial speed that pellet 2.



Which of the following statements is correct if air resistance is neglected?

A Pellet 1 will hit the inclined plane first.

B Pellet 2 will hit the inclined plane first.

C Both pellets will hit the inclined plane at the same time.

D There is insufficient information to determine which pellet will hit the inclined plane first.

Ans: **C**

Resolve acceleration due to gravity perpendicular to the plane, $g_{\perp} = g\cos\theta$, which is the same for both pellets.

The perpendicular component (to the plane) of both pellets' initial velocity is zero. As they have the same perpendicular distance from the plane, both will reach the plane at the same time.

5 A hot air balloon ascends at a constant speed of 4.0 m s^{-1} at an angle 70° to the horizontal. At a height of 100 m above the ground, a ball is released from the hot air balloon.

What is the time taken for the ball to hit the ground?

A 3.4 s **B** 4.1 s **C** 4.7 s **D** 4.9 s

Ans: **D**

$s = ut + \frac{1}{2}at^2$ (taking downwards as positive)

$100 = -(4.0)\sin 70°t + \frac{1}{2}(9.81)t^2$

$\frac{1}{2}(9.81)t^2 - (4.0)\sin 70°t - 100 = 0$

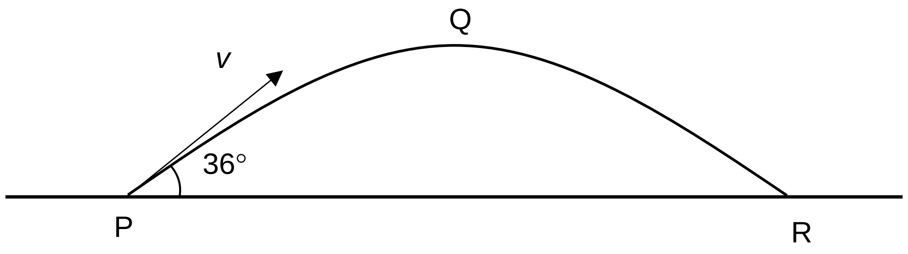
$t = 4.91$ s

A: used s = ut + at^2

B: used opposite value for u_y

C: used cosine

6 A projectile is fired with velocity v from the point P as shown below. The projectile passes point Q at the top of its trajectory and lands at point R. Air resistance is negligible.



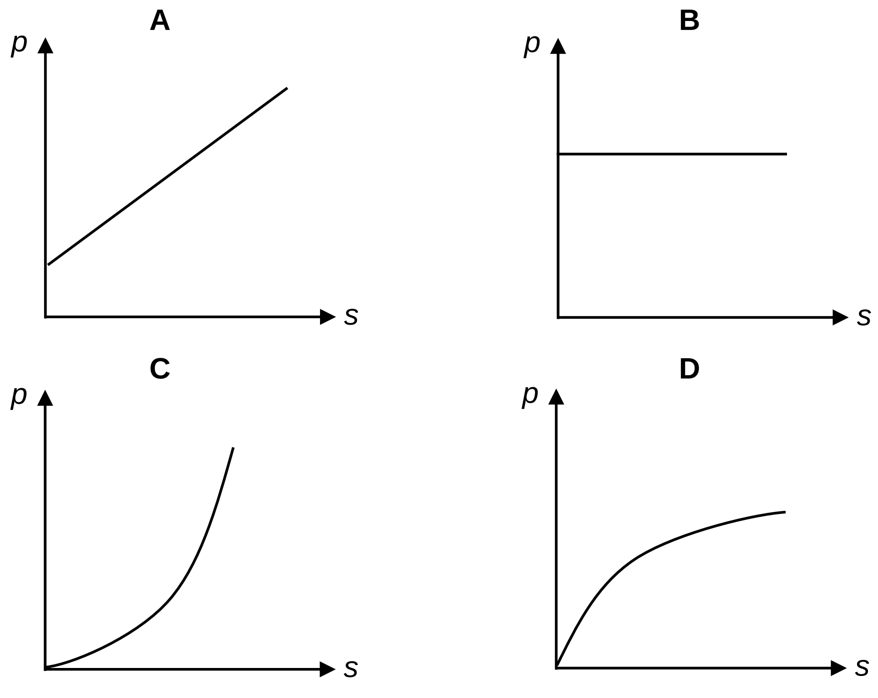
What is the magnitude of the change in velocity between Q and just before landing at R?

A $0.35v$ **B** $0.59v$ **C** $1.2v$ **D** $1.9v$

Ans: **B**
Using trigo:
$$v^2 = (\Delta v)^2 + v(\cos 36°)^2$$
$$(\Delta v)^2 = 0.34549v^2$$
$$\Delta v = 0.59v$$
A: did not square root
C: took change in velocity from *P* to *R*
D: took resultant of *Q* to *R*

7 A railway trolley starts from rest and is driven along a straight horizontal track by a motor which exerts a constant force. The effects due to resistive forces are negligible.

Which of the graphs below best represents the variation of the momentum *p* with distance travelled *s*?



Ans: D

Since the trolley is undergoing constant acceleration,

$v^2 = u^2 + 2as$ becomes $v^2 = 2as$

Graph of $y = \sqrt{x}$ gives option D

8 A soccer ball hits the window, smashing a window pane into pieces. Which one of the following statements is true?

A The force of the ball on the window pane is greater than the force of the window pane on the ball.

B The force of the ball on the window pane is the same as the force of the window pane on the ball.

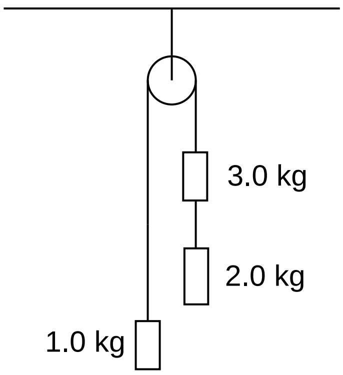
C The force of the ball on the window pane is less than the force of the window pane on the ball.

D The net force on the window pane is zero.

Ans: B

By Newton's Third Law, the two forces are action-reaction pairs.

9 A light inextensible string is wound, as shown, over a frictionless, light pulley.



What is the tension in the string between the 2.0 kg and the 3.0 kg masses when the system is released from rest?

A 6.5 N **B** 16 N **C** 20 N **D** 39 N

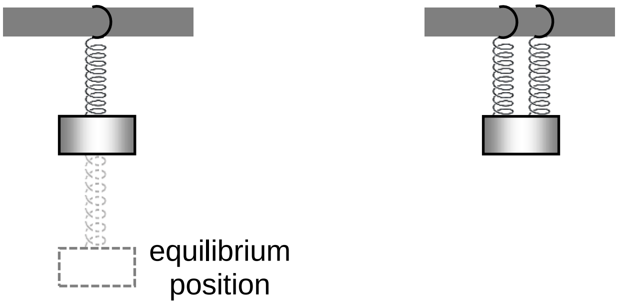
Ans: A

Let T be the tension in between the 3.0 kg and 1.0 kg masses and a be the acceleration of the system.
Considering the 3.0 kg and 2.0 kg masses taken together,
$5.0g - T = 5.0a$ (1)
Considering the 1.0 kg mass,
$T - 1.0g = 1.0a$ (2)

Solving, $a = (2/3)g$

Let T' be the tension between the 3.0 kg and 2.0 kg masses.
Considering the 2.0 kg mass,
$2.0g - T' = 2.0a$
$T' = 6.5$ N

10 A mass of weight W is attached to a vertical light spring as shown.



(a) **(b)**

In the equilibrium position of the mass-spring system as shown in **(a)**, the force in the spring is F and the energy stored in the spring is U.

Another spring identical to the first is attached to the mass in parallel to the first as shown in **(b)**. What is the total force and the energy stored in the springs in the equilibrium position of this mass-spring system?

	total force	total energy
A	$F/2$	U
B	F	$U/2$
C	F	$U/4$
D	$2F$	U

Ans: B

For a single spring: $F - W = 0 \rightarrow F = kx = W$

For two springs: $2 \times F' - W = 0 \rightarrow F' = kx' = W/2$

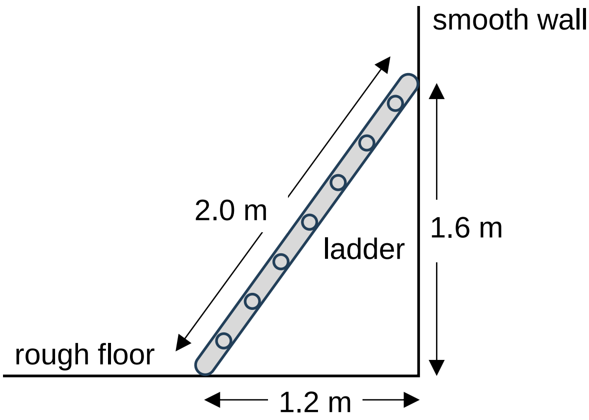
$\rightarrow x' = x/2$

$\rightarrow U' = \frac{1}{2}kx'^2 = \frac{1}{2}k(\frac{x}{2})^2 = \frac{1}{4}(\frac{1}{2}kx^2) = \frac{1}{4}U$

Total force in springs $= 2 \times F' = W = F$

Total energy in springs $= 2 \times U' = U/2$

11 A 2.0 m ladder of weight 56 N rests on a rough floor against a smooth wall, as shown below.



What is the magnitude of the force exerted by the wall on the ladder?

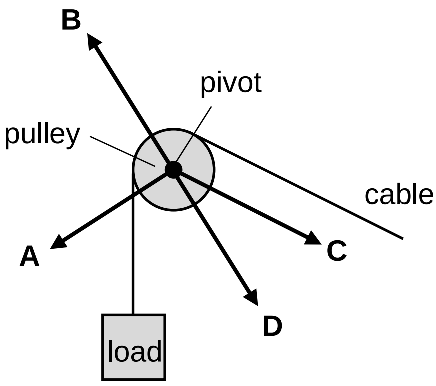
A 21 N **B** 28 N **C** 42 N **D** 60 N

Ans: A

Taking moments about the bottom of ladder:

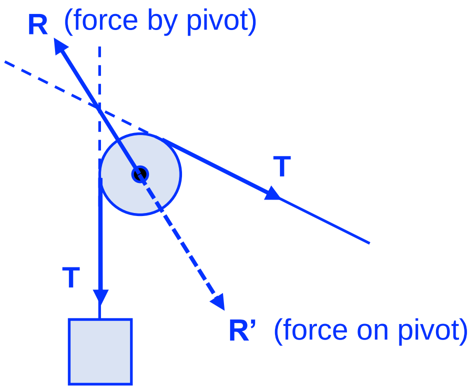
$56 \times 1.2/2 - N \times 1.6 = 0 \rightarrow N = 21$ N

12 A fixed smooth light pulley and light cable are used to slowly lift a load, as shown below.

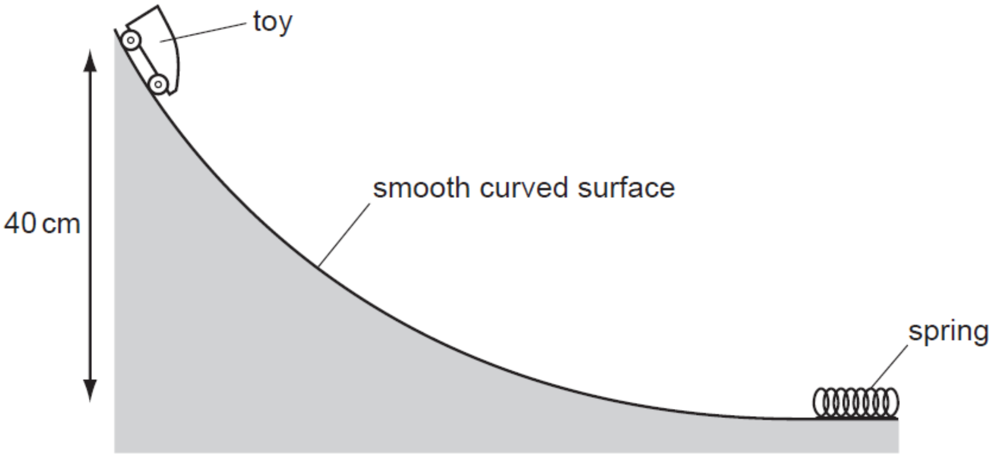


Which of the arrows best shows the direction of the force on the pivot of the pulley?

Ans: D



13 A toy is released from rest on a smooth curved surface.



The toy, of mass 0.22 kg, runs down the curved surface through a vertical distance of 0.40 m. It strikes a spring of force constant 350 N m^{-1} and compresses it a distance x before coming to rest.

Assuming no energy losses, what is the value of x?

A 4.9×10^{-3} m **B** 7.2×10^{-3} m **C** 2.2×10^{-2} m **D** 7.0×10^{-2} m

Ans: D

loss in GPE = gain in EPE

$$mgh = \frac{1}{2}k(x)^2$$

$$x = \sqrt{\frac{2mgh}{k}} = \sqrt{\frac{2(0.22)(9.81)(0.40)}{350}} = 7.0 \times 10^{-2} m$$

14 A car of mass 1000 kg is moving at 25 m s^{-1}. The brakes are applied, causing the car to stop.

The car has four brakes, each consisting of a 3.0 kg metal disc that rubs against a wheel. The specific heat capacity of the metal from which the discs are made is 400 J kg^{-1} K^{-1}.

What is the maximum rise in the temperature of the brakes?

A 2.6 °C **B** 5.2 °C **C** 65 °C **D** 260 °C

Ans: C

loss in KE = gain in thermal energy

$$\frac{1}{2}mv^2 = \mathrm{mc}\Delta\theta$$

$$\frac{1}{2}(1000)(25)^2 = (4)(3.0)(400)\Delta\theta$$

$$\Delta\theta = 65\ °C$$

15 Sky City in Tokyo is 1.0 km tall. The lifts take 2.0 minutes to reach the top. A lift of mass 450 kg carries two passengers who have a combined mass of 140 kg.

What is the average power supplied to the ascending lift?

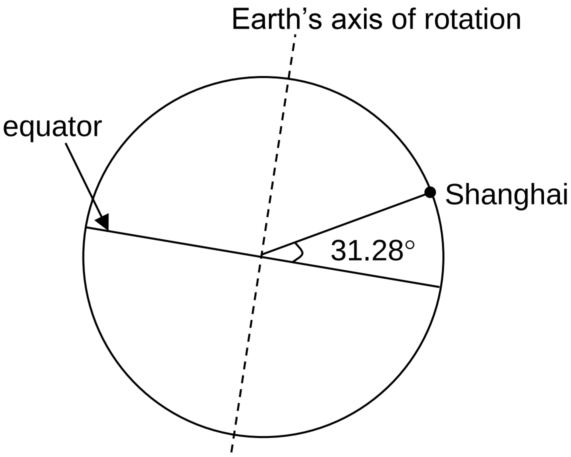
A 4.9 kW **B** 37 kW **C** 48 kW **D** 2900 kW

Ans: C

Power = rate of increase of GPE

P = mgv$_y$ $= (450+140)(9.81)(\frac{1000}{2(60)}) = 48$ kW

16 A man is located in Shanghai which has a latitude of 31.28° N as shown.



Assuming Earth to be a sphere of radius 6380 km, what is the man's linear velocity due to the rotation of the Earth about its axis?

A 241 m s^{-1} **B** 337 m s^{-1} **C** 397 m s^{-1} **D** 464 m s^{-1}

Ans: C

v = Rω

v = r (cos 31.28°) $\left(\frac{2\pi}{T}\right)$

v = (6.38 x 10^6)(cos 31.28°) $\left(\frac{2\pi}{24\times60\times60}\right)$ = 397 m s^{-1}

17 A block is attached to an elastic spring of unstretched length *a* and travels in a horizontal circle of radius 2*a* on a smooth horizontal table. The elastic spring is horizontal throughout the circular motion. The period of rotation of the block is *T*.

The block is spun at a higher speed such that it now moves in a circle of radius 3*a*. Assuming that the spring obeys Hooke's law, the period of rotation is now

A $\frac{9}{16}T$ **B** $\frac{3}{4}T$ **C** $\sqrt{\frac{3}{4}}T$ **D** $\sqrt{\frac{4}{3}}T$

Ans: C

$$\sum F = ma$$

$$kx = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

$$ka = m(2a)\left(\frac{2\pi}{T}\right)^2 \cdots [1]$$

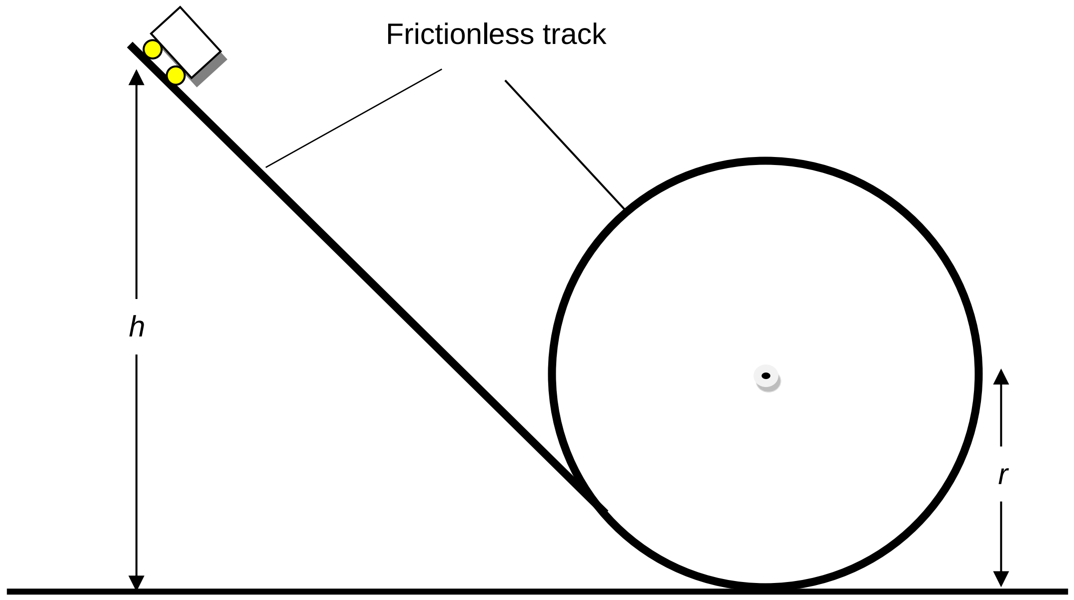
$$k(2a) = m(3a)\left(\frac{2\pi}{T_2}\right)^2 \cdots [2]$$

$$\frac{[1]}{[2]}: \quad \frac{1}{2} = \frac{\frac{2}{T^2}}{\frac{3}{T_2^{\,2}}}$$

$$\frac{3}{4} = \frac{T_2^{\,2}}{T^2}$$

$$T_2 = \sqrt{\frac{3}{4}}T$$

18 A small car of mass *m* is released from rest at the top of a frictionless track of height *h*. It then enters a vertical circular loop of radius *r*. The car can loop the loop without losing contact with the track.



Which of the following expressions correctly represents the centripetal force of the car at the top of the loop?

A $\dfrac{2mg(h-r)}{r}$ **B** $\dfrac{2mg(h-r)}{h}$ **C** $\dfrac{mg(h-2r)}{r}$ **D** $\dfrac{2mg(h-2r)}{r}$

Ans: D

Consider the motion of the small car from the point of release until it reaches the top of the loop.
By conservation of energy, Loss of GPE = Gain in KE of car

$$mg(h-2r) = \frac{1}{2}mv^2 - 0$$

$\therefore$ centripetal force $F_c = \dfrac{mv^2}{r} = \dfrac{2mg(h-2r)}{r}$

19 A piece of rock, which weighs 15 N on the Earth, weighs 2.5 N on the Moon.

What is the mass of the rock and the gravitational field strength on the Moon?

	mass / kg	gravitational field strength / N kg^{-1}
A	1.5	1.6
B	1.5	6.1
C	150	0.016
D	150	6.1

Ans: A

mass = 15/9.81 = 1.53 $\approx$ 1.5 kg

$g_M = \dfrac{2.5}{1.53} = 1.63 \approx 1.6$ N kg^{-1}

20 The planet Jupiter has satellites called Io and Europa which have different orbital radii and different orbital time periods. The table shows the orbital radii for Io and Europa and the orbital time period of Io.

	orbital radius / km	orbital time period / days
Io	4.2×10^5	1.8
Europa	6.7×10^5	T_E

What is the orbital time period T_E of Europa?

A 0.88 days **B** 2.4 days **C** 2.8 days **D** 3.6 days

Ans: D

$\dfrac{GMm}{r^2} = mr\left(\dfrac{2\pi}{T}\right)^2$

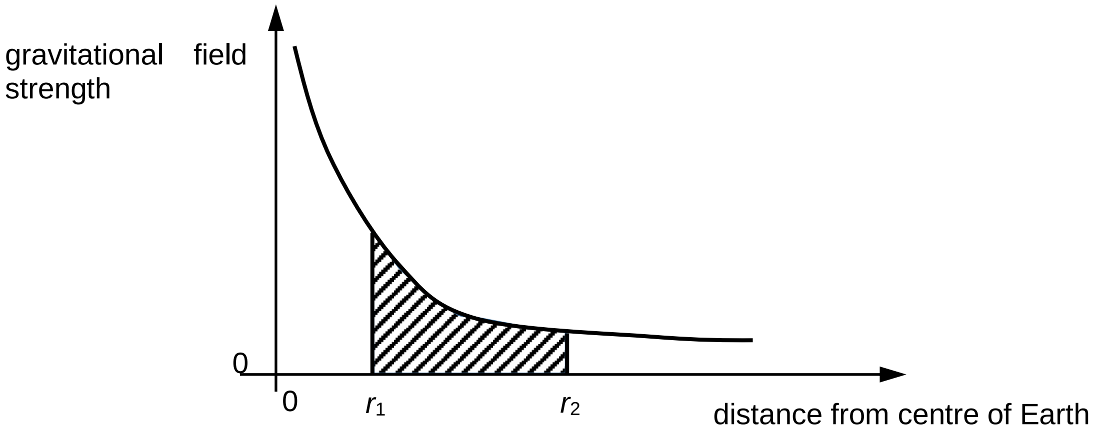
$T^2 = \dfrac{4\pi^2 r^3}{GM}$

$\left(\dfrac{T_1}{T_2}\right)^2 = \left(\dfrac{r_1}{r_2}\right)^3$

$\left(\dfrac{1.8}{T_E}\right)^2 = \left(\dfrac{4.2}{6.7}\right)^3$

$T_E = 3.6$ days

21 A satellite of mass *m* above the Earth in a circular orbit of radius r_1 is moved to a higher circular orbit of radius r_2.



The graph shows the variation of the gravitational field strength with distance.

Which of the following represents the change in gravitational potential energy of the satellite?

A Shaded area

B Shaded area $\times$ *m*

C Gradient of the graph at r_1

D Gradient of the graph at r_2

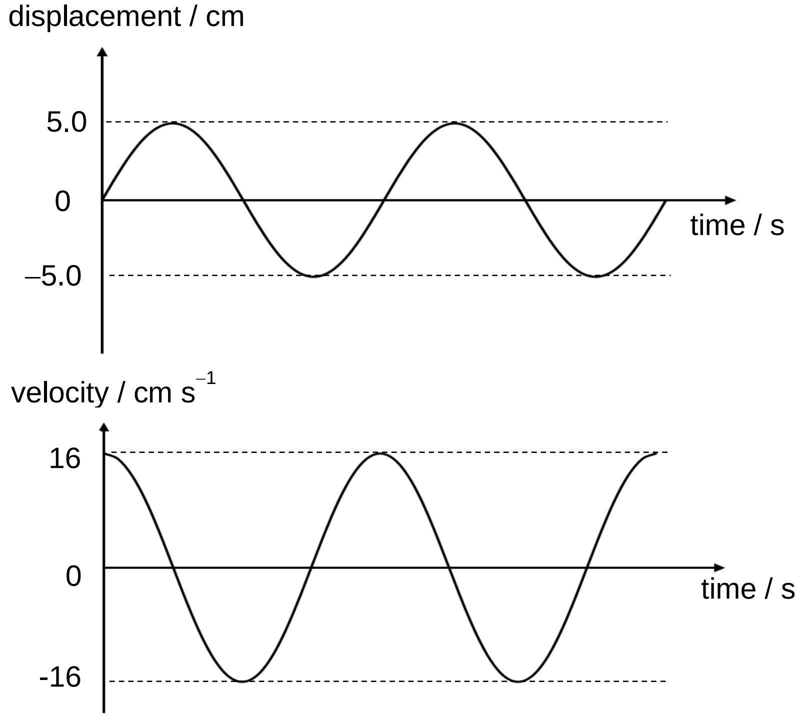
Ans: B

Since $g = -\frac{d\phi}{dr}$,

Area under $g - r$ graph represents ϕ.

Therefore, $U = \phi m$ = shaded area x m

22 The graphs below show the variation of displacement and velocity with time of a body oscillating in simple harmonic motion.



Given that T is the period of the oscillation, what is the magnitude of the acceleration of the body at $\frac{T}{8}$ s?

A 0.70 cm s^{-2} **B** 12 cm s^{-2} **C** 36 cm s^{-2} **D** 51 cm s^{-2}

Ans: **C**

$v_0 = \omega x_0$

$16 = \omega(5)$ from x–t graph

$\omega = 3.2$

$x = x_0 \sin \omega t$

$a = \omega^2 x = (\omega)^2 x_0 \sin \omega t$

$= (3.2)^2 (5) \sin\left(\frac{2\pi}{T} \cdot \frac{T}{8}\right)$

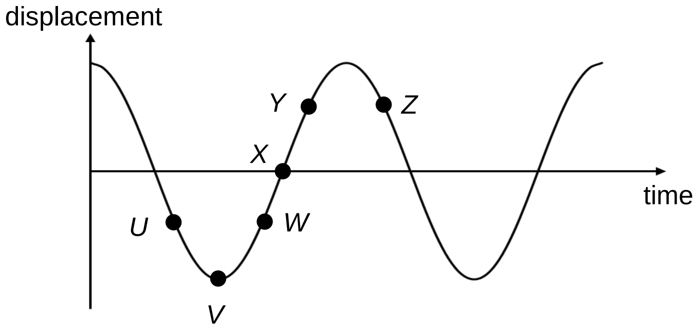
$= 34.9 = 35$ cm s^{-2}

A: used degree mode

B: used sin(T/8) instead of sinωt = 12.441

D: calculated maximum acceleration $a = \omega^2 x_0$

23 The diagram below shows the variation with time the displacement of a body undergoing simple harmonic motion.



At which points *U*, *V*, *X*, *Y*, *Z* are the velocity and acceleration in the opposite directions?

A *V* and *X* **B** *U* and *Y* **C** *W* and *Z* **D** *X* and *Z*

Ans: B
When the body is negatively displaced, the acceleration is positive (i.e. pointing upwards towards the equilibrium position), and vice versa for positive displacement.
The velocity of the body moves down (U), stops (V), changes direction and moves up (W) towards X. It then moves up (Y), stops and moves down (Z) back towards the equilibrium position.
Hence at U and Y, the velocity and acceleration are in opposite directions.

24 An ideal gas is initially at a temperature of 30 °C and its molecules are moving with a root-mean-square speed of *c*.

The gas is then heated to reach a temperature of 90 °C. What is the root-mean-square speed of the molecules at this temperature?

A 1.1 *c* **B** 1.2 *c* **C** 1.7 *c* **D** 3.0 *c*

Ans: A

Mean KE $\propto c^2 \propto T$

$c' / c = (T' / T)^{1/2} = [(90 + 273.15) / (30 + 273.15)]^{1/2} = 1.09$

25 An insulating foam cup with lid contains 250 g of hot water at 95 °C.

Assuming that the cup exchanges negligible heat with its contents and surrounding, what is the minimum amount of ice at 0 °C that must be added to the cup to bring the temperature of the water down to 70 °C?

Specific heat capacity of water = 4.2×10^3 J kg^{-1} K^{-1}
Specific heat capacity of ice = 2.1×10^3 J kg^{-1} K^{-1}
Specific latent heat of fusion of water = 3.3×10^5 J kg^{-1}

A 42 g **B** 55 g **C** 69 g **D** 80 g

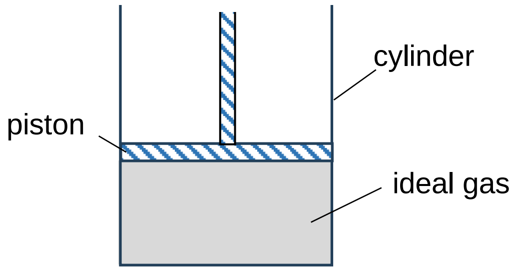
Ans: A

Heat loss by hot water = m c $\Delta\theta$ = 0.250 $\times$ 4.2×10^3 $\times$ (95 – 70) = 2.63×10^4 J

= Heat gain by ice = m l + m c $\Delta\theta$ = m (3.3×10^5 + 4.2×10^3 $\times$ 70)

$\rightarrow$ m = 42 g

26 A cylinder enclosed with a smooth piston contains a monoatomic ideal gas of internal energy U with an initial volume of V at a pressure of P. The gas is then heated so that it expands under constant pressure until its volume is 1.5V.



Which of the following gives the expression for the heat supplied to the gas?

A $\dfrac{PV}{2}$ **B** $\dfrac{3U - PV}{2}$ **C** $\dfrac{U - PV}{2}$ **D** $\dfrac{U + PV}{2}$

Ans: D

$V' = 1.5V \rightarrow T' = 1.5T \rightarrow U' = 1.5U \rightarrow \Delta U = 0.5U$

$\Delta U = Q + W \rightarrow Q = 0.5U - (-P \times 0.5V) = 0.5\,(U + PV)$

27 An antenna broadcasts a signal uniformly in all directions with a power of 240 W. What is the power received by a circular receiver dish of diameter 3.0 m positioned 750 m away?

A 9.6×10^{-7} W **B** 2.4×10^{-4} W **C** 9.6×10^{-4} W **D** 3.8×10^{-3} W

Ans : B

Intensity at 750 m = $\dfrac{P}{4\pi r^2} = \dfrac{240}{4\pi(750)^2} = 3.395 \times 10^{-5}$ W m^{-2}

Power received by dish = Intensity × Area = $(3.395 \times 10^{-5})(\pi(1.5)^2) = 2.4 \times 10^{-4}$ W

Option A: used area of sphere as $\frac{4}{3}\pi r^3$

Option C: used area of sphere as πr^2

Option D: used area of dish as $4\pi r^2$,and radius as 3.0 m

28 Plane polarised light of intensity I is incident on a polarising filter aligned so that no light is transmitted. The polarising filter is now rotated through an angle of 30°.

What is the intensity of the transmitted light?

A 0.25 I **B** 0.50 I **C** 0.75 I **D** 0.87 I

Ans : A

Initial position with zero light transmitted implies angle between polarisers is 90°.
Rotating 30° from that position means the angle between polarisers will be either $(90+30)°$ or $(90-30)°$, both of which will give us the same answer.

$I_{\text{final}} = I\cos^2(90+30)° = 0.25\ I$

OR

$I_{\text{final}} = I\cos^2(90-30)° = 0.25\ I$

29 A stationary wave is set up on a string that is stretched between two fixed points that are 48 cm apart.

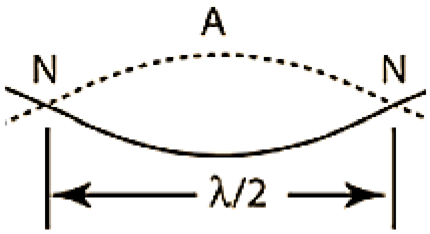
At one instant, the appearance of the string is as shown.

What is the wavelength of the stationary wave?

A 16 cm **B** 32 cm **C** 48 cm **D** 72 cm

Ans: B

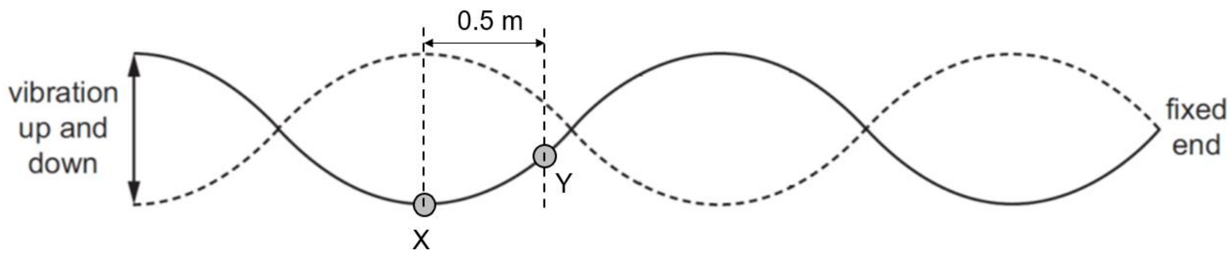
Distance of 1 segment = 0.5 λ.



Since 3 segments as shown above have a distance of 48 cm, the distance of 1 segment = 16 cm.

Therefore, wavelength of stationary wave = 16 × 2 = 32 cm.

30 The diagram shows a long rope fixed at one end. The other end is moved up and down, setting up a stationary wave of wavelength 2 m. The horizontal distance between point X and Y on the rope is 0.5 m.



What is the phase difference between the oscillations at X and Y?

A 0° **B** 90° **C** 180° **D** 135°

Ans: A

As X and Y are points between 2 adjacent nodes, they oscillate in phase. Therefore, phase difference is zero. The 0.5 m and 2 m of wavelengths are given as distractors.

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME **SOLUTION**

CLASS

TUTOR'S NAME

PHYSICS **9749/02**

Paper 2 Structured Questions **27 September 2023**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 8**
2	**/ 8**
3	**/ 8**
4	**/ 16**
Total	**/ 40**

This document consists of **10** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / {}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 (a) Explain what is meant by *displacement*.

Displacement of an object is its distance from a fixed point in a specific direction. [B1]

....[1]

Examiner's Comment:

Poorly done by the cohort. A majority of the candidates failed to bring out the directional nature of displacement in their answers. Phrases such as "displacement is the distance between 2 points" are not credited as it did not specify clearly the path that was taken, hence missing the nature of direction in the definition.

(b) Fig. 1.1 shows the variation with time the velocity v of the car travelling on a horizontal straight road. The car starts moving at time t = 0 s when displacement x = 0 m.

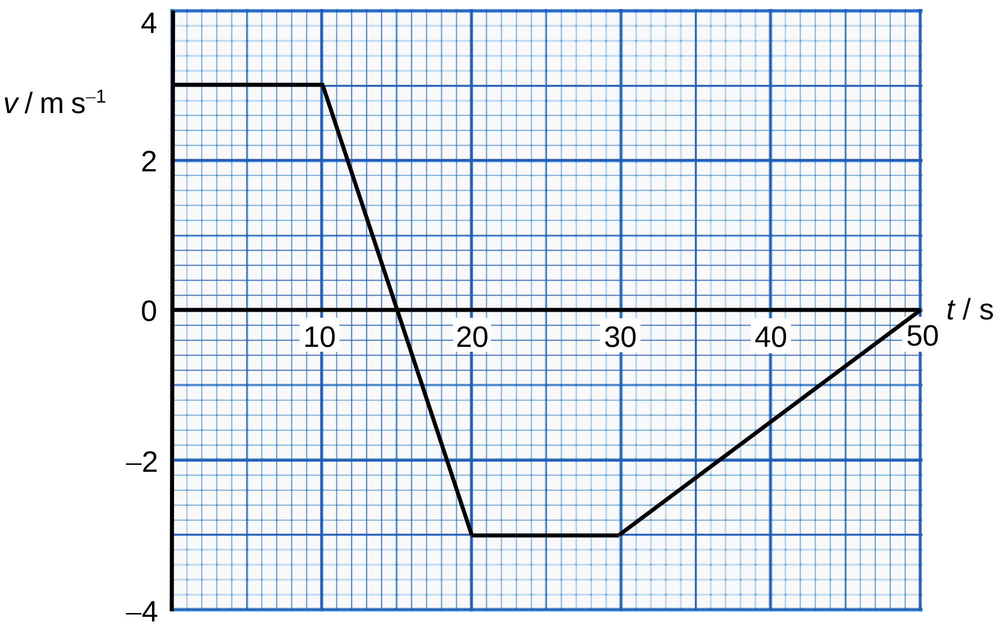


Fig. 1.1

(i) State and explain the time t at which the car returns to displacement x = 0 m.

Displacement is given by the area under the velocity time graph [B1],

hence the first time the car returns back to displacement x= 0 is at 30 s [A1],

where the area above and below the x axis is the same. ....[2]

Examiner's Comment:

Candidates need to draw the link of how displacement can be obtained from the v-t graph instead of leaving it open for interpretation. A state and explain question requires a correct explanation to precede the answer for full credit to be awarded.

(ii) Using Fig. 1.1, determine the acceleration of the car at t = 15 s.

acceleration = gradient of v - t graph at t = 15.0 s

$$= \frac{-3.0-(3.0)}{20.0-10.0} \quad \text{[B1]}$$

$$= -0.60 \text{ m s}^{-2}$$

Correct magnitude and sign given [B1]

Examiner's Comment:

A majority of the cohort lost marks in this part by failing to apply knowledge learnt in practical to theory paper. When coming to graphical read off, it is required for candidates to read off to half the smallest division before substitution is being done to calculate the gradient of the graph. Quite a number of candidate failed to include the sign of the acceleration as well.

(iii) Hence on Fig. 1.2, sketch the variation with time t the acceleration a of the car. No further calculations are required.

Correct Shape [B1]

One + one – for graph drawn at 10-20s and 30-50s [B1]

(ECF if (ii) wrong sign)

Second acceleration have smaller magnitude compared to first. [B1]

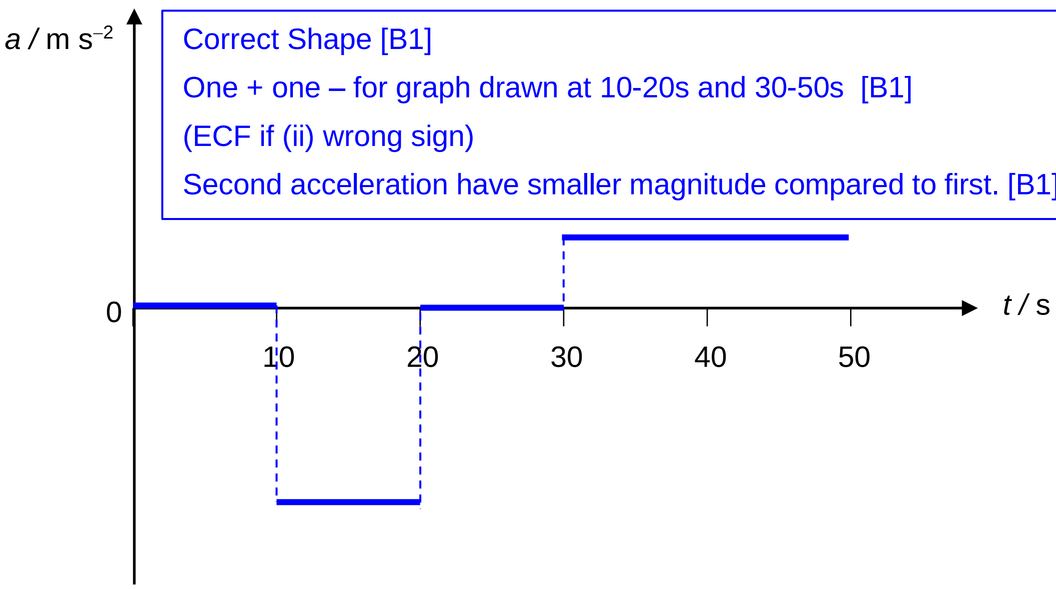


Fig. 1.2

[3]

[Total: 8]

Examiner's Comment:

Even when question asks for a sketch, it is important that candidates make it clear that the magnitude of the 1st and 2nd acceleration is different when judged using naked eyes. A number of answers have difference that are insignificant at around ±0.1 cm which are not being awarded credit. When drawing straight line, candidates are also expected to use a ruler and not free hand.

2 A non-uniform block of length 0.800 m, height 0.200 m, width 0.200 m and mass 25.5 kg is fully submerged in water of density 1.02×10^3 kg m^{-3}. It is held in a fixed position by two identical vertical cables X and Y, at each end of the block as shown in Fig. 2.1.

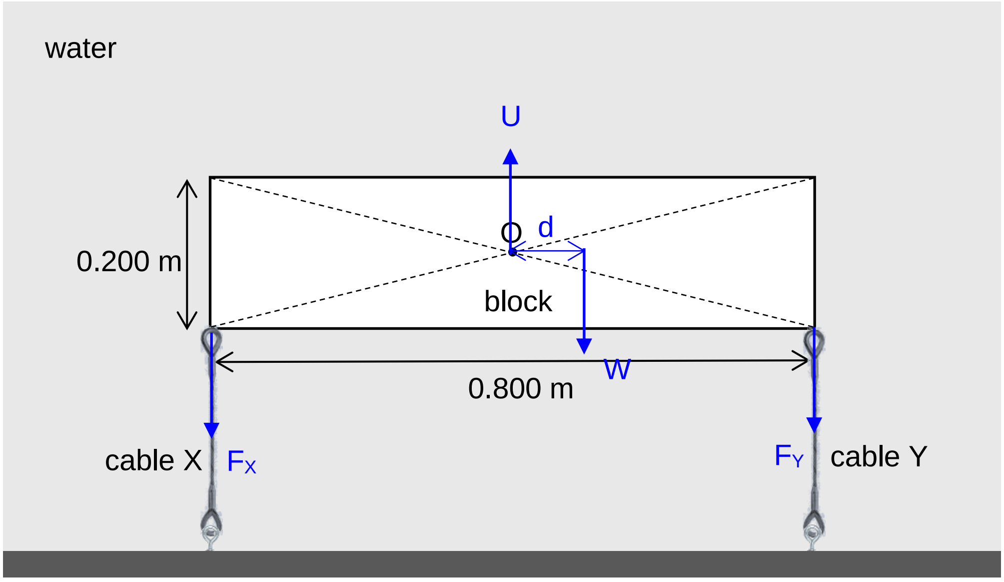


Fig. 2.1

(a) Explain the origin of *upthrust*.

Pressure due to the water is higher at the bottom surface of the block than that at the top surface.

This results in the water exerting a net upward force on the block. [2]

(b) Calculate the magnitude of the upthrust on the block.

$U = V\rho g = (0.800 \times 0.200 \times 0.200) \times 1.02\times10^3 \times 9.81$

$= 320$ N

upthrust = ... N [2]

(c) Hence show that the total force exerted by cables X and Y on the block is 70 N.

$\Sigma F = 0 \rightarrow U - F_{cables} - W = 0$

$F_{cables} = 320 - 25.5 \times 9.81 = 70$ N

[1]

(d) The force exerted by cables X and Y on the block are 45 N and 25 N respectively. Deduce why cable X exerts a larger force on the block than cable Y.

Centre of gravity of the block is closer to cable Y than cable X.

[1]

(e) Upthrust on the block acts from the geometric centre O of the block as shown in Fig. 2.1. Calculate the horizontal distance of the centre of gravity of the block from O.

Taking moments about O:

$-F_X (L/2) + W d + F_Y (L/2) = 0$

$25.5 \times 9.81\, d = (0.800/2) \times (45 - 25)$

$d = 0.032(0)$ m

distance = ... m [2]

[Total: 8]

3 A 4.00 kg mass is attached to a vertical rod using two inextensible cords of length 1.25 m. The mass rotates about the axis of the rod such that both cords are taut as shown in Fig. 3.1.

Tension in upper cord and lower cord, Weight

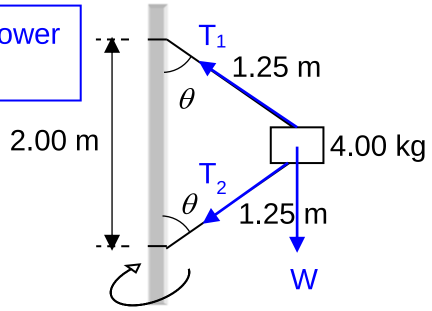


Fig. 3.1

(a) Calculate the angle θ between each of the cords and the vertical rod.

$\theta = \cos^{-1}(1.00 / 1.25)$
$= 36.870°$
$= 36.9°$

angle θ = ... ° [1]

(b) On Fig. 3.1, draw all the forces acting on the mass. [2]

(c) Hence, show that the magnitude of the tension in the upper cord is 49.1 N more than that in the lower cord.

Mass is in vertical equilibrium, $\Sigma F_y = 0$

$$T_{upp}\cos\theta = T_{low}\cos\theta + W$$

$T_{upp}\cos 36.870° = T_{low}\cos 36.870° + (4.00)(9.81)$

$T_{upp} - T_{low} = 49.1\text{N}$

Examiner's Comment:

Displacement of an object is its distance from a fixed point in a specific direction. [B1]

[2]

(d) The rotation is gradually slowed down until the lower cord just loses its tautness. Determine the frequency of rotation of the mass when this happens.

Upon losing tautness,

$T_{low} = 0$

$T_{upp} = 49.1\text{N}$

Horizontal component of tension provides centripetal force for the mass to undergo circular motion. By Newton's Second Law, $\sum F_x = ma_c$

$T_{upp} \sin\theta = ma_c$

$= mr\omega^2$

$49.050 \sin 36.870 = (4.00)(1.25 \sin 36.870)\omega^2$

$\omega = 3.1321 \text{ rad s}^{-1}$

$f = 0.49849 = 0.498 \text{ rev s}^{-1}$

frequency of rotation = ... s^{-1} [3]

[Total: 8]

4 A bridge is constructed across a river as shown in Fig. 4.1. On each side of the bridge, two towers were sunk into the riverbed and each tower supports 5 cables. Each cable forms an inverted-V where one end of the cable is attached to the roadway, passes over a tower and the other end is also attached to the roadway.

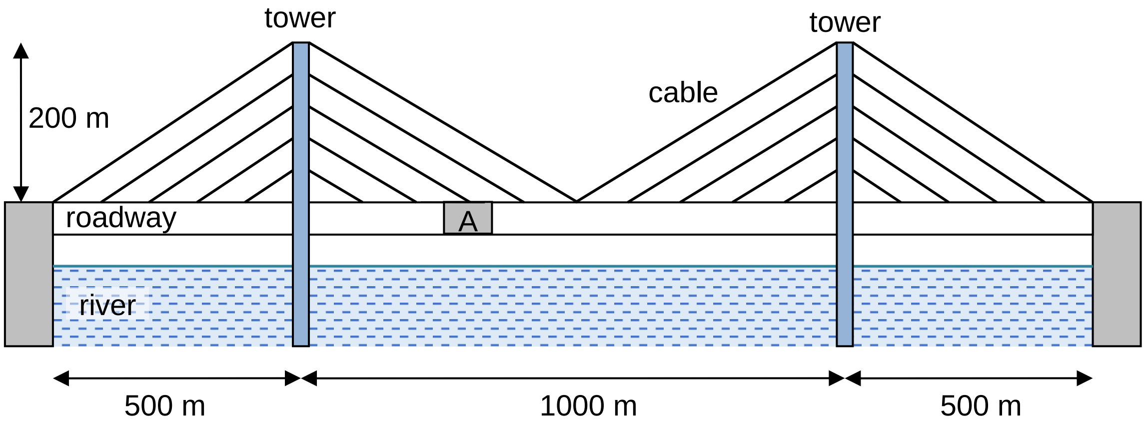


Fig. 4.1 (side view)

As a car enters the bridge, it will drive past a total of 4 towers and 20 cables on both the left and right side of the car. The arrangement and number of cables are identical on both sides of the car. Having multiple cables is a much better system than having a traditional suspension bridge which relies on the immense tensile strength of a single pair of cables taking the entire load. Simplified data concerning the bridge are given below.

Length of bridge supported by the towers	= 2000 m
Height of tower above roadway	= 200 m
Total mass of all the cables	= 1.4×10^6 kg
Mass of roadway	= 8.5×10^6 kg
Maximum mass of load of traffic	= 12.5×10^6 kg
Horizontal distance between cables	= 100 m
Vertical distance between cables	= 40 m
Total number of inverted V cables (both sides of road)	= 20

(a) Determine the maximum total mass that each of the four towers will need to support.

maximum mass for each tower = $\dfrac{(1.4+8.5+12.5)\times10^6}{4}$ [C1]

$= 5.6\times10^6$ N [A1]

Examiner's Comment:

Displacement of an object is its distance from a fixed point in a specific direction. [B1]

mass = ... kg [2]

(b) Assuming that car traffic is uniformly distributed on the bridge, determine the total mass of a 100 m section of the roadway and the traffic it supports.

mass of 100m including traffic = $\frac{(8.5+12.5)\times 10^6}{2000}\times 100$ [C1]

$= 1.05\times 10^6$ kg [A1]

mass = ... kg [2]

(c) Given that all adjacent cables are parallel to each other, calculate the angle between each cable and the horizontal.

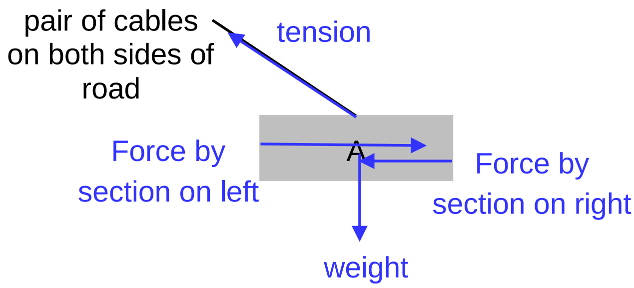
$\tan\theta = \frac{200}{500}$

$\theta = 21.8°$ [A1]

angle to horizontal = ... ° [1]

(d) On Fig. 4.1, section A is a 100 m section of the roadway which is fully laden and supported by a pair of cables. Fig 4.2 shows a close-up view of section A which is under compression.

Draw and label, on Fig. 4.2, the forces acting on section A.



- tension (along the cable) [B1]
- horizontal forces by neighbouring sections of road showing compression [B1]
- weight (downwards) [B1]

Fig. 4.2 [3]

(e) Using Fig. 4.2, determine the tension in each cable supporting section A when it is fully laden.

T_y on 100m road section = Total W of 100m road

T sin(21.8) = $1.05\times 10^6 \times 9.81$ [C1]

T = 2.774×10^7 N [C1]

Since T is due to 2 cables on both sides of the roadway,

Tension in each cable = $\frac{2.774\times 10^7}{2}$

$= 1.387\times 10^7$

$\approx 1.4\times 10^7$ N [A1]

Examiner's Comment:

Not sure of the reason for this.

tension = ... N [3]

(f) The force constant of each cable is 7.0×10^7 N m^{-1}.

Determine the increase in the length of each cable when an initially empty roadway becomes fully laden.

Since tension is proportional to the mass supported,

Increase in tension = $\dfrac{12.5}{12.5 + 8.5} \times 1.387 \times 10^7 = 8.256 \times 10^6$ N [B1]

$\Delta F = k\Delta x$

$\Delta x = \dfrac{8.256 \times 10^6}{7.0 \times 10^7}$ [C1]

$= 0.118$ m [A1]

increase in length = ... m [3]

Examiner's Comment:

Most students went to calculate the tension when the roadway is empty. However, in this process, many students missed out steps in their calculation of this tension, even though they had done it correctly in their (e) answer for tension when the roadway is fully laden. Not sure of the reason for this.

(g) Using your answer to **(d)**, suggest and explain which section of the roadway is under the greatest compression.

The section nearer to the tower exerts a larger force than the section further from it. [B1]

The section nearest to the tower will be under the greatest compression. [B1]

....[2]

[Total: 16]

Examiner's Comment:

Many students mentioned that it is the centre of the bridge that has largest compression, due to the weight of that section of bridge being furthest away from the towers and thus having the least support, or that that's where the centre of gravity is. However, if anything, that actually means that that part of the bridge will have the largest stretching tension, not

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	

PHYSICS 9749/03

Paper 3 Longer Structured Questions **2 October 2023**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 10**
3	**/ 8**
4	**/ 8**
5	**/ 12**
6	**/ 12**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This document consists of **21** printed pages and **2** blank pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ ...$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

BLANK PAGE

Section A

Answer **all** the questions in the spaces provided.

1 (a) Give a **reasoned** estimate of the area of the island of Singapore in SI unit.

From east to west, Singapore is about 40 km.
From north to South, Singapore is about 25 km.
If Singapore is a rectangle, she will have an area of 800 km^2.
But Singapore is not a rectangle. The "corners" are missing. The estimated area of the missing corners are about 100 km^2.
Therefore, the area of Singapore is about 700 km^2.

Any reasonable explanation to arrive at answer diagrams are accepted [B1]
Answer range from 600 km^2 to 900 km^2 [A1]

area = ...unit................. [2]

Examiner's comments:

It is quite a surprise that the majority of the cohort is unaware of the land area of Singapore. The answer was given during NDP celebration (2023). Some answers lost marks due to not being able to come out with clear reasons to estimate the size of Singapore. Answers such as 20km x 50km are given expecting examiners to guess for themselves what those numbers are supposed to means. A rough diagram drawn will be good in explaining for their answers.

(b) A coin is made in the shape of a circular disc, as shown in Fig. 1.1.

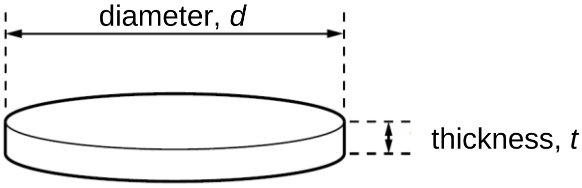


Fig. 1.1

Fig. 1.2 shows the measurements made in order to determine the density ρ of the material used to make the coin.

quantity	measurement	uncertainty
mass, *m*	8.2 g	± 0.5 g
thickness, *t*	2.00 mm	± 0.01 mm
diameter, *d*	22.1 mm	± 0.1 mm

Fig. 1.2

(i) State the name of the measuring instrument suitable for making the measurement of thickness *t*.

Micrometer screw gauge. [B1]
It has a precision of ± 0.01 mm

Examiner's comments:

Well done. With some spelling errors.

(ii) Calculate the density ρ of the coin in kg m^{-3}.

$$\rho = \frac{m}{\pi\left(\frac{d}{2}\right)^2 t} = \frac{8.2\times10^{-3}}{\pi\left(\frac{22.1\times10^{-3}}{2}\right)^2 (2.00\times10^{-3})} \quad \text{[C1]}$$

$$= 10688\ \text{kg m}^{-3}$$

$$\approx 10700\ \text{kg m}^{-3}\ \text{(3 sig. fig.)} \quad \text{[A1]}$$

Comment

Ok for student to leave to more than 3 sig. fig.

ρ = ...kg m^{-3} [2]

Examiner's comments:

Common mistakes include not knowing how to find volume of cylinder, forgetting to square the radius and forgetting to multiply with correct prefixes. Getting this question wrong is unworthy as it is a giveaway.

(iii) Calculate uncertainty of the density ρ of the coin and give the value of ρ with its actual uncertainty.

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta t}{t} + 2\frac{\Delta d}{d}$$

$$\frac{\Delta\rho}{10700} = \frac{0.5}{8.2} + \frac{0.01}{2.00} + 2\left(\frac{0.1}{22.1}\right) \quad \text{[C1]}$$

$$\Delta\rho = 802.77 \approx 800\ \text{(1 sig. fig.)} \quad \text{[C1]}$$

$$\rho = (10700 \pm 800)\ \text{kg m}^{-3} \quad \text{[A1]}$$

Examiner's comments:

A significant number of candidates failed to recall that uncertainty is reported to 1 sig. fig. Some rounded off the value of density too early in (ii)and lost some precision marks as a result. A number multiplied 2 to thickness instead of diameter.

(iv) The densities of three metals are given in Fig. 1.3.

metal	density
iron	7870 kg m^{-3}
copper	8960 kg m^{-3}
silver	10500 kg m^{-3}

Fig. 1.3

State and explain which metal the coin is made of.

As the density of silver 10500 kg m^{-3} <u>falls within the range of ρ calculated</u>, [M1]
the coin is most likely made of silver [A1]

Examiner's comments:

A significant number of candidates failed to relate the conclusion using the answers obtained in (iii).

[Total: 10]

2 An object P of mass 1.5 kg with an initial velocity u collides elastically with another object Q of mass 2.4 kg that is initially at rest. The variation of the force that P exerts on Q with time is shown in Fig. 2.1.

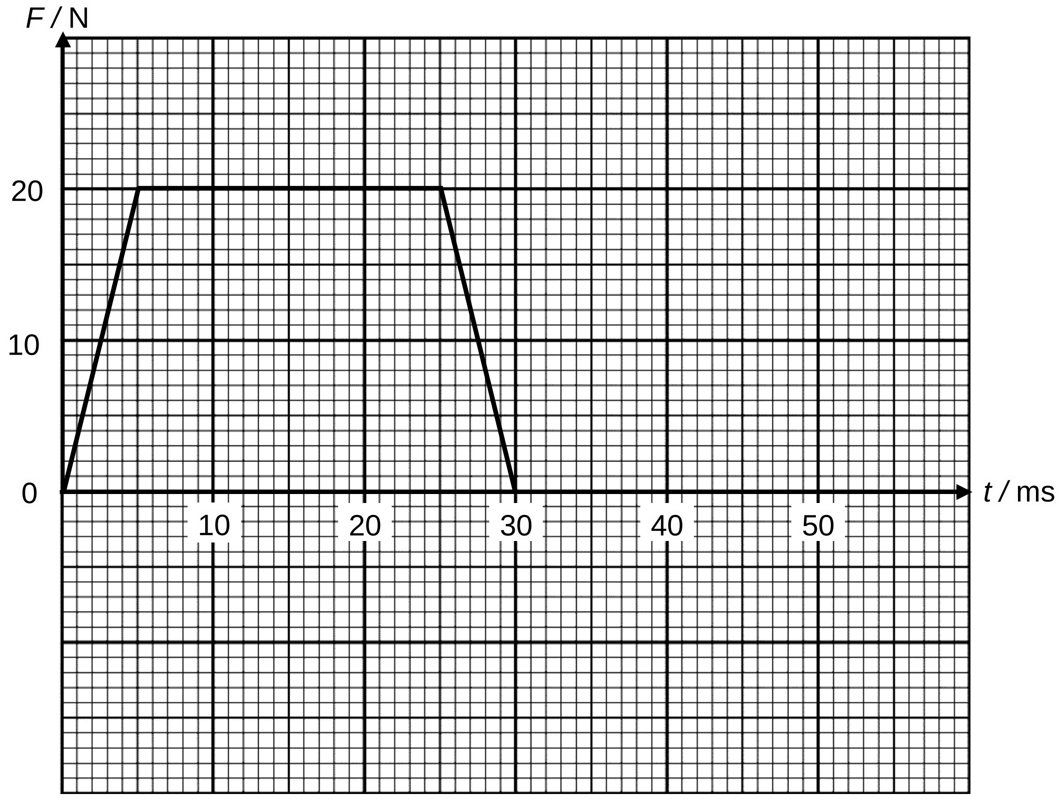


Fig. 2.1

(a) Explain what is meant by an *elastic* collision.

It is a collision in which the total kinetic energy after the collision is equal to that before the collision

....[1]

(b) Sketch, on Fig. 2.1, a graph that shows the variation of the force that Q exerts on P with time. Explain your answer.

By Newton's third law, the force exerted by P on Q is equal in magnitude and opposite in direction to that exerted by Q on P. Hence the graph is a reflection along the horizontal axis. [2]

(c) State what the area under the graph drawn in **(b)** represents.

The area under the force-time graph represents change in momentum OR impulse of object Q. [1]

(d) Calculate the velocity of Q after the collision.

Change in momentum of Q = Area under F-t graph

$$\Delta p_Q = \frac{1}{2}\times 20\times\left(50\times 10^{-3}\right)$$
$$= 0.50\text{ Ns}$$
$$m\Delta v_Q = 0.50$$
$$2.4\left(v_Q - 0\right) = 0.50$$
$$v_Q = 0.208\text{ m/s to the right}$$

velocity of Q = ... m s^{-1} [2]

(e) Calculate the velocity of P before and after the collision.

Taking rightwards positive,

By principle of conservation of linear momentum, $\Sigma p_i = \Sigma p_f$

$$m_P u_P + m_Q u_Q = m_P v_P + m_Q v_Q$$
$$1.5u_P + 0 = 1.5v_P + 2.4(0.20833) \quad \cdots(1)$$

By relative speed relation,

$$u_P - u_Q = v_Q - v_P$$
$$u_P - 0 = 0.20833 - v_P \quad \cdots(2)$$

Sub (2) into (1):

$$1.5\left(0.20833 - v_P\right) = 1.5v_P + 2.4(0.20833)$$
$$0.312495 - 1.5v_P = 1.5v_P + 0.50$$
$$3.0v_P = -0.187505$$
$$v_P = -0.0625\text{ m/s}$$
$$u_P = 0.27083\text{ m/s} = 0.271\text{ m/s}$$

velocity of P before collision = ... m s^{-1}

velocity of P after collision = ... m s^{-1} [4]

[Total: 10]

3 **(a)** Fig. 3.1 shows two graphs. Graph A shows the displacement at time t = 0 s of different points on a progressive wave. Graph B shows the displacement of the same wave at t = 0.10 s.

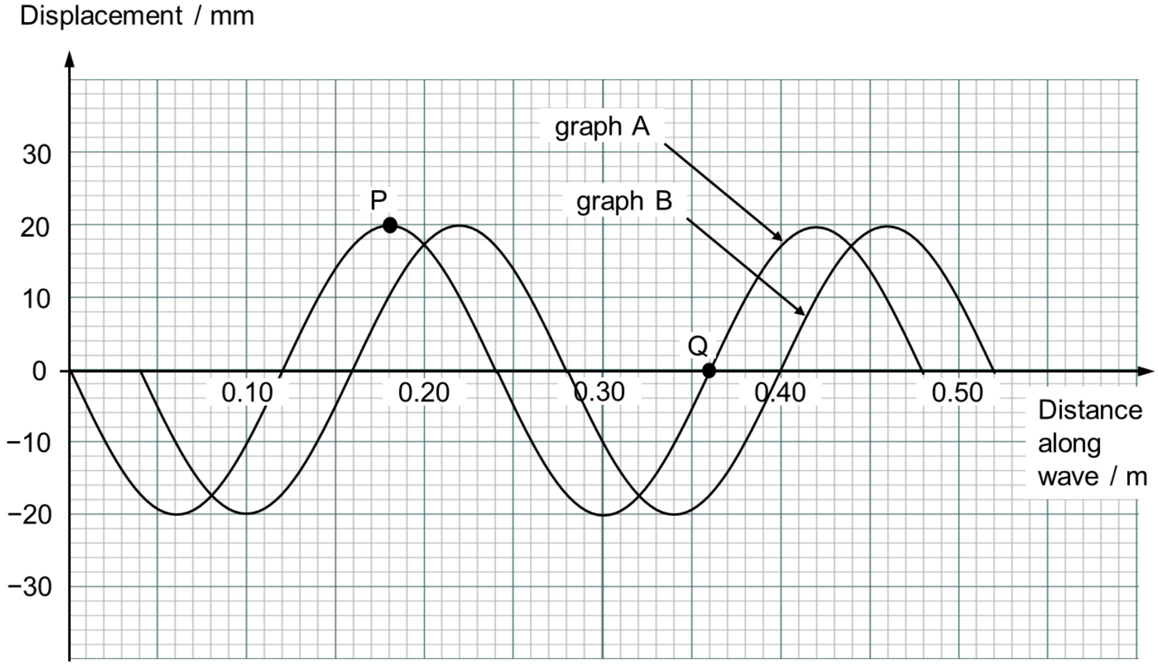


Fig. 3.1

(i) Determine the phase difference between points **P** and **Q** marked on graph **A** in terms of π.

$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$$

$$\Delta\phi = \frac{0.18}{0.24}(2\pi)$$

$$= \frac{3\pi}{2}$$

phase difference = ... rad [1]

(ii) Determine the wave speed.

From graph, distance moved in 0.10 s is 0.04 m. [C1]

$v = \frac{s}{t} = \frac{0.04}{0.10} = 0.4 \text{ m s}^{-1}$ [A1]

wave speed = ... m s^{-1} [2]

(iii) Determine the period of the wave.

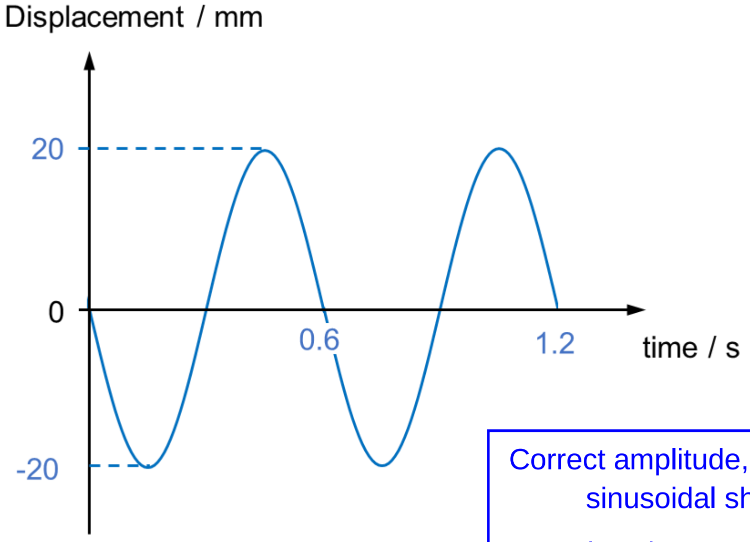
$$v = f\lambda$$

$$0.4 = (\frac{1}{T})(0.24)$$

$$T = 0.6 \text{ s}$$

period = ... s [1]

(iv) Using the grid below, sketch a graph to show the variation with time of the displacement of point **Q**, showing numerical scales on both axes.



Correct amplitude, period and sinusoidal shape [B1]

Negative sine curve [B1]

[2]

(b) (i) Explain what is meant by a *transverse wave*.

A transverse wave is a wave in which the oscillations of the particles are perpendicular to the direction of wave propagation or energy [1]

(ii) State a phenomenon that only applies to transverse waves but not longitudinal waves.

Polarisation [1]

[Total: 8]

4 A speaker emitting sound of frequency 512 Hz is placed near the open end of a narrow tube which has a moveable piston, as shown in Fig. 4.1.

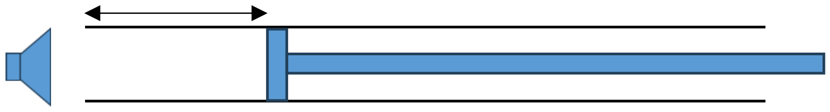


Fig. 4.1

With the piston initially positioned near the open end, the effective length L of the tube is increased by moving the piston to the right. When L reaches a certain length, a stationary wave forms in the tube and a loud sound is first observed.

(a) Explain how the stationary wave is formed inside the tube.

The incident wave and the wave reflected from the piston are identical and moving towards each other in opposite directions.

They undergo superposition to form the stationary wave.

[2]

(b) Sketch, on Fig. 4.1, the stationary wave formed in the tube when the loud sound is first observed. [1]

(c) L is further increased by 33.4 cm, during which the sound diminishes and becomes loud again. Show that the speed of sound in air is 342 m s^{-1}.

Internodal distance = 33.4 cm = $\lambda/2$

$v = f\lambda = 512 \times (2 \times 0.334) = 342$ m s^{-1}

[2]

(d) The frequency of the sound wave is now varied. Given that the maximum value of L is 64.8 cm, determine the lowest frequency of sound that can resonate in this tube.

At lowest frequency, $L = \lambda / 4 \rightarrow \lambda = 4 \times 0.648 = 2.59$ m

$f = v / \lambda = 342 / 2.59 = 132$ Hz

frequency = ... Hz [3]

[Total: 8]

BLANK PAGE

5 A fixed amount of an ideal gas undergoes a cycle of processes A → B → C → A.

The pressure and volume of the gas at each state is shown in Fig. 5.1.

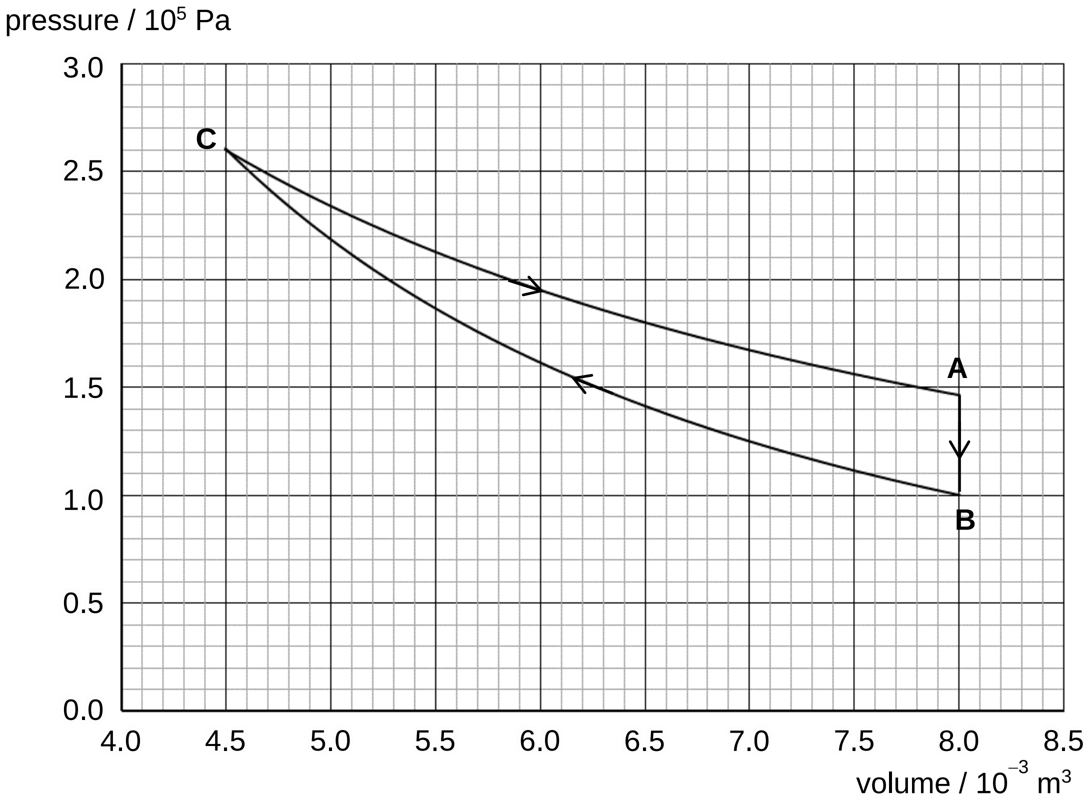


Fig. 5.1

(a) In process A → B, the gas cools at a constant volume. By considering the motion of the gas atoms, explain why the pressure exerted by the gas decreases when the gas cools.

When the gas cools, the atoms move with lower speeds.

Thus the atoms make fewer collisions per unit time and the momentum change per collision decreases in magnitude (either one).

Hence the force they exert decreases in magnitude. [2]

Examiner's Comment:

Common mistake by many is mentioning that hitting the walls at a slower speed will cause a smaller force on the wall, without mentioning momentum as the link between the two.

Handful of chemistry students made the mistake of using the term "effective collisions" when talking about collisions with the wall.

(b) The temperature of the gas at C is 434 K. Determine the temperature of the gas at B.

$pV = nRT \rightarrow 8.00\times10^{-3} \times 1.00\times10^{5} = nR \times T_B$

$\rightarrow 4.50\times10^{-3} \times 2.60\times10^{5} = nR \times 434$

$T_B = 297$ K

Examiner's Comment:

Generally quite well done.

(c) Since the temperature at A is also 434 K, it is deduced that C → A is an isothermal process. Provide an additional piece of evidence from Fig. 5.1 that supports this deduction.

At C, $pV = 2.6\times10^{5} \times 4.5\times10^{-3} = 1170$

At P, $pV = 1.8\times10^{5} \times 6.5\times10^{-3} = 1170$

At A, $pV = 1.45\times10^{5} \times 8.0\times10^{-3} = 1160$

Since pV is approximately the same at A, P and C, they are all at the same temperature and thus, CPA is an isotherm.

Examiner's Comment:

To prove that a curve is an isotherm, it is best to check at least 3 points on the curve that they are all at the same temperature. For a fixed amount of gas, the fastest way is to calculate pV for each point.

[2]

(d) In the process C → A, 675 J of heat was supplied to the gas.

Using the First Law of Thermodynamics, explain why the temperature of the gas did not increase even though heat was supplied to it.

The gas expands, so work done on the gas is negative.

When the negative work is equal to heat supplied to the gas, there is no increase

in internal energy. Thus the is no increase in temperature.

[2]

(e) The area enclosed in the loop ABCA is 115 Pa m^3.

Calculate the work done on the gas in process B → C. Explain your working.

C→A: $\Delta U_3 = Q_3 + W_3$ → $0 = +675 + W_3$

Work done on gas = –675 J → Area under C→A = 675 Pa m^3

B→C: Work done on gas = Area under B→C

= 675 – 115 = 560 J

work done on gas = ... J [3]

[Total: 12]

6 A student is investigating the angle at which a glass cylinder containing oil topples, as shown in Fig. 6.1.

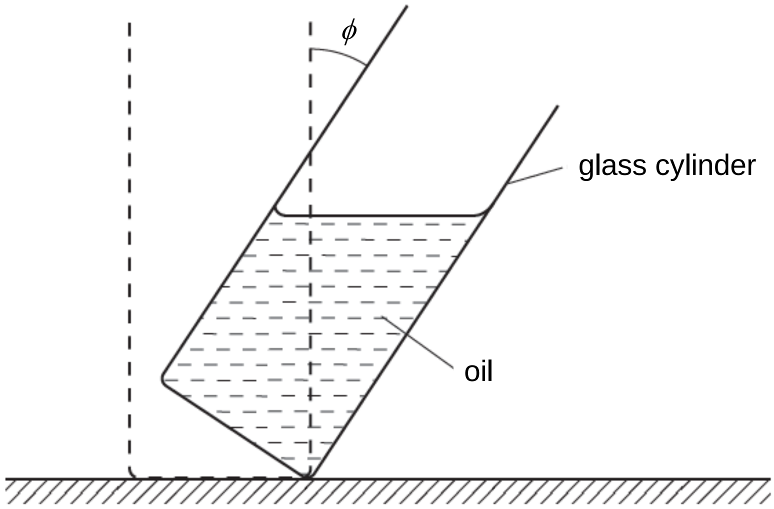


Fig. 6.1

A cylinder containing a mass m of oil can be tilted through a maximum angle ϕ from the vertical before it topples.

It is suggested that the relationship between m and ϕ is

$$\frac{1}{\tan\phi} = \frac{am}{\rho d^3} + b$$

where d is the diameter of the cylinder, ρ is the density of the oil and a and b are constants.

Design a laboratory experiment to determine the values for a and b.

Draw a diagram showing the arrangement of your equipment. You should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any precautions that should be taken to improve the accuracy and safety of the experiment.

Suggested Solution

1. Aim

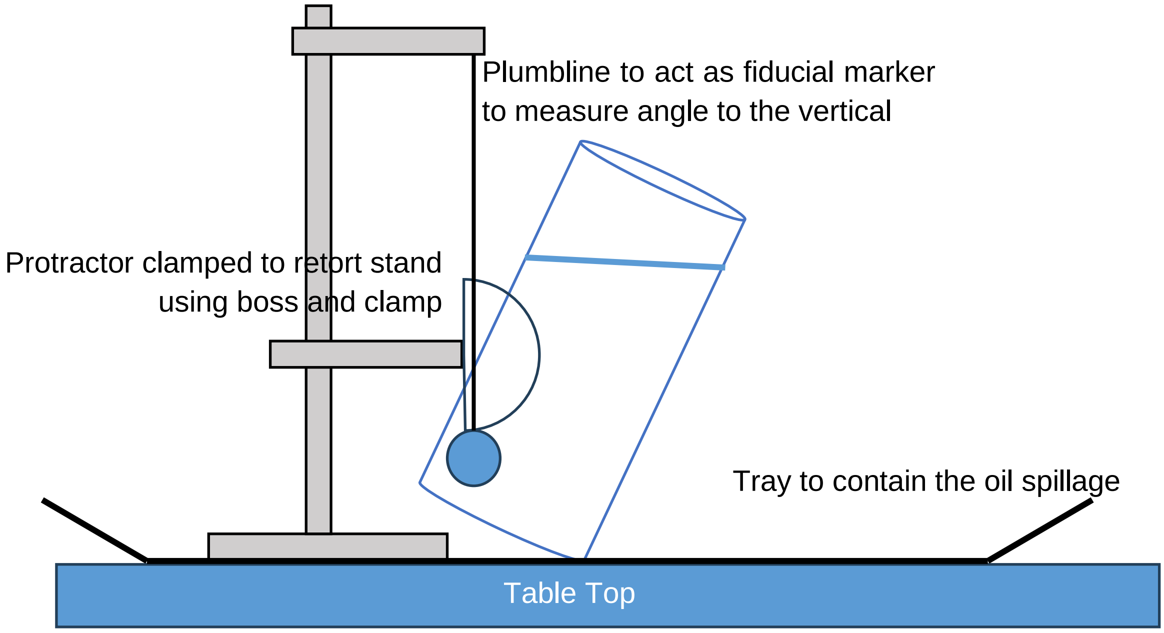
Independent variable: Mass m of oil

Dependent variable: Maximum angle of tilt ϕ of cylinder from the vertical

Control variables: Diameter d of cylinder by using the same cylinder, density ρ of oil by using the same type of oil. Keep the temperature of the oil constant. [C1]

2. Diagram with Apparatus

Correct positioning of protractor [D1]



3. Procedure

1) Set up the apparatus as shown above.
2) Measure the diameter d of the cylinder using a pair of vernier calipers and record as d. [P1]
3) Measure the mass of the empty cylinder using an electronic balance and record as m_o.
4) Pour oil into the cylinder and measure the mass of the cylinder with oil using an electronic balance and record as m'.
5) Calculate the mass of the oil using an electronic balance and record as m. [P1]
6) Tilt the cylinder slowly though a maximum angle from the vertical before it topples.
7) Measure the maximum angle of tilt from the vertical using a protractor and record as ϕ.
8) Repeat measurements of ϕ for each value of m and calculate the average ϕ. [P1]
9) Repeat steps (4) to (7) to obtain 8 sets of values of m and ϕ for increasing m while keeping d and ρ constant. This can be achieved by pouring more oil into the cylinder to increase m.

Graphical Analysis

$$\frac{1}{\tan\phi} = \frac{am}{\rho d^3} + b$$

$$\frac{1}{\tan\phi} = \frac{a}{\rho d^3}\mathrm{m} + b$$

1) Plot graph of $\frac{1}{\tan\phi}$ against m [A1], where $\frac{a}{\rho d^3}$ is the gradient and b is the y-intercept.
2) a is determined from gradient of the graph x ρd^3.
   AND b is determined from y-intercept of the graph. [A1]

Additional Details (Max 4)

1) Conduct preliminary experiments to find a suitable change in values of m that will lead to a significant change in values of ϕ.
   OR Conduct preliminary experiments to find the minimum values of m that will lead to measurable values of ϕ. [AD1]
2) Repeat measurements of d along the length of the cylinder/in different directions and calculate the average d. [AD1]
3) Measure the volume of the oil in the cylinder using a measuring cylinder and record as V. Calculate the density of the oil using $\rho = m / V$. [AD1]
4) If the graph is a straight line with a y-intercept, the relationship is valid. [AD1]
5) Place a retort stand (or Plumbline) behind the set-up as shown in the diagram to act as a fiducial marker / reference line to measure angle ϕ accurately. [AD1]
6) Slowly tilt the cylinder of oil on a rough surface to prevent the cylinder from sliding. [AD1]

Safety Precautions (Max 1)

1) Place the cylinder in a tray to prevent spillage of oil on table top.
   OR Place a lid over the cylinder to prevent spillage of oil. [S1]
2) Place a cloth beside the toppling cylinder to cushion its fall to prevent the glass from shattering. [S1]

Diagram

Marks Scheme		Marks
Diagram [1]		
1	Labelled diagram showing labelled protractor positioned to determine *Φ* for tilted cylinder. [Indicate D0 if not fulfilled] Allow distances marked to determine *Φ* and use of rule.	D1
Methods of data collection [3]		
1	Use of balance/scales to measure the mass of oil/cylinder. Taring of electronic balance to get mass of oil directly is acceptable.	P1
2	Use of vernier calipers/micrometer to measure *d.* [Ruler is not accepted]	P2
3	Repeat each experiment for the same value of *m* and average *Φ*	P3
Control of variables [1]		
1	Use the same (diameter) cylinder (not "same size" but allow "same size and shape")	C1
2	Keep temperature of oil constant OR same type of oil OR density of oil	
Method of analysis [2]		
1	Plot a graph of $\dfrac{1}{\tan\phi}$ against *m.* (allow $\dfrac{m}{d^3}$ or $\dfrac{m}{\rho d^3}$ or $\dfrac{m}{\rho}$. Do not allow log-log graphs.)	A1
2	$a = \text{gradient} \times \rho d^3$ and b = y-intercept; must be consistent with suggested graph. (*a* and *b* must be made subject of formula)	A2
Safety consideration [max 1]		
1	Precaution linked to preventing spilling oil, e.g. use a tray/lid/cloth to absorb oil (do not allow just wiping or mopping)	S1
2	Precaution linked to preventing glass cylinder breaking, e.g. padding/cushion	
Additional Details [4]		
1	Conduct of preliminary trial to determine the range of *m* to be used such that significant changes to *Φ* can be obtained. Or Conduct preliminary trial to determine the angle *Φ* just before the cylinder topples.	AD1
2	Repeat measurements of *d* in different directions/ along the length of the tube and average	AD2
3	Slowly gently/gradually tilt cylinder of oil/use rough surface (to prevent sliding)	AD3
4	Experimental method to determine density of oil and $\rho = m/V$	AD4
5	Relationship is valid if graph is a straight line; must be consistent with suggested graph	
6	Usage of fiducial marker to obtain *Φ* with description	

Examiner's comments:

As the main diagram of how to tilt the cylinder was given in the question, by redrawing it in the diagram space itself do not add value to your answer. What the examiners are looking for is how you value add the set up that you have drawn. For example, the position of where you place the protractor is important because it aids the reader to understand how the measurement of angle is made.

A number of candidates also failed to clearly mention what instrument was used to measure mass and angle etc. resulting in a lost of marks. Rulers are not accepted for measurement of *d* because there is inherent difficulties in positioning it near the cylinder to measure the correct diameter. Marks will only be awarded if the use of set squares and rulers is explained and illustrated clearly with a diagram which is just not being marks efficient.

Vague illustration of control variables are also not credited "same size" alone does not imply same diameter/shape of cylinder used.

Points on safety: Quite a number of candidates mentioned that oil can be mopped up after they are spilled. This is not given credit because the question does not require you to spill the oil unnecessarily. Just spilling it for the sake of spilling it to come out with a solution for safety shows a lack of common sense of the answer given. Instead, experimenter should think of ways to contain spillage or prevent spillage if possible.

On analysis, since question has given you an unknown equation to investigate, we can only mention that equation is valid IF a linear/straight line is obtained. The y-intercept *b* can be zero and also can be non zero. Hence, do not make the assumption in your answer about where the graph should cut the y-axis when you did not even conduct the experiment yourself such as "the graph do/do not cut through the origin".

Usage and rationale of preliminary trials must also be clear as mentioned in marks scheme. Do not just give vague answers like conduct preliminary trial and hoping for marks. It unfortunately does not work this way.

Usage of fiducial markers must also be elaborated on what apparatus is use and how it is set up to aid in the more accurate measurement of the angle is expected too. Just stating fiducial marker is use is quite vague as an answer. Just think of it as good as us saying: Just use your GC to solve this question and do not teach you how a GC is being used.

As numerical values are not given in the question itself, do not commit to numerical values to vary the mass m or any other variables. Just mention: By varying the values of m determine the value of Φ will do. You will be marked down if the values given do not give meaningful experimental results.

Lastly, this is physics 9749 paper, there is no need for you to draw table and sketch expected graphs like what you did for chemistry unless the question asks you to do so. So please know what paper you are taking. They are not the same.

[12]

[Total: 12]

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** **(i)** State *Newton's law of gravitation*.

The gravitational force is directly proportional to the product of the two point masses and inversely proportional to the square of separation between the two point masses.

[2]

(ii) Define *gravitational field strength*.

The gravitational force per unit mass acting on a test mass placed at a point in the region of gravitational field.

[1]

(iii) Explain why the gravitational field strength near surface of Earth is constant and numerically equal to acceleration of free fall.

When it is near the surface, the height is very small compared to the radius of the Earth. Hence field strength is almost constant .

When it is free –falling, the gravitational force is the only force acting on the body. Hence by N2L, the acceleration of free fall is numerically equal to gravitational field strength.

(mg = ma, $\Rightarrow$a = g)

[2]

(b) The International Space Station is travelling in a circular orbit at a distance *r* from the centre of the Earth. The radius of Earth is *R*.

(i) Show that the linear speed of the International Space Station is given by the expression

$$v = \sqrt{\frac{gR^2}{r}}$$

where *g* is the acceleration of free fall at the surface of Earth.

The gravitaional force provide the centripetal force.[B1]

$$\frac{GMm}{r^2} = \frac{mv^2}{r} \qquad [B1]$$

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{r}} = R\sqrt{\frac{g}{r}}$$

[2]

(ii) The radius R of Earth is 6400 km and orbital radius r of the Space Station is 6.8×10^6 m.

Use the expression in **(b)(i)** to determine the orbital period of the International Space Station.

$$v = R\sqrt{\frac{g}{r}} = (6.4\times10^6)\sqrt{\frac{(9.81)}{(6.8\times10^6)}} = 7.7\times10^3$$

apply v = rω and T=$\frac{2\pi}{\omega}$

OR

$$T = \frac{2\pi(6.8\times10^6)}{(7.7\times10^3)} = 92 \text{ min}$$

period = ... min [3]

(iii) Explain why the apparent weight of an astronaut inside the International Space Station is zero.

Both the spacecraft and the astronaut are doing a circular orbit with the same acceleration. Since the gravitational force acting on the whole system provides the required centripetal force to do a circular orbit, they must have a common acceleration numerically equal to g.

Hence there is no apparent weight(normal contact force) for the astronaut.

..........[2]

(c) **(i)** Using the expression in **(b)(i)**, show that the total energy E_T of the International Space Station is given by the expression

$$E_T = -\frac{gR^2m}{2r}$$

where m is the mass of the International Space Station.

$$GPE = -\frac{GMm}{r} = -\frac{gR^2m}{r}$$

Hence E_T = GPE + KE

$$= -\frac{gR^2m}{r} + \frac{gR^2m}{2r}$$

$$= -\frac{gR^2m}{2r}$$

[2]

(ii) The mass m of the International Space Station is 4.2×10^5 kg.

Determine the total energy of the International Space Station.

$$E_T = -\frac{gR^2m}{2r} = -\frac{(9.81)(6.4\times10^6)^2(4.2\times10^5)}{2(6.8\times10^6)} = 1.2\times10^{13}$$

energy = ... J [1]

(iii) Due to air resistance, the total energy of the Space Station will gradually decrease.

Explain the energy changes as the Space Station orbits around Earth.

The total energy will decrease resulting in radius of orbit gradually decreasing.

The rate of loss of GPE = the rate of increase of kinetic energy and rate of work done against air resistance.

....

....[3]

(iv) Thrusters are used to re-boost the Space Station every few months.

Suggest how the Space Station should fire its thrusters to restore its total energy and orbital radius to their original values.

The rocket thrust is fired in the same direction as the tangential velocity of the Space Station so that the speed can be increased .

This will allow the station to gradually orbiting with increasing radius.

....

....[2]

[Total: 20]

8 (a) State what is meant by *simple harmonic motion*.

The motion of the particle is such that the acceleration is proportional to the displacement from the equilibrium position [B1] and the acceleration is always directed to the equilibrium position [B1] OR the direction of the acceleration is always opposite to the displacement. [B1] [2]

(b) A smooth cylindrical tube, containing some sand, floats upright in a liquid of density ρ as shown in Fig. 8.1.

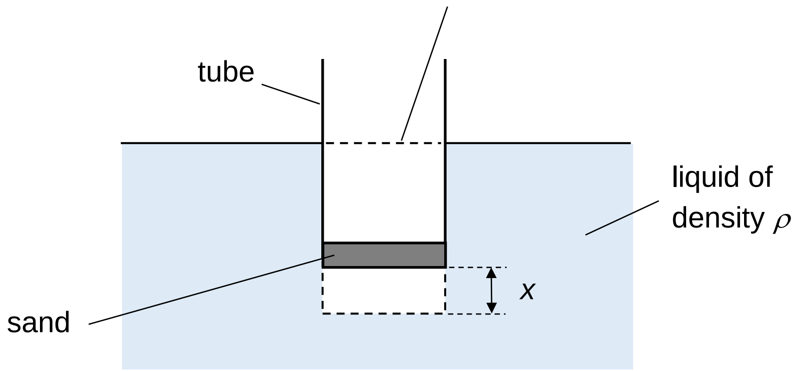


Fig. 8.1

The tube has cross-sectional area A. The total mass of the tube and sand is M.

The tube is displaced vertically downwards and then released. The tube oscillates vertically.

(i) Derive an expression, in terms of ρ A, x and the acceleration of free fall g, for the resultant force F acting vertically on the tube when the displacement of the tube from its equilibrium position is x. Explain your working.

The forces acting on the object is upthrust U and weight W. Let h be depth of tube and when floating at its equilibrium position,

$$U = W$$

$$\rho g V = Mg$$

$$\rho g A h = Mg \quad \text{[B1]}$$

Taking downwards as positive, when tube is displaced downwards, upthrust increases, hence there is a *net force acting upwards*.

$$F_{\text{net}} = -\rho g A(h + x) + Mg \quad \text{[B1]}$$

$$= -\rho g A(h + x) + \rho g A h$$

$$= -\rho g A x \quad \text{[A1]}$$

[3]

(ii) Using the expression derived in **(b)(i)**, show that the acceleration *a* of the tube at displacement *x* is given by

$$a = -\left(\frac{\rho A g}{M}\right)x.$$

Hence, by N2L, and taking downwards as positive,

$$F_{\text{net}} = Ma \qquad \text{[B1]}$$

$$-\rho g A x = Ma \qquad \text{[B1]}$$

$$a = -\frac{\rho g A}{M}x$$

[2]

(iii) The mass *M* of the tube and sand is 120 g. The area *A* of the cross-section of the tube is 5.8 cm^3.

Calculate the frequency of the oscillation of the tube when floating in water of density 1.0×10^3 kg m^{-3}.

$$\omega^2 = \frac{\rho g A}{M} \qquad \text{[B1]}$$

$$\omega = \sqrt{\frac{\rho g A}{M}} = \sqrt{\frac{(1.0\times10^3)(9.81)(5.8\times(1\times10^{-2})^3)}{120\times10^{-3}}} \qquad \text{[M1]}$$

$$= 0.6885855 \qquad \text{[C1]}$$

$$= 2\pi f$$

$$f = 0.10959$$

$$= 0.110 \qquad \text{[A1]}$$

frequency = ... Hz [4]

(iv) State and explain the changes to your answer in **(b)(iii)** if the tube is now floating in cooking oil.

Since oil is less dense than water, the value of ρ is now smaller [M1]. Hence

frequency of the oscillation decreases [A1] since $f = \frac{1}{2\pi}\sqrt{\frac{\rho g A}{M}}$.

....[2]

(c) The smooth cylindrical tube in **(b)** is now incident with water waves. The water waves cause resonance in the up-and-down motion of the tube.

(i) Explain what is meant by the term *resonance*.

Resonance occurs when an oscillating system achieves maximum amplitude due to an external driving force. [B1]

This occurs when the driver frequency is equal to the natural frequency of the oscillating system. [B1]

.... [2]

(ii) Water waves of variable frequency and constant amplitude y are now incident on the tube and causes forced oscillation.

1. On Fig. 8.2, sketch a labelled graph to show the variation with frequency of the water waves of the amplitude of oscillation of the tube. Include the natural frequency of the block and the amplitude y of the water waves on the axes.

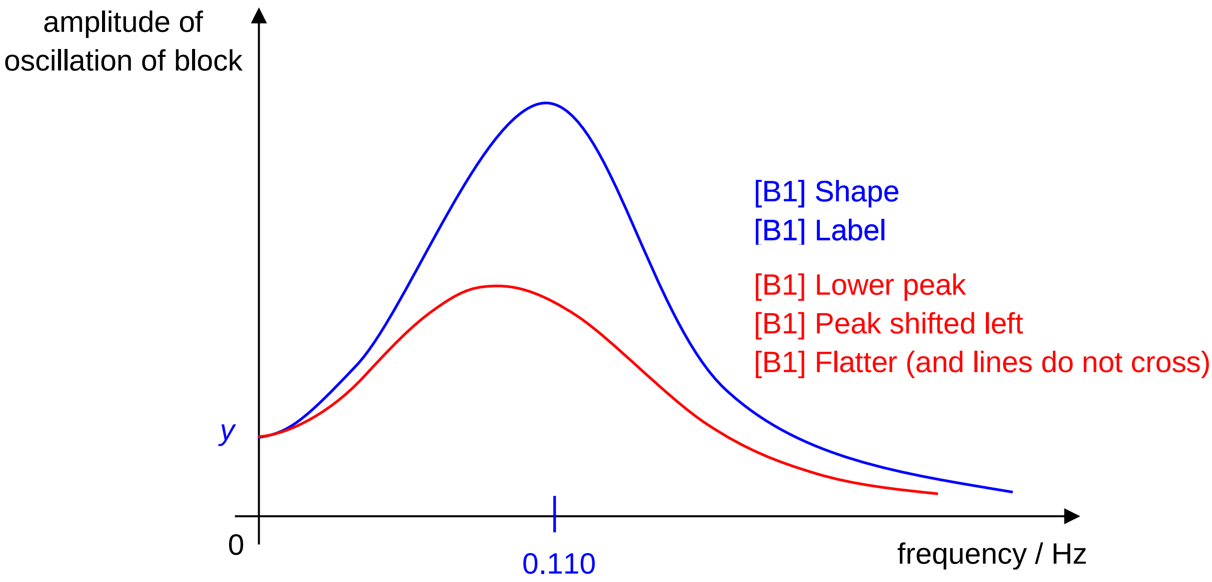


Fig. 8.2

[2]

2. On Fig. 8.2, sketch a graph to show the variation with frequency of the water waves of the amplitude of oscillation of the tube, if the tube is rough. [3]

[Total: 20]

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 1 END OF YEAR EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS 9749/01

Paper 1 Multiple Choice

30 September 2022

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of 15 printed pages.

Data

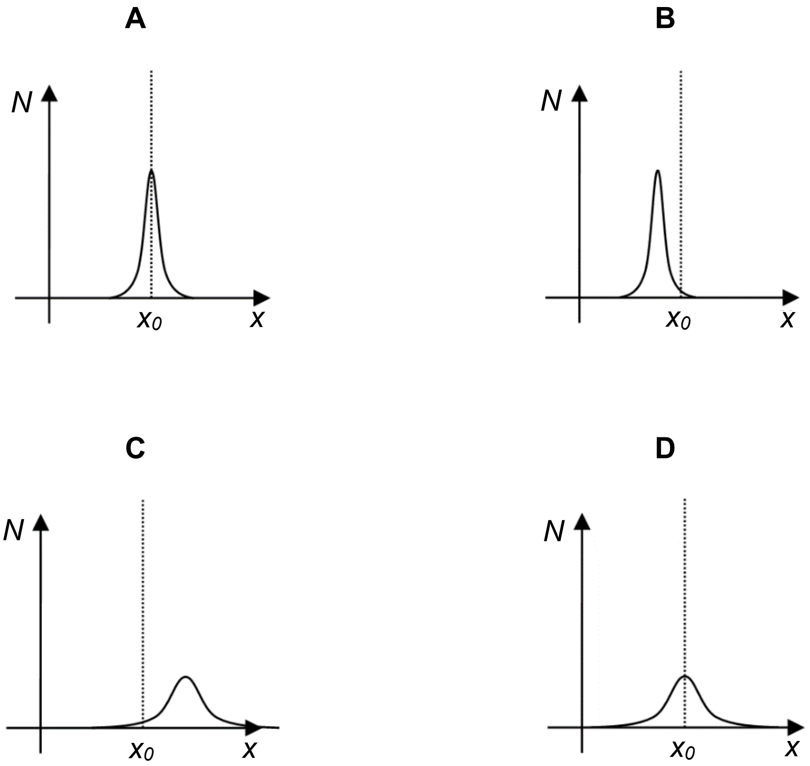
speed of light in free space	$c = 3.00 \times 10^8$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 The true value of a quantity x is x_0. In an experiment, the quantity is measured many times and the number of readings, N, giving a value x, is plotted against x.

Which of the following graphs best shows measurements that are precise but inaccurate?



Ans: B

The graph in Option B is narrower, therefore has the smaller spread of data (hence, it is precise) and its peak value is further from the true value x_0 (hence, it is inaccurate).

2 In an experiment to determine the acceleration of free fall, g, a student presented his calculated value as 9.7846 m s^{-2} which has a percentage uncertainty of 5%.

Which of the following gives his result reduced to the appropriate number of significant figures?

A 10 m s^{-2} **B** 9.8 m s^{-2} **C** 9.78 m s^{-2} **D** 9.785 m s^{-2}

Ans: B

$$\frac{\Delta g}{g} \times 100\% = \pm 5\%$$

$$\frac{\Delta g}{g} = \pm 0.05$$

$$\Delta g = \pm 0.05g = \pm 0.05(9.7846) = \pm 0.5\ \text{ms}^{-2}$$

$$g = 9.8 \pm 0.5\ \text{ms}^{-2}$$

3 In still air, a bird can at a speed of 10 m s^{-1}. The wind is blowing from the east at 8.0 m s^{-1}.

In which direction must the bird fly in order to travel to a destination that is due north of the bird's current location?

A 37° east of north **B** 37° west of north **C** 53° east of north **D** 53° west of north

$$\theta = \sin^{-1}\left(\frac{8}{10}\right) = 53^o$$

Ans: C

4 A golfer hits a golf ball on a flat goft course. The golf ball travels a horizontal distance of 500 m before bouncing. It reaches a maximum height of 210 m.

What is the approximate angle to the horizontal at which the golf ball leaves the golf club? Air resistance may be assumed to be negligible.

A 30° **B** 40° **C** 50° **D** 60°

At max height,

$$v_y{}^2 = u_y{}^2 - 2gs_y$$
$$0 = u_y{}^2 - 2gs_y$$
$$u_y{}^2 = 2gs_y$$

$$s_y = u_y t - \frac{1}{2}gt^2$$
$$0 = t\left(u_y - \frac{1}{2}gt\right)$$
$$t = 0 \text{ or } \frac{2u_y}{g}$$

$$s_x = u_x t$$
$$u_x = \frac{s_x}{t}$$

$$\frac{u_y}{u_x} = \tan\theta$$
$$\frac{u_y}{\left(\frac{s_x}{t}\right)} = \tan\theta$$
$$\frac{u_y}{\left(\frac{s_x g}{2u_y}\right)} = \tan\theta$$
$$\frac{2u_y{}^2}{s_x g} = \tan\theta$$
$$\frac{2(2\cancel{g}s_y)}{s_x\cancel{g}} = \tan\theta$$
$$\theta = 59.2^o$$

Ans: D

5 Water is pumped through a hose-pipe at a rate of 90 kg per minute. Water emerges horizontally from the hose-pipe with a speed of 20 m s^{-1}.

What is the minimum force required from a person holding the hose-pipe to prevent it moving backwards?

A 30 N **B** 270 N **C** 1800 N **D** 108 000 N

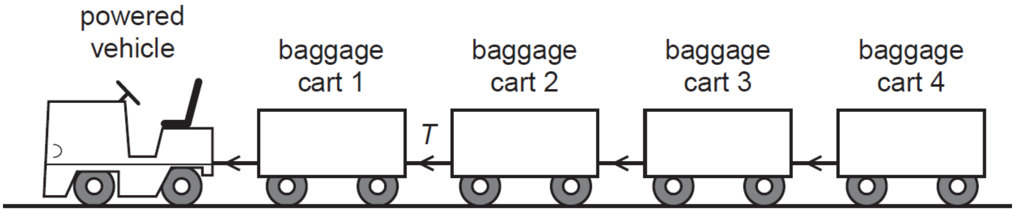
Ans: A

$F_{hw} = \dfrac{m(v-u)}{t} = \dfrac{90(20-0)}{60} = 30\text{ N}$

By Newton's 3rd Law, $F_{wh} = -F_{hw} = -30\text{ N}$

By Newton's 1st Law, $F_{ph} = -F_{wh} = 30\text{ N}$

6 A transport system, used to move luggage from the airport terminal to the aircraft, consists of a powered vehicle connected to four baggage carts by a series of connecting bars.



The mass of the powered vehicle is 200 kg and each of the baggage carts has a mass of 400 kg. The system starts with an acceleration of 2.0 m s^{-2}.

What is the tension *T* in the connecting bar between baggage carts 1 and 2? (Ignore any friction forces on the carts.)

A 800 N **B** 1200 N **C** 2400 N **D** 3600 N

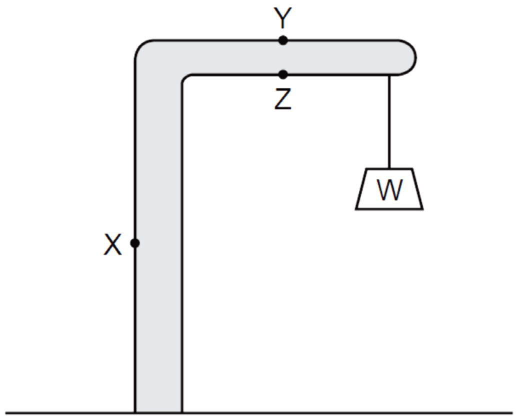
Ans: C

Referring to the FBD of cart 2, 3 and 4 as a system,

$\Sigma F = ma$

$T = (400 \times 3)(2.0) = 2400\text{ N}$

7 A simple light crane consists of a rigid vertical pillar supporting a horizontal beam.



A weight W is lifted by a rope at the end of the beam.

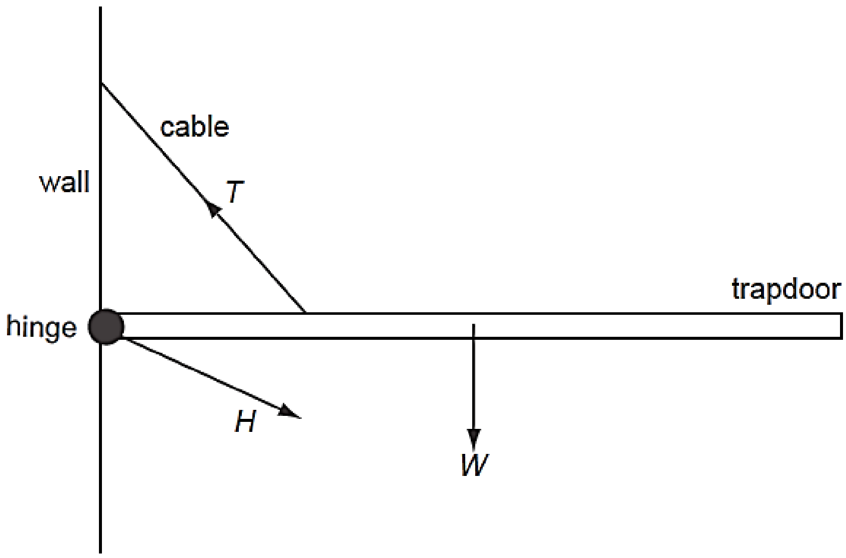
What are the forces at points X, Y and Z?

	force at X	force at Y	force at Z
A	tension	tension	compression
B	tension	compression	tension
C	compression	tension	tension
D	compression	compression	compression

Ans: A

Under this loading condition, the outer surface (consisting of *X* & *Y*) will be stretched while the inner surface (consisting of *Z*) will be compressed.

8 A hinged trapdoor is held closed in the horizontal position by a cable that is connected midway between the hinge and the centre of gravity of the trapdoor.



(forces are not drawn to scale)

Three forces act on the trapdoor: the weight W of the trapdoor, the tension T in the cable and the force H at the hinge.

Which list gives the three forces in increasing order of magnitude?

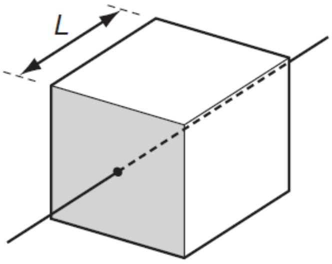
A H, W, T **B** H, T, W **C** W, H, T **D** W, T, H

Ans: C

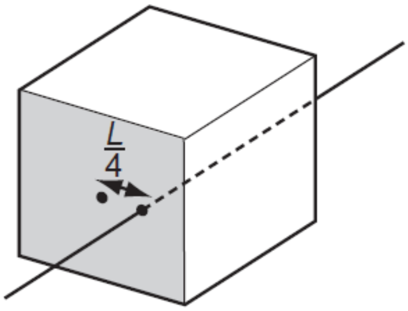
Taking moment about point that cable is connected to the trapdoor, the vertical component of H must be equal to W.
Hence $H > W$.

Considering the sum of vertical forces, the vertical component of T must be equal to sum of W and vertical component of H, while the horizontal component of T is equal that of H.
Hence, $T > H$.

9 The diagram shows a solid cube with weight W and sides of length L. It is supported by a frictionless spindle that passes through the centers of two opposite vertical faces. One of these faces is shaded.



The spindle is now removed and replaced at a distance $\frac{L}{4}$ to the right of its original position.



When viewed from the direction of the shaded face, what is the torque of the couple that will now be needed to stop the cube from toppling?

A $\dfrac{WL}{2}$ anticlockwise

B $\dfrac{WL}{2}$ clockwise

C $\dfrac{WL}{4}$ anticlockwise

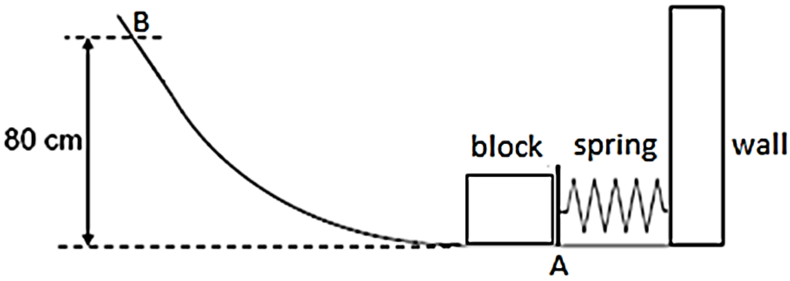
D $\dfrac{WL}{4}$ clockwise

Ans: D

In the second position, there is a resultant anti-clockwise torque of $W\left(\dfrac{L}{4}\right)$ (due to the couple consisting of the downward W and upward contact force at the spindle)

Hence to ensure block remains in equilibrium, a clockwise torque of $W\left(\dfrac{L}{4}\right)$ is needed.

10 A 1.5 kg block rests against a spring that has a compression of 30 cm as shown in the diagram. Upon release, the spring pushes the block up a curved frictionless track.



If the force constant of the spring is 350 N m^{-1}, what is the speed of the block at position B at a height 80 cm above position A?

A 0 m s^{-1} **B** 2.30 m s^{-1} **C** 4.58 m s^{-1} **D** 7.37 m s^{-1}

Ans: B

By conservation of energy,

GPE gain by the block + KE gain by the block = EPE loss by spring

$$(mgh - 0) + \left(\frac{1}{2}mv^2 - 0\right) = \frac{1}{2}kx^2$$

$$(1.5)(9.81)(0.80) + \frac{1}{2}(1.5)v^2 = \frac{1}{2}(350)(0.30)^2$$

$\therefore$ v = 2.30 m s^{-1}

11 Two iceboats hold a race on a frictionless and horizontal frozen lake. The two iceboats have masses *m* and 2*m*, respectively. Each iceboat has an identical sail, so the wind exerts the same constant force on each iceboat. The two iceboats start from rest and cross the finishing line a distance *s* away.

Which of the following statements is correct?

A The two iceboats have the same kinetic energy at the finishing line.

B The heavier iceboat attains a greater kinetic energy at the finishing line.

C The lighter iceboat attains a greater kinetic energy at the finishing line.

D The kinetic energy of the two iceboats is the same initially. However, the kinetic energy differs when the two iceboats reach the finishing line.

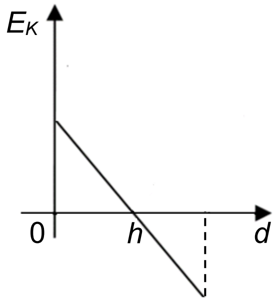
Ans: A

Both iceboats travel the same distance *s*, and only the horizontal force *F* in the direction of motion does work on both iceboats. Therefore, the total work done between the starting line and the finish line is the same for each iceboat. Since the work done by the iceboat is converted to the kinetic energy of the iceboat at the finish line, the two iceboats will have the same kinetic energy at the finish line

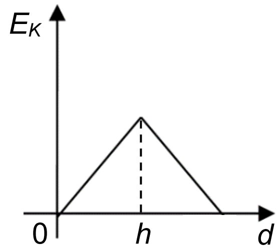
12 A ball, thrown vertically upwards, rises to a height h and then falls to its starting point. Air resistance may be taken as negligible.

Which graph best shows the variation with distance d travelled of the kinetic energy E_k of the ball?

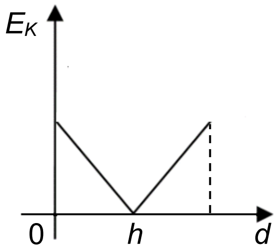
A



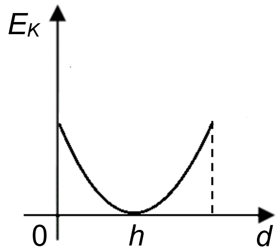
B



C



D

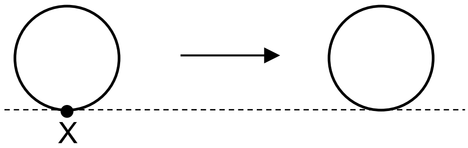


Ans: C

Kinetic energy ($\frac{1}{2}mv^2$) is always a positive value and is 0 J at maximum height h since velocity of the ball is momentarily 0 m s^{-1} at maximum height h.

Since $v^2 = u^2 - 2gs$, therefore $v^2 \propto s$. Hence, $KE \propto s$ (straight line graph).

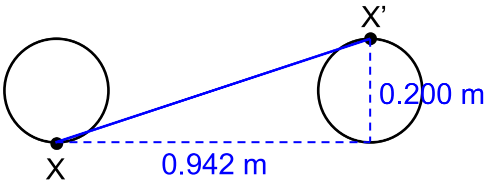
13 A cylinder of radius 0.100 m is rolling at a constant angular velocity of $\frac{3}{4}\pi$ rad s^{-1} along a horizontal surface from left to right. The side view of the cylinder is as shown. The point X is initially at the bottom of the cylinder.



After 4.00 s, what is the displacement of X?

A 0.020 m **B** 0.150 m **C** 0.942 m **D** 0.963 m

Ans: D

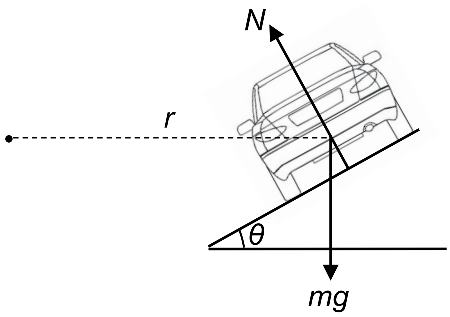


ang. disp., $\theta = \omega t = \frac{3}{4}\pi \times 4.00 = 3\pi$ rad $\equiv 1.5$ rounds

horizontal disp. $= 1.5 \times 2\pi(0.100) = 0.942$ m

disp. of X $= \sqrt{0.942^2 + 0.200^2} = 0.963$ m

14 A car of mass m is moving with speed v in a horizontal circle of radius r on a banked road inclined at an angle θ to the horizontal, as shown. The normal contact force on the car is N.



Which of the following expressions is correct?

A $N\cos\theta = mg$ **B** $N = mg\cos\theta$ **C** $v^2 = \frac{rg}{\sin\theta}$ **D** $v^2 = \frac{rg}{\tan\theta}$

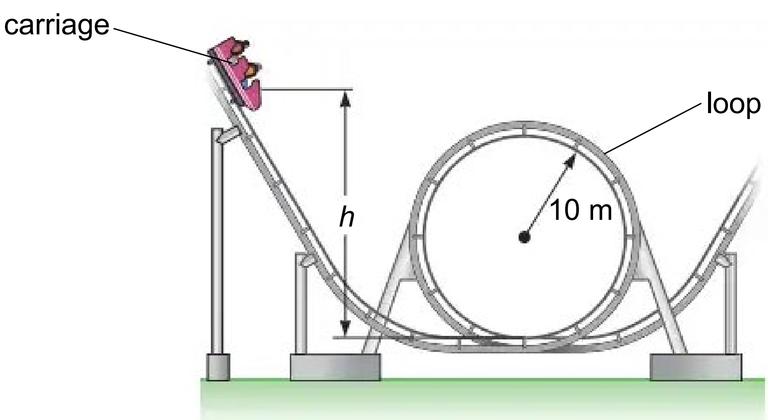
Ans: A

$N\cos\theta = mg$ ---(1)

$N\sin\theta = \frac{mv^2}{r}$ ---(2)

$\frac{(2)}{(1)}$, $\tan\theta = \frac{v^2}{rg}$

15 In a segment of a rollercoaster track, a carriage descends from rest at a vertical height h measured from the lowest point of the track, as shown. Friction between the carriage and the track may be taken as negligible.



If the carriage is to complete the loop without leaving the track, what is the minimum value of the height h?

A 15 m **B** 20 m **C** 25 m **D** 30 m

Ans: C

At top of loop, $v \geq \sqrt{rg}$

By COE, $Ep_i + Ek_i = Ep_f + Ek_f$

$$\cancel{m}gh + 0 = \cancel{m}g(20) + \frac{1}{2}\cancel{m}\left(\sqrt{10 \times 9.81}\right)^2$$

$h = 25$ m

16 Why does the Moon stay in its orbit at a constant distance from the Earth?

A The gravitational pull of the Earth on the Moon balances the gravitational pull of the Moon on the Earth.

B The gravitational pull of the Earth on the Moon is just sufficient to cause the centripetal acceleration of the Moon.

C The gravitational pull of the Moon on the Earth is negligible at this distance.

D The centripetal force the Earth exerts on the Moon balances the centripetal force the Moon exerts on the Earth.

Ans: B

Centripetal force of Moon is provided by gravitational force on Moon due to Earth.

17 Two moons were discovered to be orbiting around Jupiter with the same period.

Which one of the following quantity for the moons must be the same?

A mass

B momentum

C kinetic energy

D radii of orbit

Ans: D

$$\frac{GMm}{R^2} = mR\left(\frac{2\pi}{T}\right)^2$$

$$T^2 \propto R^3$$

Since T is constant, R is constant.

18 The escape speed (i.e. the speed which a body must have in order to escape to an infinite distance from the Earth) of an oxygen molecule at the Earth's surface is 1.1×10^4 m s^{-1}.

What is the escape speed of the oxygen molecule at a height 0.2 R_E above the Earth's surface, where R_E is the radius of the Earth?

A 0.9×10^4 m s^{-1} **B** 1.0×10^4 m s^{-1} **C** 1.2×10^4 m s^{-1} **D** 1.3×10^4 m s^{-1}

Ans: B

$$\frac{1}{2}mv^2 = \frac{GMm}{R}$$

$$\Rightarrow v = \sqrt{\frac{2GM}{R}}$$

$$\therefore \frac{v_1}{v_2} = \sqrt{\frac{R_2}{R_1}}$$

$$\frac{v_1}{1.1\times10^4} = \sqrt{\frac{1.0}{1.2}}$$

$$v_1 = 1.0\times10^4 \text{ m s}^{-1}$$

19 A point mass moves with simple harmonic motion. Which of the following statements is false?

A An oscillation system with larger amplitude will have a longer period.

B An oscillation system with larger amplitude will have a greater maximum velocity.

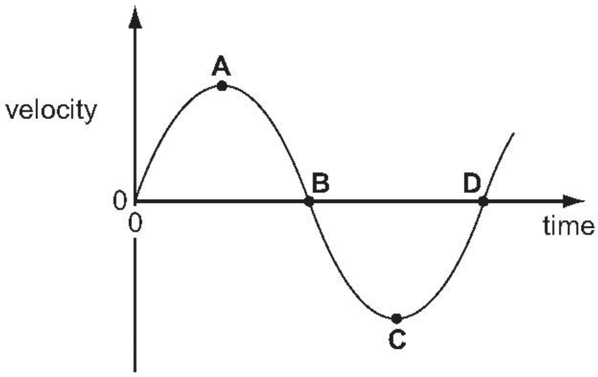
C The maximum kinetic energy of the mass is dependent on the frequency of the oscillation.

D The time taken for the system to change form maximum kinetic energy to maximum potential energy is a quarter of the period of the oscillation.

Ans: A

Amplitude is independent of the frequency.
Max kinetic energy = ½ mv_o^2 = ½ $m\omega^2 x_o^2$ = ½ $m(2\pi f)^2 x_o^2$
The kinetic energy is 2 cycles within 1 period, thus, max KE to Max PE is only ¼ of a period.

20 The diagram shows a velocty-time graph for a mass moving up and down on the end of a spring. Taking upwards as positive, which point represents the velocity of the mass when it is at the equilibrium position and moving towards the highest point?



Ans: A

At the equilibrium position, the velocity is at the max, so possible point will be A or C. When it is moving towards the highest point, the veocity has to be positive, thus, point A only.

21 A simple pendulum is 1.0 m long and oscillates with simple harmonic motion of angular amplitude 0.050 rad and period 2.0 s.
What is the angular speed of the pendulum bob when the angular displacement is 0.030 rad?

A 0.0010 rad s^{-1} **B** 0.020 rad s^{-1} **C** 0.050 rad s^{-1} **D** 0.13 rad s^{-1}

Ans: D

Method 1 (by SHM)

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2.0} = \pi \text{ rad s}^{-1}$$

$$v = \omega\sqrt{x_0^{\,2} - x^2} \text{ where x is linear displacement from e.p.}$$

$$= \pi\sqrt{(1.0\sin 0.05)^2 - (1.0\sin 0.03)^2}$$

$$= 0.12559 \text{ m s}^{-1}$$

$$\omega = \frac{v}{r} = \frac{0.12559}{1.0} = 0.13 \text{ rad s}^{-1}$$

Method 2 (by COE)

$$\Delta h = (1.0 - 1.0\cos 0.05) - (1.0 - 1.0\cos 0.03)$$

$$= 0.000799773 \text{ m}$$

$$\frac{1}{2}\cancel{m}v^2 = \cancel{m}g\Delta h$$

$$v = \sqrt{2g\Delta h}$$

$$= \sqrt{2 \times 9.81 \times 0.000799773}$$

$$= 0.1252 \text{ m s}^{-1}$$

$$\omega = \frac{v}{r} = \frac{0.1252}{1.0} = 0.13 \text{ rad s}^{-1}$$

22 Which of the following gives three regions of the electromagnetic spectrum in order of increasing frequency

A gamma rays, microwaves, visible light

B radio waves, ultraviolet, X-rays

C Ultraviolet, infrared, microwaves

D visible light, gamma rays, radio waves

Ans : B

23 The least distance between two points of a progressive transverse wave which have a phase difference of $\frac{\pi}{3}$ rad is 0.050 m. If the frequency of the wave is 500 Hz, what is the speed of the wave?

A 75 m s^{-1} **B** 150 m s^{-1} **C** 250 m s^{-1} **D** 1670 m s^{-1}

Ans : B

$$\Delta\phi = \frac{\Delta x}{\lambda} \times 2\pi$$
$$\frac{\pi}{3} = \frac{0.050}{\lambda} \times 2\pi$$
$$\lambda = 0.30 \text{ m}$$
$$v = f\lambda$$
$$= 500 \times 0.30$$
$$= 150 \text{ m s}^{-1}$$

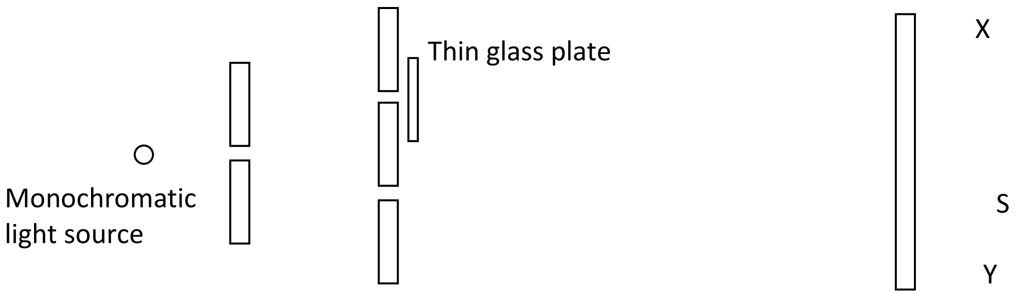
24 A person is initially 10.0 m from a point source which emits energy uniformly in all directions at a constant rate. If the power of the source is to be doubled but the sound is to be as loud as before, at what distance should the person be from the source?

A 5.0 m **B** 7.1 m **C** 14 m **D** 20 m

Ans : C

$$I \propto \frac{1}{r^2}$$
$$\frac{2I}{I} = \frac{r^2}{10^2}$$
$$r = \sqrt{200} = 14.1 \text{ m}$$

25 The diagram below illustrates an experimental arrangement that produces interference fringes with a double slit.



When slit S_1 is covered with a very thin plate of glass as shown, the speed of light decreases when light passes through it. Which of the following is observed?

A The separation of the fringe increases

B The separation of the fringe decreases

C The fringe pattern moves towards X

D The fringe pattern moves towards Y

Ans: C

The thin glass plate is an optically denser medium (than air). Wave from S_1 incur a phase change (due to slower speed and shorter wavelength) as compared to wave from S_2. The whole fringe pattern moves towards X.
For example the n = 0 maximum will not occur at center of screen but is moved toward X.

26 The angular resolution of a vertical slit for horizontally separated objects is 0.50×10^{-3} rad.

What is the angular resolution if the width of the slit is halved?

A 0.25×10^{-3} rad **B** 0.50×10^{-3} rad

C 1.0×10^{-3} rad **D** 2.0×10^{-3} rad

Ans: C

Since $\theta = \dfrac{\lambda}{b}$, is b is halved, the angular resolution will be doubled.

Hence angular resolution $= 2 \times 0.50 \times 10^{-3} = 1.0 \times 10^{-3}$ rad

27 A diffraction grating has N lines per unit length and is placed at 90° to monochromatic light of wavelength λ.

What is the expression for θ, the angle to the normal to the grating at which the second order diffraction peak is observed?

A $\sin\theta = \dfrac{1}{2N\lambda}$ **B** $\sin\theta = \dfrac{2\lambda}{N}$

C $\sin\theta = \dfrac{N\lambda}{2}$ **D** $\sin\theta = 2N\lambda$

Ans: D

$$d\sin\theta = n\lambda$$

$$\sin\theta = \frac{n\lambda}{d} = \frac{2\lambda}{\frac{1}{N}} = 2N\lambda$$

28 The resistance of a thermistor depends on its temperature and the resistance of a light-dependent resistor depends on the illumination.

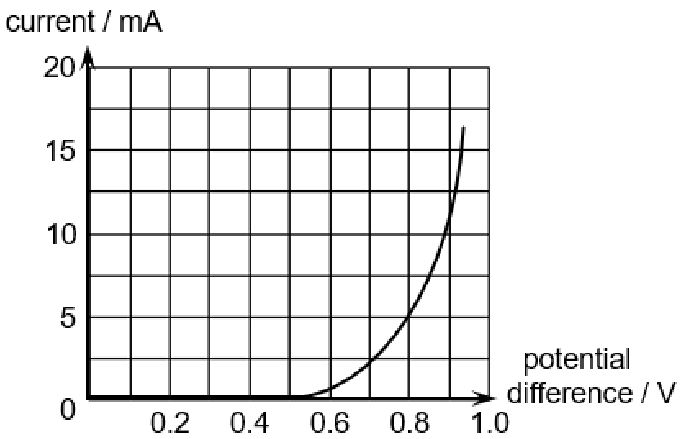
Under what conditions will the effective resistance of a thermistor and a light-dependent resistor connected in series be the maximum?

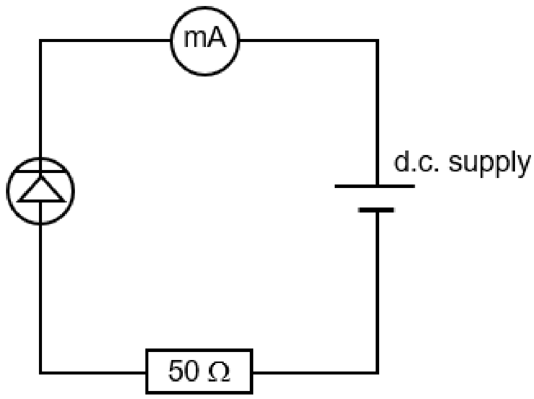
	thermistor	light-dependent resistor
A	high temperature	high illumination
B	high temperature	low illumination
C	low temperature	high illumination
D	low temperature	low illumination

Ans: D

For maximum effective resistance of components connected in series, individual resistance must be maximum. Resistance of thermistor increases as temperature decreases. Resistance of light-dependent resistor increases as illumination decreases.

29 A diode with forward I-V charecteristics shown below is connected in series with a low-voltage variable d.c. power supply, a milli-ammeter of negligible internal resistance and a 50 Ω resistor as shown below.





When the milliammeter shows 5.0 mA, the potential difference across the d.c. power supply is

A 0.25 V **B** 0.55 V **C** 0.80 V **D** 1.05 V

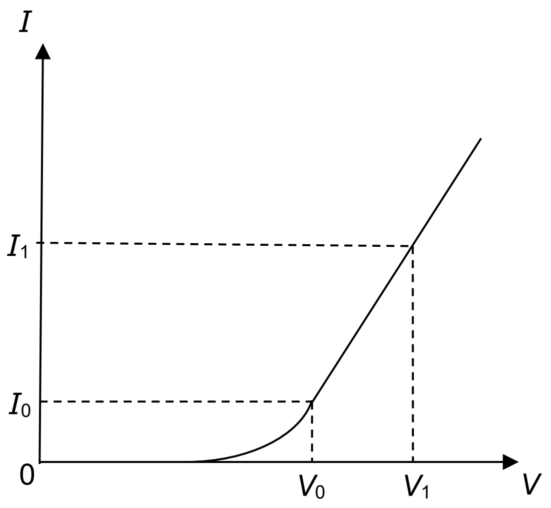
Ans: D

$V_{diode} = 0.8$ V (from graph)

$V_{50\Omega} = 0.005 \times 50 = 0.25$ V (using $V = IR$)

$V_{supply} = V_{diode} + V_{50\Omega} = 1.05$ V

30 The graph below shows the I-V charecteristics of an electrical component.



What is the resistance of the component at potential difference V_1 and how does the resistance change, if at all, when the potential difference increases from V_0 to V_1?

	resistance at V_1	change between V_0 and V_1
A	$\dfrac{V_1 - V_0}{I_1 - I_0}$	no change
B	$\dfrac{V_1 - V_0}{I_1 - I_0}$	decreases
C	$\dfrac{V_1}{I_1}$	no change
D	$\dfrac{V_1}{I_1}$	decreases

Ans: D

Resistance of component is the ratio of potential difference across it to the current through it.

$$\frac{I_0}{V_0} < \frac{I_1}{V_1} \quad \rightarrow \quad \frac{V_0}{I_0} > \frac{V_1}{I_1} \quad \rightarrow \quad R_0 > R_1$$

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END OF YEAR EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS 9749/02

Paper 2 Structured Questions

30 September 2022

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 6**
2	**/ 7**
3	**/ 7**
4	**/ 20**
Total	**/ 40**

This document consists of **15** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 A speed-time graph for an MRT train travelling between two stations is shown in Fig. 1.1.

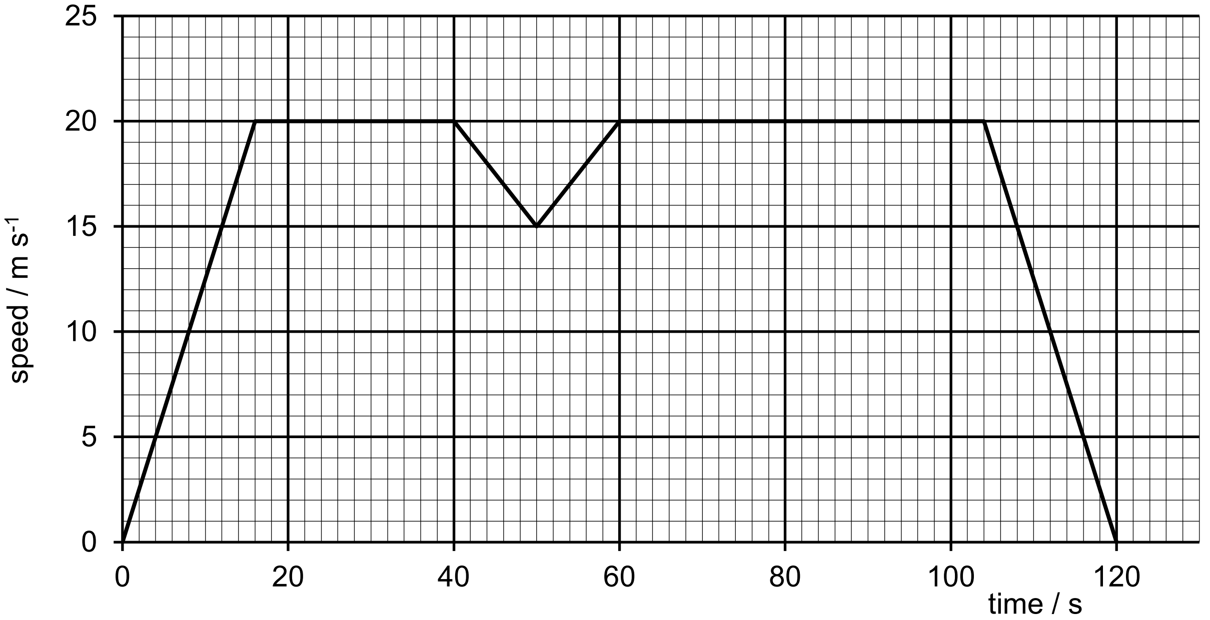


Fig. 1.1

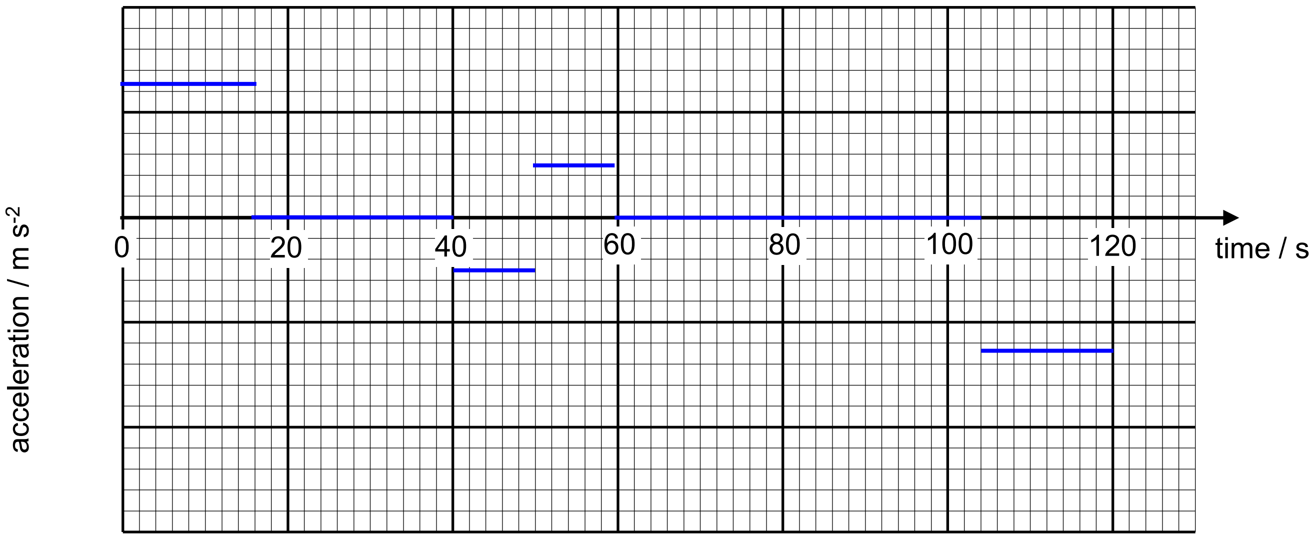


Fig. 1.2

(a) On Fig. 1.2, draw the corresponding acceleration-time graph. Label numerical values on the acceleration axis. [2]

acceleration $_{0 \text{ to } 16s}$ = (20 – 0) / (16) = 1.25 ms^{-2} acceleration $_{40 \text{ to } 50s}$ = (15 – 20) / (10) = - 0.500 ms^{-2}

acceleration $_{50 \text{ to } 60s}$ = (20 – 15) / (10) = 0.500 ms^{-2} acceleration $_{104 \text{ to } 120s}$ = (0 – 20) / (16) = -1.25 ms^{-2}

Examiner comments:
The speed time graph converts to acceleration time graph easily by looking at the gradient of the speed time graph.
The scale of the graph should be appropriate. Use a ruler if a straight line is required. There is no acceleration after 120s. The increase in speed is a positive acceleration and decrease in speed will result in a negative acceleration.

(b) Calculate the distance travelled between the two stations.

Distance = area under graph

= ½ (20)(120+88) - (½)(20)(5)

= 2030

Examiner comments:
Careless students are not able to obtain the distance accurately.

distance = ... m [2]

(c) On Fig.1.3, sketch a distance-time graph of the train between the two stations from time t = 0 to t = 60 s. Numerical values on the distance axis are not required.

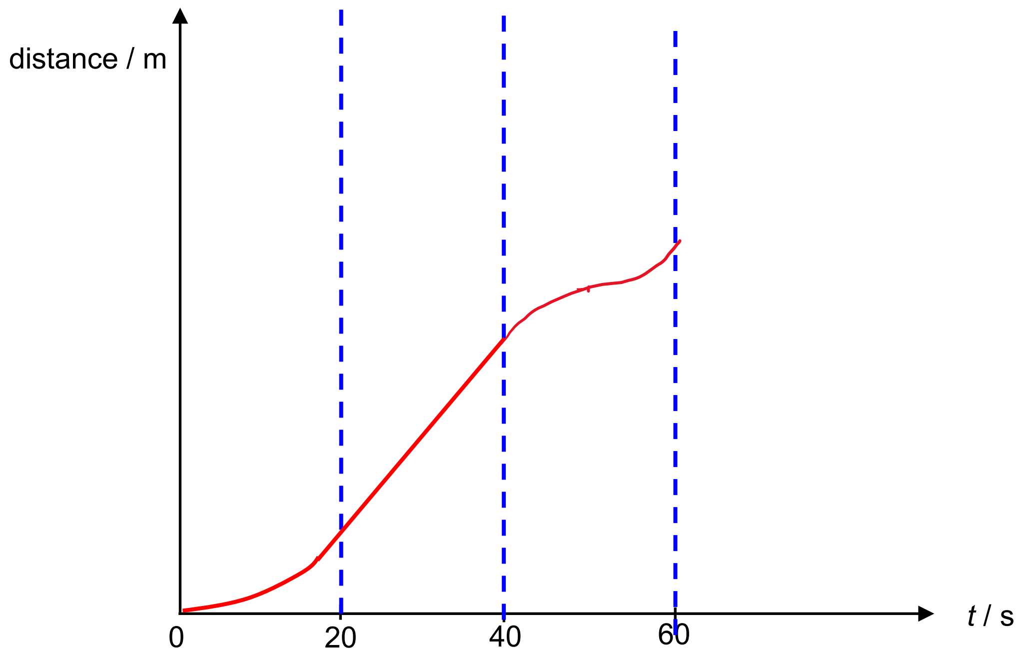


Fig. 1.3

[2]

[Total: 6]

Examiner comments:
The drawing of the distance time graph was quite badly done. There should not be any point where the gradient of the graph is drastically changed. You should realize that the gradient of the graph drawn will give you the graph in Fig 1.1. From 0 to 16s, the graph will curve with an increasing gradient and gradient is constant from 16s till 40s. From 40s to 50s, the gradient is should be decreasing and from 50s to 60s, the gradient of the line should be increasing. Thus, any kinks in the graph drawn will be penalized.

2 Fig. 2.1 shows a ride in an amusement park. A cabin is mounted on one end of an arm, and a counterweight is attached to the opposite end. A man of mass 80 kg sits in the cabin, which moves at constant speed in a vertical circle of radius 8.0 m. In one minute, the man completes 14 revolutions. When the cabin is at the top of the circle, the man in it is upside down, as shown.

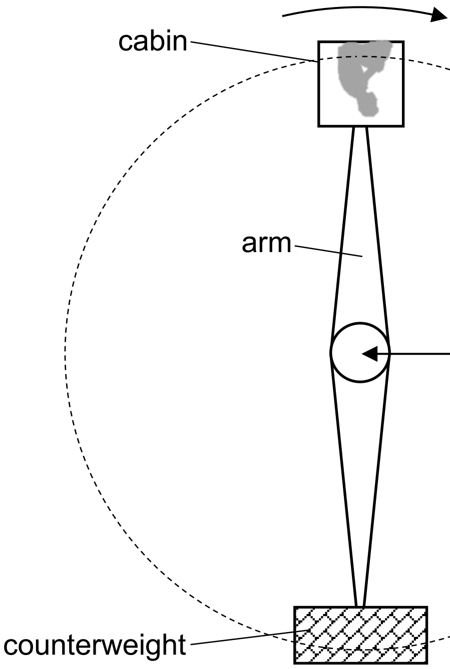


Fig. 2.1

(a) (i) Explain, for the man to remain on the floor of the cabin, why his centripetal acceleration at the top of the circle must be greater than the acceleration of free fall.

For man to remain on floor, a normal contact force (from floor) must act on him [B1].

Since his centripetal force is the sum of his weight and normal contact force, so centripetal force is greater than his weight [B1], hence centripetal acceleration is greater than acceleration of free fall.

.... [2]

Examiner comments: This is a word-based explanation question, hence students cannot present their answers in mathematical and inequality statements, and in the worst case, not defining the symbols used. For e.g. what is N and F_c ? Being key points in the answer, the terms 'normal contact force' and 'centripetal force' must be spelt out clearly. No one is stopping you from using inequalities as part of your 'thinking process' (which you can scribble at the side), but in the end, you must still translate your answers into proper worded statements (otherwise what are the given lines for?). Students tend to use 'force' and 'acceleration' interchangeably; these are different quantities. Some students think that if weight is from acceleration of free fall, then normal contact force would provide additional acceleration, so centripetal acceleration is greater. Some students think that centripetal acceleration/force is pointing upwards/outwards, or talked about tangential components when the man is moving at constant speed.

(ii) Calculate the centripetal acceleration of the man.

$$a_c = r\omega^2$$
$$= 8.0 \times \left(\frac{14 \times 2\pi}{60}\right)^2 \quad [C1]$$
$$= 17 \text{ m s}^{-2} \quad [A1]$$

Examiner comments: Some students do not know how to find ω from the info given in the question. Some students gave centripetal force instead. Quite a few also made calculation errors, which is a pity.

centripetal acceleration = ... m s^{-2} [2]

(b) Determine the minimum speed at the top of the circle for the man to remain on the floor of the cabin.

Examiner comments: Common mistake is to use the centripetal acceleration found earlier, not knowing what minimum speed means.

At the top, $N \geq 0$ to maintain contact

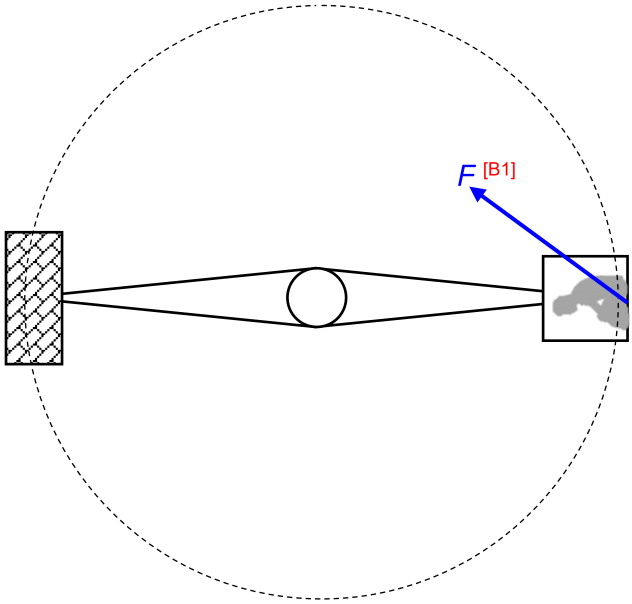
$$N + mg = \frac{mv^2}{r}$$
$$\frac{mv^2}{r} - mg \geq 0$$
$$v \geq \sqrt{rg}$$
$$v \geq \sqrt{8.0 \times 9.81} \quad [C1]$$
$$v \geq 8.9 \text{ m s}^{-1} \quad [A1]$$

At the top, $a_c \geq g$ to maintain contact

$$\frac{v^2}{r} \geq g$$
$$v \geq \sqrt{rg}$$
$$v \geq \sqrt{8.0 \times 9.81} \quad [C1]$$
$$v \geq 8.9 \text{ m s}^{-1} \quad [A1]$$

minimum speed = ... m s^{-1} [2]

(c) Fig. 2.2 shows the arm in a horizontal position.



Examiner comments: A large number of students drew the force radially towards the centre, likely thinking that F represents the centripetal force.

*refer to the pilot question, last part, in tutorials for the explanation to the direction of F.

Fig. 2.2

On Fig. 2.2, draw an arrow to show the direction of the force F exerted by the floor of the cabin on the man. [1]

[Total: 7]

3 Fig. 3.1 shows a circuit consisting of a battery of electromotive force (e.m.f.) *E*, internal resistance *r*, an ammeter of negligible resistance and a variable resistor *R*.

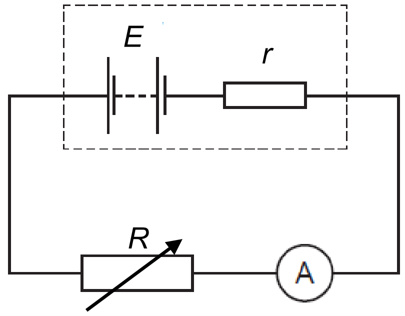


Fig. 3.1

The graph in Fig. 3.2 below shows how current I in the circuit varies as the potential difference *V* across the variable resistor changes

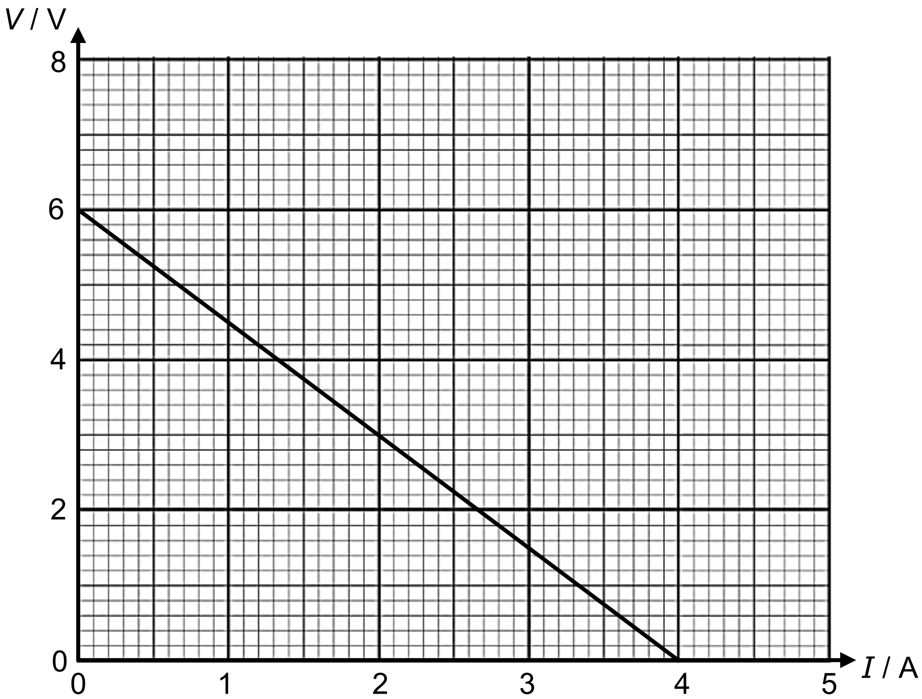


Fig. 3.2

(a) Explain the difference between p.d. and e.m.f. using energy considerations.

The potential difference across a device is the electrical energy converted to other forms of energy per unit charge passing through the device. [B1]

The electromotive force of a source is the electrical energy, converted from other forms of energy per unit charge, transferred by the source in driving unit charge round a complete circuit. [B1]

....[2]

Examiner comments:

This part of the question is generally not well answered. A number of students explained the difference between p.d. and e.m.f using work done considerations. This is unacceptable because this question requires explanation using **energy** considerations which is required in the A-level syllabus. It is unacceptable to use words such as “required”, “needed”, “transferred”, “rate of conversion”, “conversion”. Do note that p.d. and e.m.f. are energy, not a process.

A number of students did not mention “per unit charge”.

(b) **(i)** State the value of *E*.

$E = 6.0$ V   Not accepting 6 V

E = ... V [1]

Examiner comments:

A number of students gave the answer as “6 V” which is unacceptable. Please note that the graph given is plotted accurately on the grid lines. Therefore, all points read off from the graph must be **accurate to ½ of the smallest square in the graph**.

(ii) Determine the power dissipated in the variable resistor *R* when the current in the circuit is 1.2 A.

From graph, when I = 1.2 A, V = 4.2 V.   [C1]

$P = IV$

$P = (1.2)(4.2)$

$P = 5.04$ W   [A1]

power dissipated = ... W [2]

Examiner comments:

Most students did well in this part of the question. However, some students are careless and read off the value of V that corresponds to I=1.2 A wrongly. Some students wrote the power formula wrongly.

A few students have mistakenly thought that R is a constant and did not realise that it is a variable as stated in the question. As a result, they used the wrong value of I that does not correspond to the value of R in the calculation of power dissipated in the variable resistor.

(iii) Calculate the internal resistance *r* of the battery.

$E = V + Ir$

$6.0 = 4.2 + 1.2r$ [M1]

$r = 1.5\ \Omega$ [A1]

internal resistance *r* = ... Ω [2]

Examiner comments:

Some students gave alternative good answers based on the Principle of Conservation of Energy.

Some students have mistakenly omitted the negative sign in the expression $r = -$ gradient of V-I graph.

4 In the design of structures such as buildings, towers or bridges, an engineer may use a cantilever beam to allow for overhanging structure without external bracing. A cantilever is a beam supported only at one end.

The engineer will make calculations to ensure that the cantilever beam is strong enough to withstand any forces applied on it and ensure that there is not too much vertical deflection. An appropriate beam can then be chosen based on the maximum allowable load to be applied.

Fig. 4.1 illustrates a cantilever of length L loaded with a point load P at its end. A vertical deflection y of the free end of the cantilever will result from the loading.

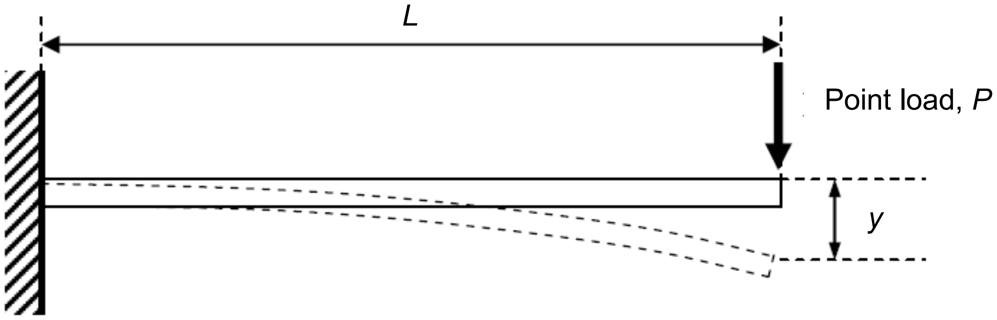


Fig. 4.1

A student was asked to investigate the behaviour of such an arrangement and found an expression for the vertical deflection of a loaded cantilever which was given by Equation 1:

$$y = \frac{4PL^3}{kbh^3} \qquad \textbf{(Equation 1)}$$

where

k is a constant

b = breadth of cantilever

h = height of cantilever

(a) The student first used two steel cantilevers to investigate the relationship between y, P and L. He first kept L constant and varied P to obtain the results as shown in Fig. 4.2.

P (N)	10	20	40	50	68 –70	90
y (mm) for Cantilever A	1.9	3.9	7.8	9.9	13.8	17.7
y (mm) for Cantilever B	10.8	16.8	28.6	34.4	46 – 47	57.9

Fig. 4.2

The graph showing the relationship between y and P for Cantilever A has been sketched on Fig. 4.3. Some of the data points of Cantilever B have also been plotted in Fig. 4.3.

(i) Complete Fig. 4.2. [A1: for P value of cantilever A only] [1]

(ii) On Fig. 4.3, complete the plot and sketch the graph to show the relationship between *y* and *P* for Cantilever B.

Graph of Deflection *y* (mm) against Point Load *P* (N)

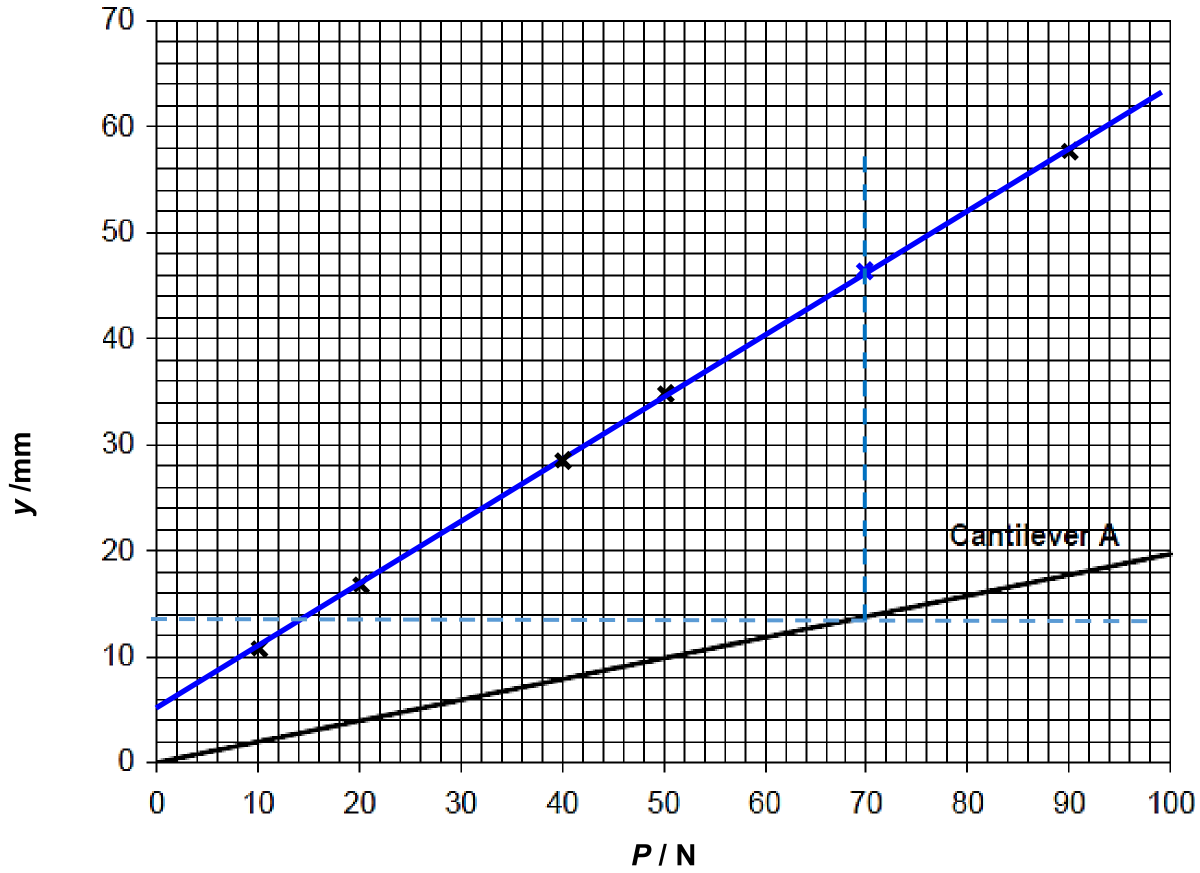


Fig 4.3

[A1: correct plot for P value of cantilever B only, must be in line with reading of cantilever A],
[A1: BFL of cantilever B only. Line should not be forced to cut the origin.] [2]

(iii) Explain how the graph of Cantilever A supports Equation 1.

The graph shows a **linear relationship** between *y* and *P* and [B1]

it **passes through the origin**. [B1]

Or The data support Equation 1 as ***y* is directly proportional to *P***.

.... [2]

(iv) Explain how the graph suggests that the measurements for Cantilever B were subjected to systematic error.

When **no point load is being applied to cantilever B (*P* = 0), there should not be any deflection (*y* = 0) [B1].**

However, from the graph, there seems to be **a deflection when *P* = 0** for Cantilever B [B1], suggesting the presence of a systematic error.

.... [2]

Examiner comments:
Both cantilevers (A & B) are subjected to the same experimental conditions and hence the equation that is valid for A should likewise apply to B.
The graph for B should be linear and cut through the origin.
But the best fit line indicated that when *P* = 0 (no force applied) a deflection is shown. Hence a systematic error has occurred.

(v) Hence, estimate the amount of systematic error.

[B1: 4 – 6 mm, depending on student's graph]

.... [1]

(vi) Suggest a reason how this error may have arisen.

The elastic limit of Cantilever B might have been exceeded. [B1]

The cantilever was already warped before measurements were taken.

Positive non-zero measurement instrument to measure y/ incorrect calibration.]

Examiner comments:
Parallax error or observer bias can also be a source of random error-not recommended to use as a specific cause for systematic error.
Incorrect fiducial point violates the question. The diagram specifically identify well defined points for measurement.

(b) The student continued his investigation by keeping *P* constant and varying *L*, obtaining the results for Cantilever A as shown in Fig. 4.4.

L / m	1.0	1.5	2.0	2.5	3.0	3.5	4.0
y / mm	1.6	5.3	12.5	24.6	42.4	67.2	99.9

Fig. 4.4

These results did not suggest direct proportionality between y and L. The student proceeded to sketch a graph showing the variation of lg y against lg L as shown in Fig. 4.5.

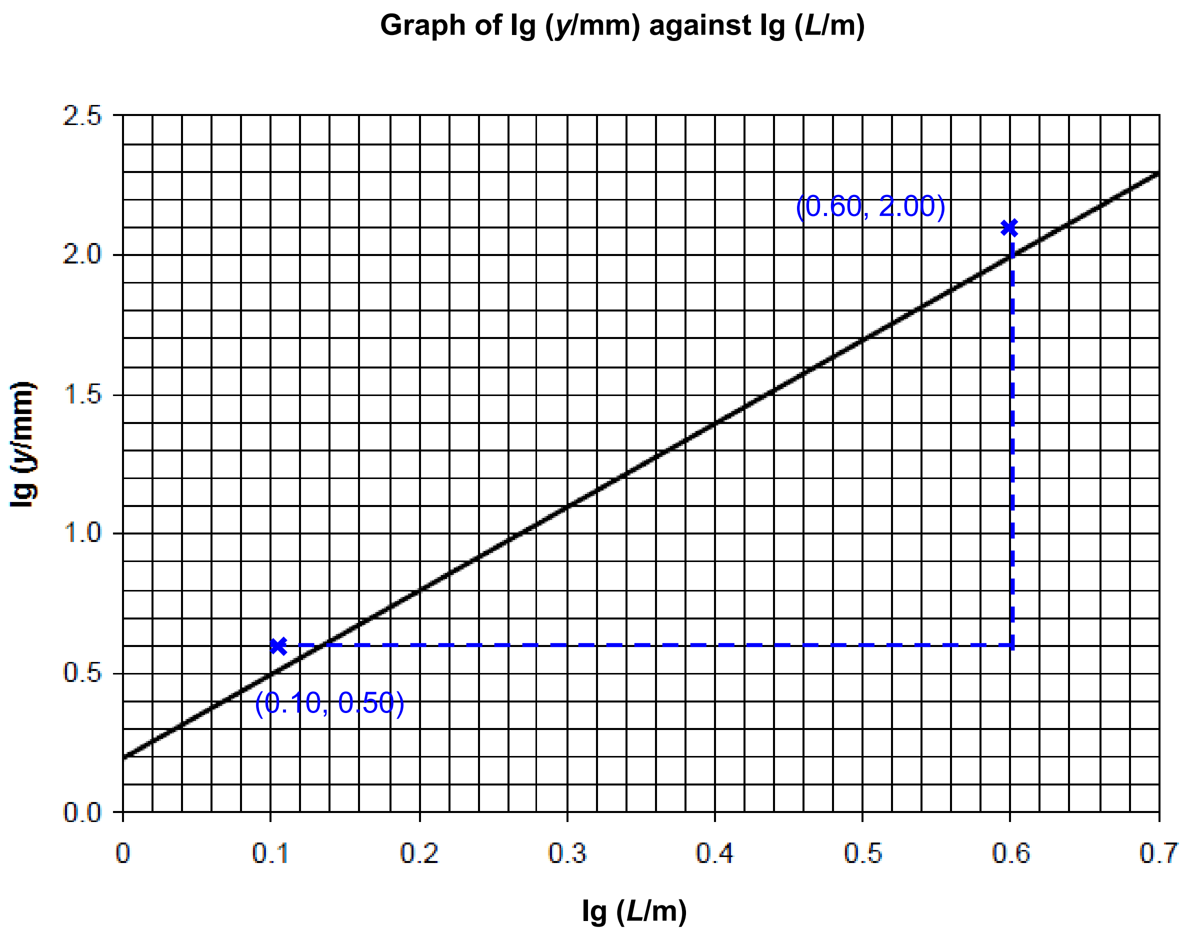


Fig. 4.5

(i) Determine the gradient of the graph. Show your working.

$$\text{Gradient} = \frac{2.00 - 0.50}{0.60 - 0.10} = 3.0 \text{ [A1]}$$

(precision to half the smallest square, calculation to correct d.p. and s.f. and triangle should be more than half the line drawn) [A1]

Gradient = ……………………………… [2]

(ii) Hence discuss whether the data in Fig. 4.4 support Equation 1.

………………………………………………………………………………………………

………………………………………………………………………………………………

The data supports Eq 1 as **the gradient of the graph lg y against lg L gives the order of the relation between y and L [B1].** ..

[2]

From the data, **y is proportional to L^3 [B1]** which support Equation 1.

OR

The graph of lg y vs lg L shows a gradient of magnitude of 3. [B1]

A non-zero vertical intercept. [B1]

Examiner comments:
Many students just mentioned that the (gradient of graph) data points and equation agrees that y is proportional to L^3 and did not go further to mentioned that both graph and equation suggest that there is a non-zero vertical intercept.
Many students wrongly wrote that since y is proportional to L^3, then the vertical intercept should be zero – this must be seen in the context of the graph plotted (lg y vs lg L).
Weak math also contribute to incorrect linearization of the equation.

(c) After researching further into the subject, the student found out that the constant k in Equation 1 is known as the Young's Modulus which is a property of the material of the cantilever.

(i) Use Equation 1 to show that the S.I. unit of k is Pa. [2]

$$y = \frac{4PL^3}{kbh^3}$$

$$k = \frac{4PL^3}{ybh^3} \text{ [C1]}$$

$$[k] = \left[\frac{PL^3}{ybh^3}\right]$$

$$= \frac{\text{N} \times \text{m}^3}{\text{m} \times \text{m} \times \text{m}^3} = \frac{\text{N}}{\text{m}^2} \text{ [B1]}$$

$$= \text{Pa [A0]}$$

Examiner comments:
Many students did not show proper working using correct [ ] which implies unit of. Common mistakes include y = [m].

(ii) A steel cantilever has breadth 0.12 m, height of 0.040 m and length of 2.0 m as shown in Fig. 4.6. If a point load of 1.0 kN is applied at the end, a vertical deflection of 2.0 cm was measured at the end.

Calculate the Young's Modulus of steel.

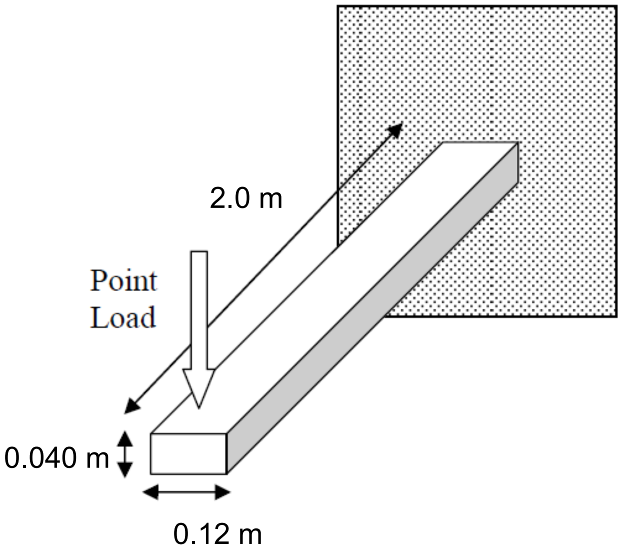


Fig. 4.6

$$k = \frac{4PL^3}{ybh^3} = \frac{4(1.0\times10^3)(2.0)^3}{0.020(0.12)(0.040)^3} \text{[C1]}$$
$$= 2.1\times10^{11} \text{ Pa [A1]}$$

Young's Modulus = ……………………………Pa. [2]

Examiner comments:
Many students used the wrong equation with omitting 4 from the equation or omitting power of 3 for h or L. Another mistake is the wrong conversion of 2.0 cm.

(iii) To increase the maximum allowable load for a given vertical deflection, the student proposed to orientate the direction of the steel cantilever in **(c)(ii)** differently to the new orientation as shown in Fig. 4.7.

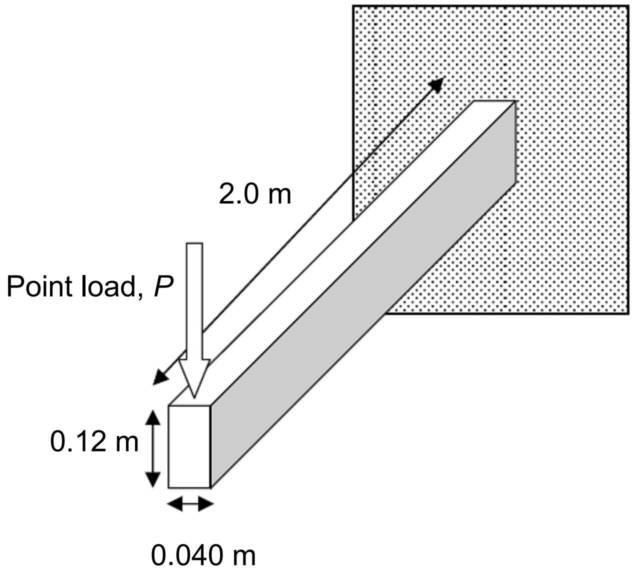


Fig. 4.7

Suggest, with reason, whether the student's proposal should be adopted.

....

....

....

.... [2]

For a given deflection *y* and length *L*, *P* is proportional to the product of bh^3. With the **new orientation, the product** $\boldsymbol{bh^3}$ **is significantly larger** [M1]. Thus, for a given deflection *y* and length *L*, the maximum allowable load will be increased. Therefore, the student's proposal should be adopted. [A1]

Examiner comments:

A number of students opined that the proposal in this part of the question should not be adopted because a reduction in the top surface area of the cantilever will result in an increase in pressure exerted on it which will in turn, cause it to break.

Some students stated wrongly that the value of Young's Modulus, K, will change. Do note that Young's Modulus is a constant because it is the property of material and is independent of the shape and size of the object.

A number of students focused on the effect of h but not b which will also have an effect on the maximum allowable load. Instead, the term "bh^3" should be considered in the analysis.

Some students wrongly concluded that the maximum allowable load will decrease when deflection of the cantilever decreases due to the same point load.

(iv) In the construction industry, steel beams normally come in an "I" shape with a cross section as shown in Fig. 4.8.

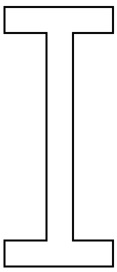


Fig. 4.8

Suggest a reason why they are designed this way instead of the rectangular cross section shown in **(c)(iii)**.

....

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

Less material need to be used to construct the steel beam, cost can be saved.

Reduce the weight of the beam. [B1]

Examiner comments:

The following are common mistakes made by students:
- Shape offers better grip.
- Shape makes the cantilever more stable due to broader base.
- Shape reduces pressure due to larger surface area at the top of cantilever.
- Shape makes the cantilever less flexible but stronger and prevent it from breaking under stress.

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 1 END OF YEAR EXAMINATION
Higher 2

CANDIDATE NAME	

CLASS		TUTOR'S NAME	Solution

PHYSICS **9749/03**

Paper 3 Longer Structured Questions **27 September 2022**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 8
2	/ 4
3	/ 9
4	/ 9
5	/ 12
6	/ 9
7	/ 12
8	/ 12
Total	/ 75

This document consists of **19** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / °\text{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ ...$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** the questions in the spaces provided.

1 **(a)** There are two possible methods of measuring the volume of a cylindrical container. The first method is by measuring the inner diameter and the height of the container and calculating the volume. The readings are as follows:

Inner diameter = (1.98 ± 0.01) cm

Height = (4.5 ± 0.1) cm

(i) Calculate the volume with its associated uncertainty.

$$V = \frac{\pi d^2}{4}h = \frac{\pi (1.98)^2}{4} x4.5 = 13.86 \text{ [A1]}$$

$$\frac{\Delta V}{V} = \frac{2\Delta d}{d} + \frac{\Delta h}{h}$$

[M1]

$$\Delta V = (\frac{2\Delta d}{d} + \frac{\Delta h}{h})V = (\frac{2x0.01}{1.98} + \frac{0.1}{4.5})x13.86 = 0.4$$

$V \pm \Delta V = (13.9 \pm 0.4)$ cm^3 [A1]

Examiner comments:
The preliminary calculated value of V should be displayed to 4-5 sf and not be rounded off at this stage. A minority of students calculate this value wrongly ie using $V = \pi d^2 h$.

Many students made the mistake by halving either Δd for Δr but not halving d for r. This is not consistent treatment of fractional error.

$$\frac{\Delta V}{V} = \frac{2\Delta d}{d} + \frac{\Delta h}{h} = \frac{2\Delta r}{r} + \frac{\Delta h}{h}$$

$$\frac{2\Delta d}{d} \neq \frac{2\Delta r}{d} \neq \frac{2\Delta d}{r}$$

A minority of students wrongly equate the answer of $\frac{\Delta V}{V}$ as the answer for ΔV.

volume = ... ± .... cm^3 [3]

(ii) The second method is by filling the container with water, and then pouring the water out into a measuring cylinder. The measuring cylinder can read to the nearest cm^3. With reference to your answer in **(a)(i)**, state and explain which method would give a more precise value.

Method 1 is more precise. [M0]
Method 1 has an uncertainty of 0.4 cm^3 which is 1 d.p. more than Method 2 [A1]

....[1]

Examiner comments:
The question reads ‘measuring cylinder can read to the nearest cm^3’, this means that the least uncertainty is 1 cm^3. It is not necessary to halve this value.

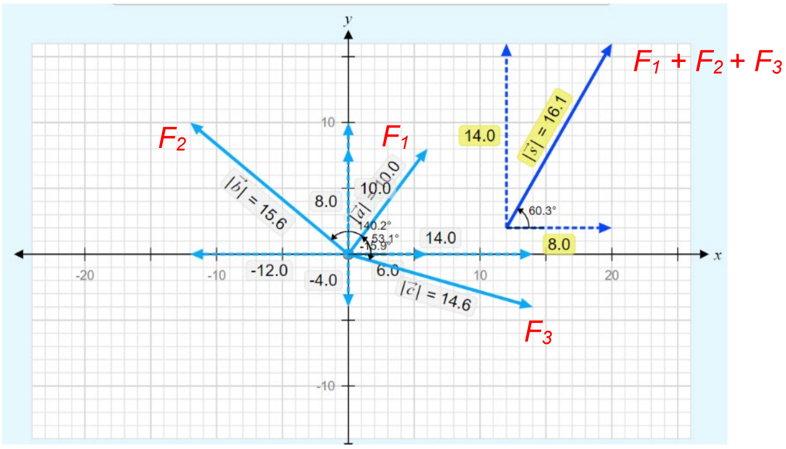
The value obtained in (a)(i) should be compared with (a)(ii) to draw a conclusion.

(b) Three forces act on a stationary object with magnitude and direction as shown in the table.

Force	Magnitude / N	Direction (anticlockwise from positive *x*-axis)	*x*-component of force / N	*y*-component of force / N
F_1	10.0	53.1°	6.0	8.0
F_2	15.6	140.2°	-12	10
F_3	14.6	344.1°	14	- 4.0
$F_1 + F_2 + F_3$	16.0	60.3°	8.0	14

By resolving vectors into its *x*-component and *y*-component, complete the table. [4]

[Total: 8]



Examiner comments:
In column of *x* and *y* components of force, a common mistake is wrongly assigning +ve and -ve in violation of the sign convention used.
The magnitude of $F_1 + F_2 + F_3$ is not obtained by adding the individual magnitude of the forces. These are vectors and should not be treated as scalars.

Question 2 continues on the following page.

2 An astronaut of mass *m* is at a distance of several metres from the entrance of his space shuttle. The astronaut is stationary relative to the space shuttle. He wishes to return to the space shuttle by means of his jetpack. The jetpack is attached to his body and it ejects a stream of exhaust gas when it is turned on.

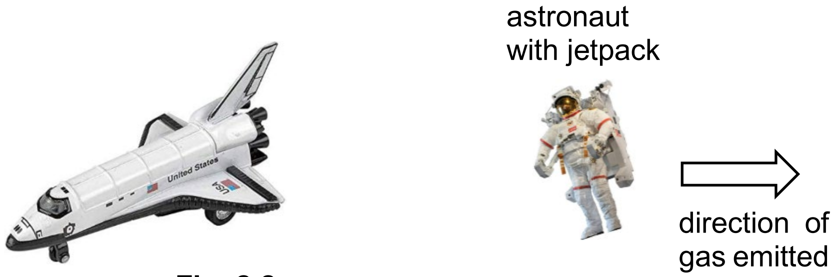


Fig. 2.2

(a) The jetpack emits gas in a rightward direction as shown in Fig. 2.2.

Use momentum considerations to explain why the jetpack produces a leftward force on the astronaut.

When the gas is ejected away from the shuttle, the gas gains momentum in a rightward direction. [B1] By conservation of momentum, the astronaut gains momentum of equal magnitude in the leftward direction. [B1] By Newton's second law, a rate of change of momentum to the left implies that there is a leftward force acts on the astronaut. [B1]
Or
When the gas is ejected away from the shuttle, the gas gains momentum in a rightward direction. [B1] By Newton's second law, a rate of change of momentum to the right implies that there is a rightward force acts on the gas. [B1] By Newton's third law, a force of equal magnitude and opposite direction will act on the astronaut. [B1]

[3]

Examiner comments:
No mark is not awarded for stating the principle of conservation momentum. Instead, students are expected to state the **directions of the momenta** of the gas and the astronaut with jetpack. Rationale is that question wants the students to explain why the force is **leftward**, showing that it is critical to state clearly the direction.
Many students stated the definition of Newton's laws of motion without context of this question. Always remember to customize the laws to the context of the question.
Quite a number of students stated equations and symbols instead of using words. In qualitative question like this, try not to write short form (eg. N2L, COM etc), and you should write proper words like velocity instead of *v* (unless the question has defined *v* for you).

(b) State and explain how the time taken for the astronaut to return to his space shuttle will change, if any, if his mass is greater than *m*.

With the same gain in momentum, the gain in velocity of the astronaut will be lower. Hence it will take a longer time to reach the space shuttle. [A1]

[1]

Examiner comments:
When explaining why the time should be longer, the most direct and expected explanation is with regards to the change in the magnitude velocity. Inertia or reluctance to change astronaut's state of motion is not sufficient.
There are also a large number of students stating this *"the velocity will decrease, hence the time is longer"*. This gives the examiner the wrong impression that the astronaut will slow down when the jetpack is activated. Students must learn to write in a clear manner. The actual fact is, it is the **gain in** velocity that will **lower**. (*lower* is preferred as *decrease* seems to suggest that the velocity *becomes smaller with time*.)

3 **(a)** **(i)** Explain the origins of *upthrust*.

It is the upward force exerted by a fluid on an object submerged fully or partially in the fluid due to the difference in pressure exerted by the fluid on the upper and lower surfaces of the object. [B1]

....[1]

Examiner comments:
Most students answered correctly.
Mark was not awarded when students did not mention pressure difference is caused by fluid.
Common mistake: some wrote that pressure difference is caused by 'liquid' which is not totally correct as fluid includes both liquid and gaseous substances

(ii) State the point which upthrust acts through.

It acts through the centre of mass of the displaced fluid. [B1] ....[1]

Examiner comments:
This part was badly done.
Frequently rejected answer: centre of gravity of object
Other rejected answers: centre of mass of object, centre of mass/gravity of object submerged or/and partially submerged in a fluid
Accepted answers: centre of mass of the displaced fluid , centre of buoyancy

Two misconceptions here
(1) Strictly speaking - centre of mass is not always the same as centre of gravity. They coincide only when the gravitational field strength is uniform.
(2) Upthrust only acts through the centre of mass of the partially or totally submerged object if the object is uniform. Only then will it coincide with centre of buoyancy or centre of mass of displaced fluid.

(b) A student conducted an experiment to study the buoyancy of a rock. He established that the rock has a mass of 500 g and a volume of 47.6 cm^3.

He put the rock into a rectangular transparent glass tank with a base of dimensions 15.0 cm by 15.0 cm, and poured in water till it reached a depth of 2.0 cm and the rock is completely submerged as shown in Fig. 3.1.

2 upward forces (Normal force and upthrust) and 1 downward force (weight) vector drawn-[B1]

correct relative length of 3 these forces, correct starting points of arrows, correct label (no abbreviations) for these 3 forces-[B1]

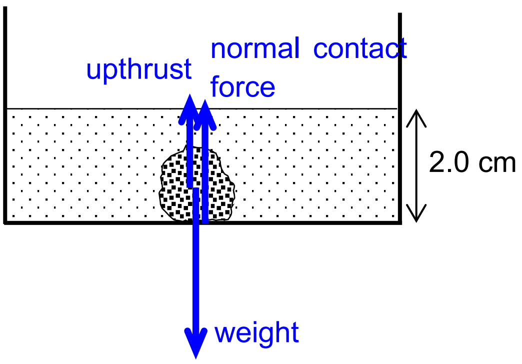


Fig. 3.1

(i) On Fig. 3.1, draw and label all forces acting on the rock. [2]

Examiner comments:
Most students were awarded 1 mark only. Many lost 1 mark due to reason (b)- see below.
(a)One mark was awarded for the labelling part of the forces as long as diagram showed 2 upwards forces and 1 downwards force that can be assumed to indicate correctly the nature of the forces.

(b)Common penalty (max1 mark) incurred due to one or more of the following reasons:
-Inappropriate lengths of the 3 forces relative with one another (frequent mistake made by students)
-use of abbreviations for at least one of the forces labelled.
-incorrect positions of force vectors drawn- some drawn upthrust starts from the tank instead of centre of rock etc.
-spacing between upthrust and/or normal force are/is too far apart from the centre of buoyancy or centre of mass.

Learning point for students:
Since the rock is in equilibrium, total upward forces (upthrust and normal force) is equal to downward force(weight) which many students know. However, care must be taken to demonstrate this aspect by drawing the total upward magnitude (length) to be the same as the downward magnitude (length)

(ii) Determine the magnitude of the force exerted by the base of the tank on the rock. The density of water is 1.0 g cm^{-3}.

$$W = N + U$$
$$mg = N + V\rho g$$
$$(0.500)(9.81) = N + (47.6\times10^{-6})(1\times10^{3})(9.81) \quad \text{[M1]}$$
$$N = 4.44 \text{ N} \quad \text{[A1]}$$

magnitude of force = ... N [2]

Examiner comments:
Most students were able to score full mark except for some who
-convert the units for mass, volume and density incorrectly (awarded 0 mark)
-'forget' to convert for every term and thus answer calculated is 1000 times larger (power of ten error) (awarded 1 mark)

Acceptable final answer can be written as 2 s.f or 3 s.f

(c) A second liquid of density 13.5 g cm^{-3} is slowly poured in the tank until the rock just lifts off the bottom of the tank as shown in Fig. 3.2.

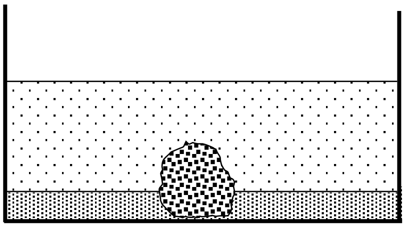


Fig. 3.2

Determine the volume of the second liquid displaced by the rock at this instant.

Let the volume of water and liquid displaced be V_1 and V_2 respectively.

Since the rock is totally submerged:
$V_1 + V_2 = 47.6 \times 10^{-6}$ [M1] -------- (1)

Since rock is in equilibrium:
$mg = \rho_1 V_1 g + \rho_2 V_2 g$ [C1]
$0.5 = 1000V_1 + 13\,500V_2$ -------- (2)

Solving equation (1) and (2),
$V_2 = 36.2 \times 10^{-6}\ m^3 = 36.2\ cm^3$ [A1]

volume of second liquid displaced = ... cm^3 [3]

[Total: 9]

Examiner comments:
This question was badly done.
Many students did not know that normal force is zero, hence weight of rock is needed to support the total upthrust due to water and 2nd liquid displaced.

At equilibrium, according to Newton 1st law,
Net force = 0
mg – Normal force - upthrust due to water – upthrust due to 2nd liquid = 0

Strictly speaking for rock to just lift off from the bottom of the tank:
$N \leq 0$
mg – upthrust due to water – upthrust due to 2nd liquid ≤ 0
total upthrust ≥ mg
volume of 2nd liquid displaced ≥ 36.2 cm^3

No mark was awarded when some students
-simply equate weight of rock to the upthrust of second liquid displaced or
-equate part (a)(ii) answer, Normal force to upthrust of liquid displaced

Some students who knew the equations, they were penalised for wrong conversion of units , or they failed to substitute volume of displaced water as 47.6 – V but use 47.6 instead.

Accepted final answer can be written as 2 s.f or 3 s.f

4 A particular type of slide for children in a theme park is called a 'drop slide'. This is a slide in which the first part of the fall is vertical. Fig. 4.1 shows a child of mass 28 kg on a drop slide.

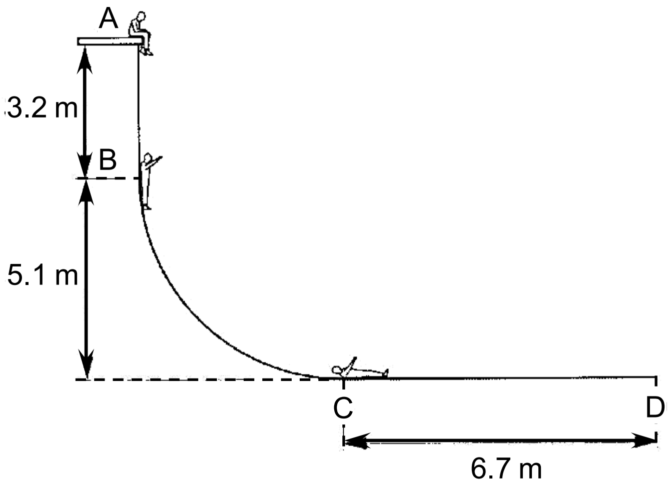


Fig. 4.1

The child drops from A to B, a distance of 3.2 m, before reaching the surface of the slide and then travels around a bend from B to C, while falling a further vertical distance of 5.1 m. At C the child's speed is the same as it was at B. After this the child travels 6.7 m horizontally before stopping at D.

(a) **(i)** Calculate the child's speed at B.

By conservation of energy,

Loss in GPE = Gain in KE

$mgh = \frac{1}{2}mv^2 - 0$ [M1]

$v = \sqrt{2gh} = \sqrt{2(9.81)(3.2)} = 7.92 = 7.9 \text{ m s}^{-1}$ [A1]

speed = ... m s^{-1} [2]

(ii) State one assumption made in this calculation.

There is no frictional force against the slide / air resistance / resistive force acting on the child [A1].

....[1]

(b) Determine the loss of gravitational potential energy of the child between B and C.

Loss in GPE $= mgh = (28)(9.81)(5.1)$ [M1]

$= 1400$ J [A1]

loss of gravitational potential energy = ... J [2]

(c) Explain how it is possible for the child's speed to be the same at B and at C.

It is possible if the loss in gravitational potential energy is equal to the work done against friction force due to the slide [M1], resulting in no change in kinetic energy [A1].

....

....[2]

Examiner comments:
As the question did not mention that BC is a shape of a circular arc, the motion may not be a circular.
Some students mistakenly thought that the kinetic energy has increased.
As the mark scheme stated M1 followed by A1, the answer for M1 must be correct before scoring the A1 mark. (in another word, if you don't get the M1 mark, you get zero, regardless of what you wrote for A1)

(d) Calculate the average frictional force slowing the child between C and D.

$$\left.\begin{array}{l}\text{Loss in KE} = \text{work done agains friction} \\ \frac{1}{2}mu^2 - 0 = fd\end{array}\right\} \text{[M1]}$$

$$\frac{1}{2}(28)(7.92)^2 = f(6.7)$$

$f = 130\text{ N}$ [A1]

Examiner comments:
Some students just substitute the value of the kinetic energy at C into the work done against resistive force without explanation.

force = ... N [2]

[Total: 9]

5 Fig. 5.1, which is not to scale, shows how the gravitational potential between the surface of the Moon, A, and the surface of the Earth, B, varies along the line joining their centres. At point P, the gravitational potential is a maximum.

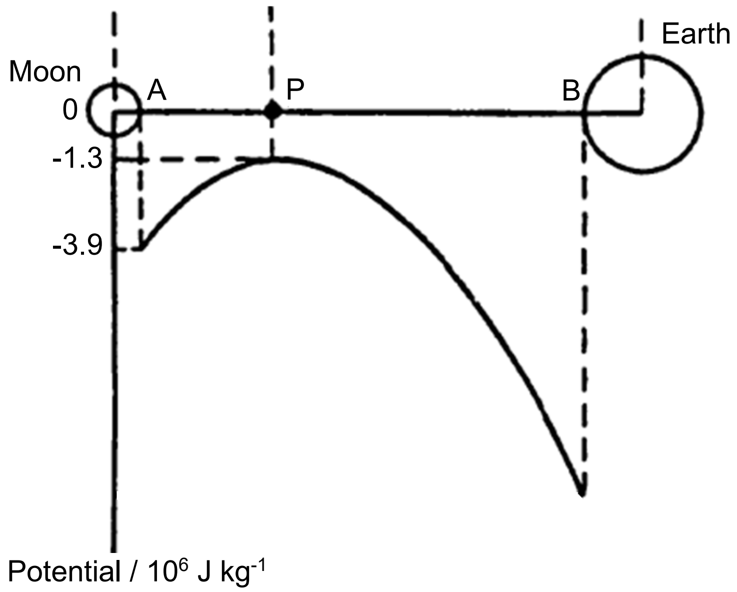


Fig. 5.1

The distance between the centres of the Moon and the Earth is about 470 000 km.

The table below gives approximate values of the radius *R* and mass *M* of the Earth and Moon.

Table 5.1

	R / 10^6 m	M / 10^{24} kg
Earth	6.4	6.0
Moon	1.7	0.074

(a) Define *gravitational potential* at a point.

Gravitational potential at a point is the work done per unit mass by an external agent in bringing a test mass from infinity to that point (without a change in kinetic energy). [B1]

..........[1]

Examiner comments:

Students are strongly advised to state the standard definition given in the school notes.

A number of students omitted "per unit mass" and stated "external force" instead of "external agent".
Some students wrongly stated "object", "body" or "source" instead of "external agent".
Some students wrongly stated "point mass", "object" or "body" instead of "test mass".

(b) Explain why the values of gravitational potential in Fig. 5.1 are negative.

Gravitational potential at infinity is taken to be zero. [B1]
The gravitational force is **attractive in nature** and force exerted by the external agent is acting in **opposite direction** to the displacement of a small test mass. [B1]

..........[2]

Examiner comments:

Cambridge examiners expect candidates to mention that the gravitational force is attractive in nature.

A number of students did not mention that the gravitational potential at infinity is taken to be zero.

A number of students wrongly stated that the work done by external agent is in opposite direction to the displacement of a test mass. Students are reminded that work done is a scalar quantity with no direction.

(c) Calculate the gravitational potential at point B.

Gravitational potential at the surface of the Earth

= potential due to Moon + potential due to Earth

$$= -\frac{GM_M}{(470000000 - R_E)} - \frac{GM_E}{R_E} \quad \text{[M1]}$$

$= -6.25 \times 10^7$ J kg^{-1} [A1]

[2]

Examiner comments:

A number of students did not consider the gravitational potential due to Moon which is small compared to that due to the Earth.

Some students did not read the question carefully and misinterpreted that the distance 470 000 km excludes the radius of moon.

Some students wrongly subtract the gravitational potential due to Earth from gravitational potential due to Moon.

(d) **(i)** State, in words, how the magnitude of the resultant gravitational force on a mass at any point between the Moon and the Earth could be deduced from Fig. 5.1.

The product of the mass of the body and the magnitude of the gradient of graph at the point where the body is. [B1]

[since $F = mg = m\left(-\frac{d\phi}{dr}\right)$] [1]

Examiner comments:

Students are strongly advised to use the suggested answer because Cambridge examiners expect students to use “product” instead of “multiply” or “times”.

A number of students omitted “magnitude” in their answer even though the question is related to “magnitude of the resultant gravitational force”.

Some students give an equation such as F=ma instead of explanation using works, especially when the question stated this requirement clearly and lines are included for answer to be written in words.

A number of students omitted the mention of “mass” and wrongly stated that the gravitational force is equal to the gradient of the graph.

A number of students did not make any references to the graph in Fig. 5.1 even though the question requires that. Instead, they use the formula for gravitation force due to the Earth and the Moon to explain.

(ii) Describe how the resultant gravitational force on a mass changes as it travels from the Moon to the Earth along line AP.

The resultant gravitational force acting on a mass decreases from A to P (at decreasing rate) [B1]

and equals zero at P. [B1] [2]

(From Fig. 5.1, gradient becomes less and less steep from A to P, zero at P, and then becomes steeper and steeper from P to B.)

Examiner comments:

A number of students wasted their time and effort in providing an explanation for the journey of a mass from point P to B when it is not required by the question.

Some students explained using “less negative force” which is unacceptable.

A number of students did not state that the resultant force at P is 0 N even though it is on the line AP.

(e) **(i)** Determine the minimum speed required for a meteorite leaving the Moon’s surface to reach point P.

minimum KE of meteorite = gain in GPE between O and P

$\frac{1}{2}mv_0^2 = m\left[-1.3-(-3.9)\right](10^6)$ [M1] where m: mass of meteorite

$v_0 = 2280 \text{ ms}^{-1}$ [A1]

minimum speed = ... m s^{-1} [2]

Examiner comments:

A number of students made the following mistakes:

- Did not include prefix “ 10^6 ” for gravitational potential at point A and point P.
- Attempted the wrong approach of using the formula for gravitation potential energy to solve this part of the question.
- Wrongly apply the formula for escape velocity to solve this part of the question.
- Wrongly apply the concept of centripetal force to solve to solve this part of the question.

(ii) Explain why the minimum speed required for the meteorite leaving the moon’s surface to reach the Earth is the same as that required to reach P.

Possible explanation 1:

From A to P, meteorite needs sufficient kinetic energy (KE) to overcome the increase in gravitational potential energy. [B1]

Beyond point P, the meteorite will lose gravitational potential energy and this converts into KE which will bring the meteorite towards the Earth. Hence as long as the meteorite has sufficient KE to reach point P, it will be able to reach the Earth. [B1]

OR

Possible explanation 2:

The meteorite needs sufficient KE to do work against the opposing gravitational force when travelling from the Moon to the point P. [B1]

Beyond point P, the Earth’s gravitational force is greater than the Moon’s gravitation force. Work is done by the **resultant** gravitational force to bring the meteorite towards the Earth; that is, no additional work done required by the meteorite. [B1]

[2]

Examiner comments:

A number of students uses forces instead of energy to explain in their answers. Energy considerations, in particular, energy conversions involved, need to be mentioned to link speed to energy conversion that is taking place.

A number of students wrongly stated that the kinetic energy at P is zero since the resultant force at P is zero.

Some students wrongly stated that the mass at point P is no longer under the influence of the Moon's gravitational field and therefore, the velocity of the mass at P is the escape velocity.

[Total: 12]

6 A cylindrical tube, containing some sand, floats upright in a liquid of density ρ as shown in Fig. 6.1.

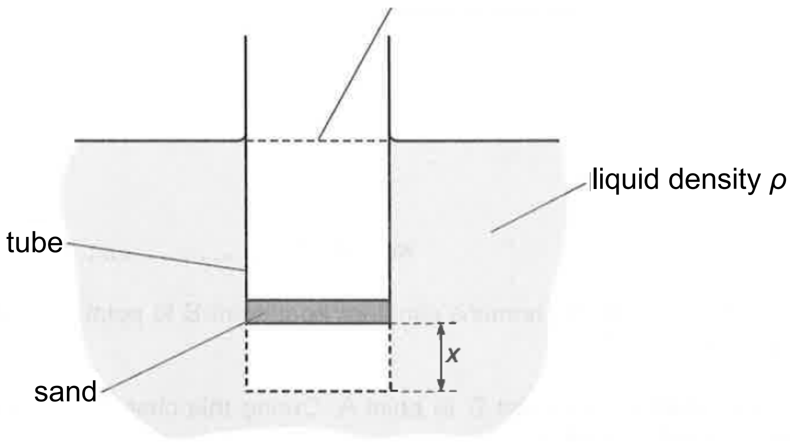


Fig. 6.1

The tube has a cross-sectional area A. The total mass of the tube and sand is M. The tube is displaced vertically downwards and then released. The tube oscillates vertically.

(a) The displacement of the tube from its equilibrium position is x. Show that acceleration of the tube at displacement x is given by

$$a = -\left(\frac{\rho A g}{M}\right)x$$

Explain your working.

At equilibrium, $F_{net} = 0$

$U - W = 0$

$(L\ A)\rho g = W$ [B1]

At the displacement x,(direction of displacement is downwards positive)

$W - U' = Ma$ [B1]

$(LA)\rho g - (L+x)A\rho g$ [M1] $= Ma$

$a = -(xA\rho g)/M$

Examiners Comment

For a show question, please use fundamental laws to start your working. Show all steps clearly, do not skip any step. When you apply Newton's second law to the diagram above, you will get an unknown term of W. Thus, you need to use another equation to remove this unknown term.

Common mistakes include

1. $M = xA\rho$
2. $F_{net} = 0$
3. Setting direction to be upwards positive and let $U - W = -Ma$. There is no sense to the equation formed, why is the acceleration negative?
4. Not differentiating U and U'. assume that they are the same.
5. Use of net upthrust, this imply that they are 2 upthrust acting at the same time, which is not correct.

[3]

(b) Fig.6.2 shows the variation with time *t* of the vertical displacement *x* of the tube.

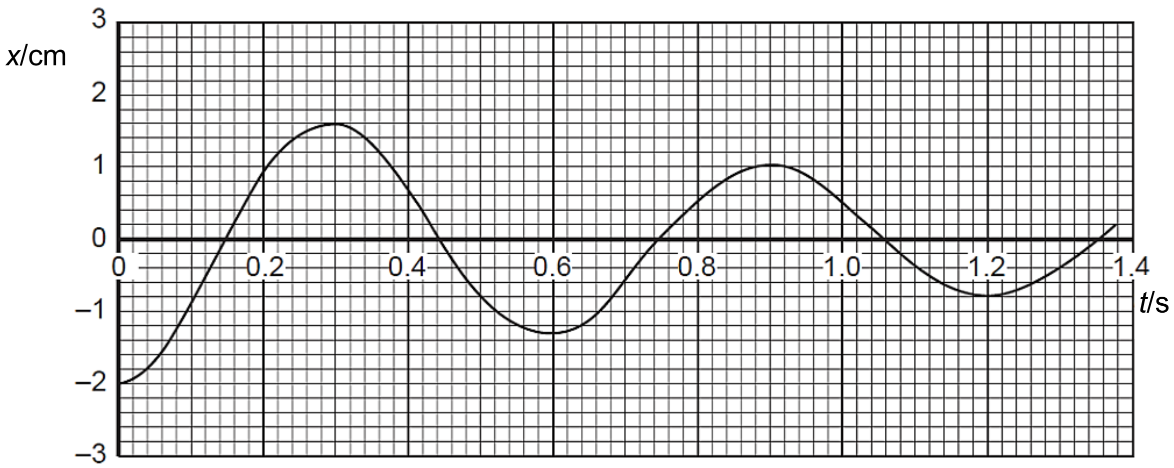


Fig. 6.2

(i) The tube has an external diameter of 2.5 cm and is floating in a liquid of density 1050 kg m^{-3}. By using equation in **(a)** and Fig. 6.2, calculate the mass of the tube and its contents.

From Fig. 6.2,

$2T = 1.20$ s

$T = 0.600$ s. [M1]

$\omega^2 = \rho A g / M$

$(2\pi/0.600)^2 = (1050)(\pi \times 0.0125^2 \times 9.81) / M$ [B1]

$M = 0.0461$ kg [A1]

Examiners Comment

This is the displacement time graph, thus, acceleration cannot be obtained from the graph and finding the gradient of the graph only gives the velocity, which is not helpful. Kinematics equations cannot be applied as the acceleration is not constant. The only useful information from the graph is the period which allows the calculation of angular frequency. The period read from the graph should be 0.60 s, and not 0.6 s which is 1 s.f. since $a = -\omega^2 x = -(\rho A g/M)x$, M can be determined from the square of the angular frequency.

mass = ... kg [3]

(ii) Explain how Fig. 6.2 indicate that the oscillations are damped.

The amplitude of the oscillation decreases with time.

....

...[1]

Examiners Comment

Correct term is amplitude of the oscillation, or maximum displacement.

Mistakes such as displacement or maximum amplitude are not accepted.

(c) State and explain how the displacement - time relationship of the tube in Fig. 6.2 will change when it is submerged into a new liquid of higher density.

Since the liquid has a higher density but the tube remains unchanged, the angular frequency of the oscillation increases. [B1] This is imply that the period decreases and the duration of 1 cycle in Fig 6.2 will decrease. Number of cycles will increase in Fig 6.2. [B1]

...

...

...

....[2]

Examiners Comment

State : number of cycles observed over the same time duration will increase. Majority are unable to state the outcome correctly.

Explain : The maximum displacement depends on the initial displacement of the oscillation and acceleration increased can be due to the increase in displacement. Thus, to explain, you must show a clear link to increase in density of liquid lead to a higher angular frequency and thus shorter period for the oscillation. Some students stop at just increase in angular frequency which does not link to the displacement time graph.

7 **(a)** The apparatus illustrated in Fig. 7.1 is used to demonstrate two-source interference using light.

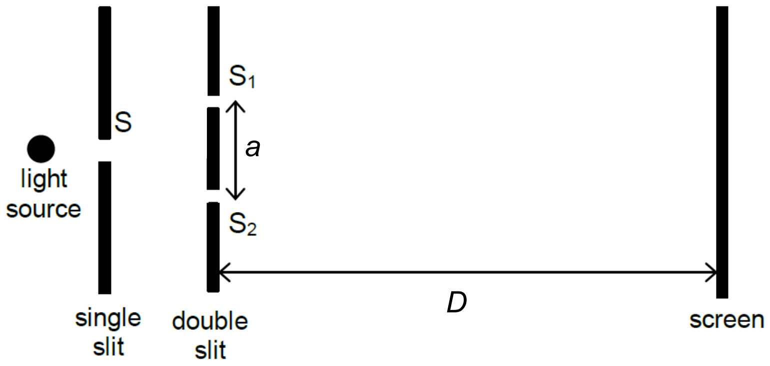


Fig. 7.1 (not to scale)

The separation of the two slits in the double slit arrangement is a and the interference fringes are viewed on a screen at a distance D from the double slit. When light of wavelength λ is incident on the double slit, the separation of the bright fringes on the screen is x.

(i) For a typical laboratory setting, suggest a suitable value for the separation, a, of the slits in the double slit.

between 0.1 mm and 3 mm [A1]

....[1]

Examiner comments:
This part of question was badly done.
Majority of the cohort could not estimate the value within the range.
Students usually estimated too large a value!
Could they mis interpreted the question – thinking that the question asked for distance D? or
Was it the issue of connecting reality to the diagram (not drawn to scale) above?

(ii) Describe the effect, if any, on the separation and on the maximum brightness of the fringes when the following changes are made independently of each other.

1. The distance D is increased to $3D$, while keeping a and λ constant.

separation between fringes will triple [B1]
bright fringes are less bright [B1]

....[2]

2. The wavelength λ is increased to 2λ, while keeping a and D constant.

separation between fringes will double [B1]
bright fringes are less bright [B1]

....[2]

3. The intensity of the light incident on the double slit is increased, while keeping λ, a and D constant.

separation between fringes remains unchanged [B1]
bright fringes are brighter [B1]

....[2]

Examiner comments:
Comments for part 1. and part 2.
Most students were able to deduce correctly the effect [increment of 3x(part 1) and 2x(part 2)]of the fringe separation in both parts.
A small group of students lost mark when they failed to mention the quantity of increment [increment of 3x(part 1) and 2x (part 2)].

Many lost marks when they deduced that max brightness of fringes remained unchange.
Misconception:
Especially for part (2), since the equation for fringe separation does not involve 'intensity' or 'amplitude', and slit separation a, and screen distance D, remained unchanged, students thought that max brightness of fringes is not affected.

Many students wrote the 'reasons for the effects' which was uncalled for in the questions. Such answers were 'ignored' by markers.

Part 3. were done very well.

(b) A glass tube, closed at one end, has fine dust sprinkled along its length. A sound source is placed near the open end of the tube, as shown in Fig. 7.2.

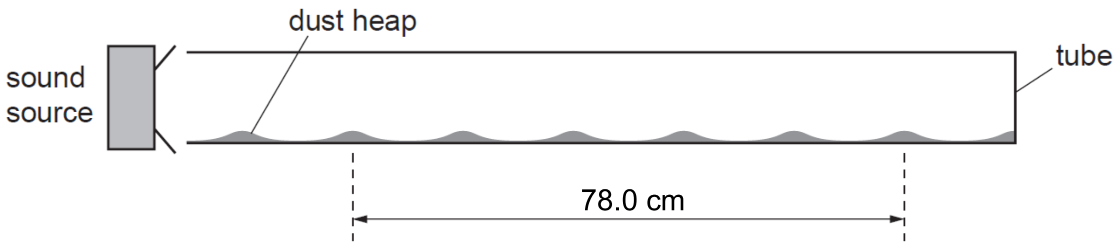


Fig. 7.2

The frequency of the sound emitted by the source is varied and, at one frequency, the dust forms small heaps in the tube.

(i) One frequency at which heaps are formed is 1.07 kHz. The distance between six heaps, as shown in Fig. 7.2, is 78.0 cm.

Calculate the speed of sound in the tube.

wavelength of sound wave:

$$\lambda = \frac{78.0}{2.5} = 31.2 \text{ cm}$$ [C1]

$$v = f\lambda$$
$$= (1.07\times10^{3})(31.2\times10^{-2})$$
$$= 334 \text{ m s}^{-1}$$ [A1]

speed = ... m s^{-1} [2]

Examiner comments:
This part of the question was badly answered.
Many wrote that there were 5 wavelength or loops between the distance of 78.0cm. They failed to realise that every 1 loop occupies 0.5 wavelength. Hence there are only 2.5 wavelengths instead of 5.0 wavelengths.
As such the common wrongly calculated speed is half of the original correct speed of sound.

Penalty (s.f error) was imposed if correct final answer was not written to 3 s.f.

(ii) The wave in the tube is a stationary wave. Explain, by reference to the formation of a stationary wave, what is meant by the speed calculated in **(b)(i).**

interference / superposition / overlap of 2 waves, consisting of the one produced by the source and its reflection, travelling in opposite direction. [B1]
two waves of same type, amplitude , frequency and speed [B1]
speed calculated is the speed of wave traveling down the tube / reflected wave directions [B1]

[3]

Examiner comments:
This question was badly done.

Many failed to mention there was a reflected wave travelling in the opposite direction due to reflection from the closed end of the tube. Simply stating that the incident wave superimpose on the wave travelling in the opposite direction will not be awarded 1 mark.

Some did not mention that the 2 progressive waves must have the same speed. Simply stating that the waves must be the same type, with same frequency and amplitude will not be awarded 1 mark.

Students who wrote the phrase ‘reflected back’ but no mention of reflected back in the opposite direction was not awarded mark.

If answers did not mention that the 2 waves overlap or superimpose with each other, 1 mark penalty will be separately imposed.

Students who wrote about the conditions for constructive and destructive interferences and formation of nodes and antinodes were not awarded any marks.

Many lost 1 mark when explaining the calculated speed of sound.
The following answers were commonly written but not awarded any mark:
-speed of ‘particles vibrating up and down
-speed of sound emitted from the sound source / from the heap of dust
-the resultant speed of the 2 waves
-vector sum of the displacement of each wave over time
-speed of sound wave
-speed of sound from the source

8 A student investigates the vertical oscillations of a solid cylinder which floats in cooking oil. Fig. 8.1 shows a cylinder of radius r.

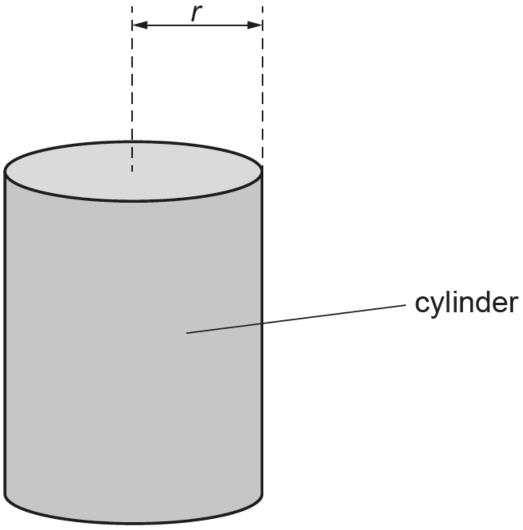


Fig. 8.1

The student places the cylinder of mass m in the oil. The cylinder is displaced vertically from its equilibrium position and released so that it oscillates. The period T of the oscillations is determined.

A number of cylinders of different mass are available.

It is suggested that the relationship between T and m is

$$T = 2\sqrt{\frac{\pi m}{\sigma K r^2}}$$

where σ is the density of the oil and K is a constant.

Examiner comments:
Regarding procedures: Students measured radius r directly using ruler. For cylindrical objects, best to use vernier calipers or micrometer. For radius, you can only measure the diameter and divide by 2. When a new quantity is to be introduced, you must define its symbol accordingly, for e.g. mass of oil, m_{oil}. Examiner will not interpret the symbol for you. If you used m, m is already reserved for mass of cylinder in the question. The density of oil is denoted by σ (sigma), not the number '6' or 'ρ'! Many students wrote "start timing immediately". While not incorrect in the context of planning, it reflects poor experimental habits which you are likely to also commit when doing taking oscillations in an actual practical, which also mean you lacked the awareness of ignoring the first few unsteady oscillations, which also mean you would not write this point to gain 1 mark of additional detail. Some students thought the raw timing is magically the period, and some students only timed 1 oscillation (again bad practice). Fiducial markers should be placed at the centre of oscillation, not at the edge of the oscillations (since it is already difficult to judge the start and end of oscillation, why still put a marker there?). When repeating steps, specify which steps, as not all steps need to be repeated. To 'repeat the experiment' for every step is like dismantling the set up and then setting up again each time a new reading is to be taken. Some students attached strings/springs to their oscillating cylinders or confined the oscillating cylinder to a narrow tube. This impedes oscillations and affect the results.
Regarding analysis: When finding K, students must express K as the subject in its simplest form. If you wrote K can be found from y-intercept etc, it is as good as not saying at all since who doesn't know this. Also, avoid using ln when the equation is not an exponential function.

Methods of data collection	
Labelled diagram of workable experiment including: • beaker/container with oil on a bench or supported by stand where stand is on a bench • cylinder partially submerged in oil • beaker/container, cylinder and oil labelled.	M1
Method to determine radius of cylinder (radius = diameter / 2), e.g. micrometer or calliper to measure diameter (metre rule not acceptable)	M2
Method to determine mass m of cylinder, e.g. use a weighing balance.	M3
Method to determine period or T, e.g. use a stopwatch / timer to time oscillations.	M4
Vary mass of cylinder, m, repeat and measure period T.	M5
Method of Analysis	
Plots a graph of <u>T^2 against m</u>. (Allow other valid graphs, e.g. <u>T against $m^{0.5}$</u> or <u>lg T against lg m</u>) & Relationship valid if a <u>straight line</u> passing through the <u>origin</u> is produced. (No need to mention 'pass through origin' if lg T against lg m).	A1
$K = \dfrac{4\pi}{\text{gradient} \times \sigma r^2}$ ($K = \dfrac{4\pi}{\text{gradient}^2 \times \sigma r^2}$ for T against $m^{0.5}$ or $K = \dfrac{4\pi}{10^{2\times\text{y-intercept}} \times \sigma r^2}$ for lg T against lg m).	A2
Additional Details (Max 4 marks)	
Keep density of the oil constant / Keep radius of cylinder constant / Method to ensure temperature of oil constant (any one of the above details)	D1
Mass of oil = mass of beaker and oil – mass of beaker and use a measuring cylinder to determine the volume of the oil.	D2
Methods to measure volume of oil and determine mass use equation density = mass / volume for measurements.	D3
Time N oscillations and divide NT by N where $NT \geqslant 10$ s / Repeat experiment for each value of m and average T / Repeat measurements of diameter in different directions and average. (any one of the above details)	D4
Wait for oscillations to become even / steady before measuring the time of oscillations.	D5
Take preliminary readings in order to check range of m that would cause a significant change in T that can be measured.	D6
Place fiducial marker of centre of oscillation to judge the start and end of oscillation accurately.	D7
Use cylinders of good contrasting colour to the oil so that oscillations can be seen clearly.	D8
Other sensible answers	D9
Safety Precaution	
Use gloves to prevent oil contacting skin / slippery hands OR Perform experiment in a tray to prevent oil spillages.	S1

[Total: 12]

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: **SOLUTION**

CLASS:

TUTOR'S NAME:

PHYSICS 9749/01

Paper 1 Multiple Choice

4 October 2021

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and tutor's name in the spaces at the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Which list of quantities contains only one vector?

A density, electric charge, power

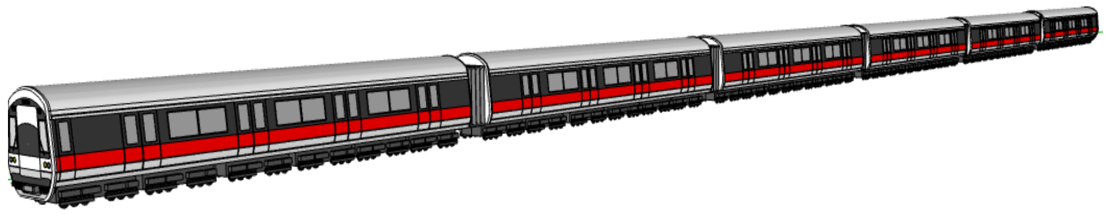
B speed, impulse, upthrust

C current, torque, pressure

D gravitational potential, moment of force, displacement

Ans: C

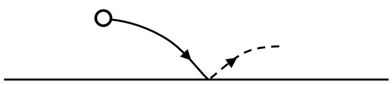
2 What is the order of magnitude of the volume of an SMRT train along the North−South line?



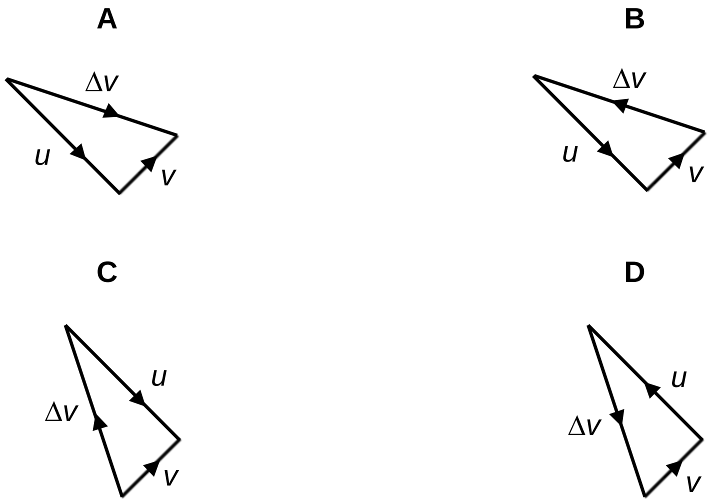
A 10^1 m^3 **B** 10^3 m^3 **C** 10^5 m^3 **D** 10^7 m^3

Ans: B
SMRT C151 train: 6 carriages (full length approx 138 m)
Single carriage length = 23.65 m, Width = 3.2 m, Height = 3.69 m
Total Volume = 1675.56 m^3 = 2 × 10^3 m^3

3 A ball hits the floor with velocity u. It rebounds with velocity v which is half its initial speed.



Which diagram correctly indicates the change in velocity Δv of the ball?



Ans: C
$\Delta v = v - u = v + (-u)$

4 A stone is thrown vertically downwards from the edge of a cliff with an initial speed of 15 m s^{-1}. Just before hitting the ground, it has a final speed of 45 m s^{-1}.

If the stone were thrown horizontally outwards from the top of the cliff with the same initial speed, what is its final speed just before hitting the ground?

A 34 m s^{-1} **B** 37 m s^{-1} **C** 45 m s^{-1} **D** 48 m s^{-1}

Ans: C
When projected vertically.

$v_y^2 = u_y^2 + 2gs_y$

$s_y = \dfrac{v_y^2 - u_y^2}{2g} = \dfrac{45^2 - 15^2}{2 \times 9.81} = 91.7 \text{ m s}^{-1}$

When projected horizontally

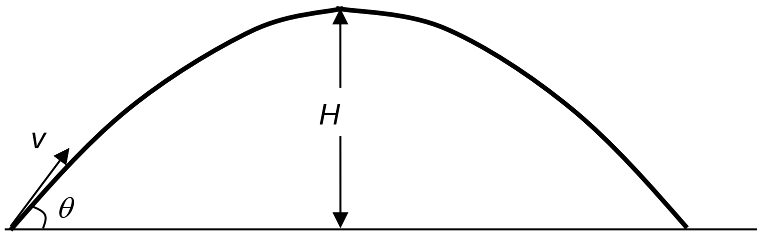
$v_y^2 = u_y^2 + 2gs_y$

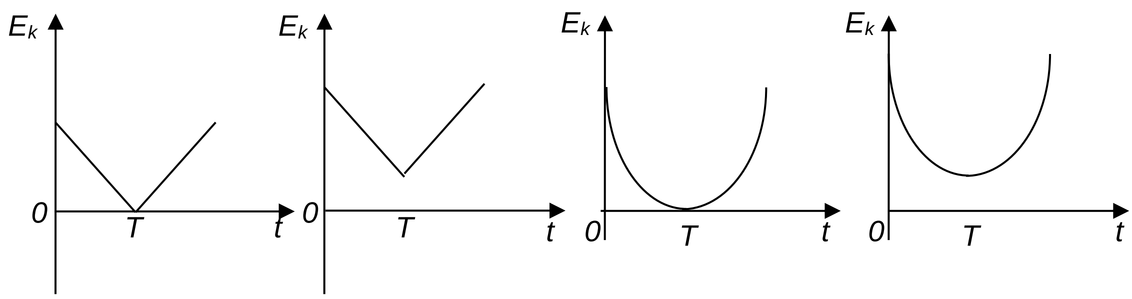
$v_y = \sqrt{2gs_y} = \sqrt{2 \times 9.81 \times 91.7} = 42.4 \text{ m s}^{-1}$

$v = \sqrt{v_y^2 + v_x^2} = \sqrt{42.4^2 + 15^2} = 45 \text{ m s}^{-1}$

By COE, since both situations start with same kinetic energy; and it falls through the same height, the gravitational potential energy converted to kinetic energy is also the same.
The final kinetic energy is the same and hence the final speed is also the same.

5 A ball was projected from the ground with a velocity v at an angle θ to the horizontal. It traces a parabolic path as shown below, reaching a maximum height H after a time T and then falls back down to the ground. Air resistance may be assumed to be negligible. Which graph best shows the variation of kinetic energy E_k of the ball with time t?





A **B** **C** **D**

Ans: D

Note that at maximum height, the ball still has a speed of $v \sin\theta$. Hence E_k is not equal to zero at $t = T$. Options A and C are out.

KE due to horizontal velocity = constant → horizontal line --------- (1)

Vertically, $v = u + at$
KE due to vertical velocity = ½ $m(u + at)^2$ → quadratic curve --------- (2)

Summing up (1) and (2), our answer is D.

6 A boy holding a ball is standing on the floor of a lift. The lift then starts accelerating from rest at 4.9 m s^{-2} upwards. After 2.0 s, he releases the ball at 1.2 m with respect to the floor of the lift. At the moment the ball is released, the lift comes to a sudden complete stop.

What is the time taken for the ball to reach the floor of the lift?

A 0.49 s **B** 1.1 s **C** 2.1 s **D** 3.0 s

Ans: C

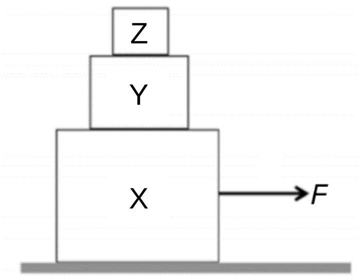
$v = u + at = 4.9 \times 2.0 = 9.8\ \text{m s}^{-1}$

$s = ut + \frac{1}{2}at^2$

$-1.2 = 9.8t - 4.9t^2$

$t = 2.12$ s

7 Three boxes X, Y and Z with masses 3*M*, 2*M* and *M* respectively are stacked on top of each other on a smooth floor. A horizontal force *F* is applied to box X as shown, causing the boxes to accelerate rightwards together.

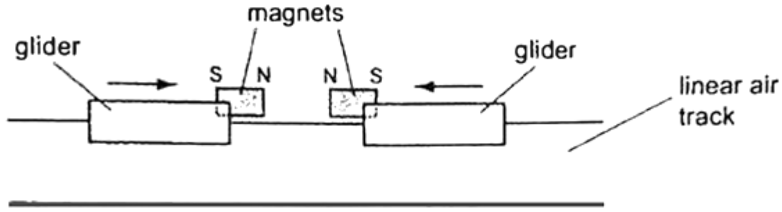


If the friction between boxes X and Y is f_1, and the friction between boxes Y and Z is f_2, which of the following gives the correct ratio $F : f_1 : f_2$?

A 3 : 2 : 1 **B** 3 : 1 : 1 **C** 6 : 5 : 3 **D** 6 : 3 : 1

Ans: D
Boxes have the same acceleration *a*;
Net force on X + Y + Z: $\sum F_{X+Y+Z} = (M_X + M_Y + M_Z)\,a$ → $F = 6Ma$
Net force on Y + Z: $\sum F_{Y+Z} = (M_Y + M_Z)\,a$ → $f_1 = 3Ma$
Net force on Z: $\sum F_Z = (M_Z)\,a$ → $f_2 = Ma$
Consider (1), (2) & (3), $F : f_1 : f_2 = 6 : 3 : 1$

8 Two gliders of equal mass, each fitted with a magnet, move along a linear air track without friction.



They move towards each other with equal initial speeds. As they approach, the magnets repel each other. Each glider decelerates to rest, then accelerates and moves off in the opposite direction.

Which statement is true throughout the whole motion?

A Kinetic energy is conserved because none is converted to heat.

B Kinetic energy is not conserved because neither moves at constant speed.

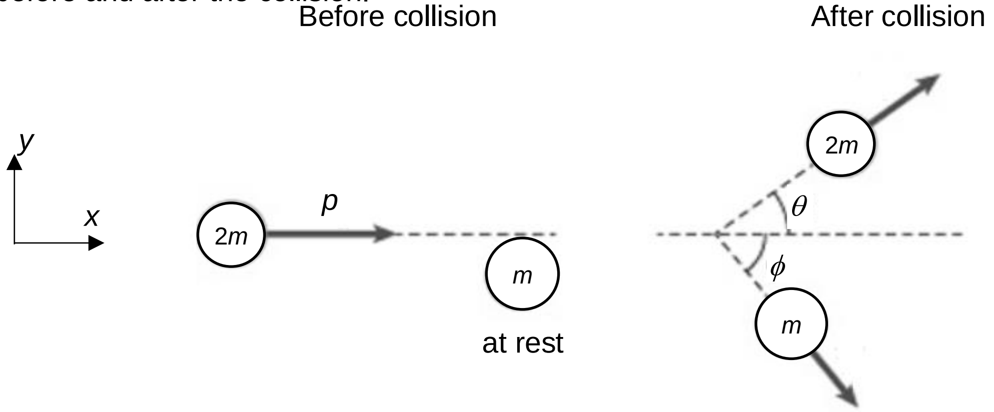
C Momentum is conserved because no external force acts on the gliders.

D Momentum is not conserved because at the instant of closest approach, both gliders are at rest.

Ans: C

Law of conservation of momentum
A – incorrect. KE is not conserved as it is converted to potential energy during collision
B – incorrect reason for non-conservation of KE
D – incorrect. Total momentum is conserved. Since total momentum at any one time is zero, there can be an instance where both are at rest.

9 A puck of mass $2m$ with momentum p in the x-direction is travelling along a frictionless surface of an air hockey table. It strikes the edge of another puck of mass m which is initially at rest, resulting in an elastic collision. The diagrams below show the top view of the motion of the pucks before and after the collision.



Which of the following gives the correct expressions for the magnitude of the total momentum in the x-direction and kinetic energy of the pucks after the collision?

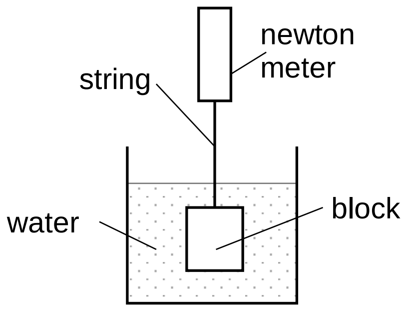
	Total momentum in the x-direction	Total kinetic energy
A	$p\,(\cos\theta + \cos\phi)$	$\dfrac{p^2}{4m}$

B	$p\ (\sin\theta + p\sin\phi)$	$\dfrac{p^2}{2m}$
C	p	$\dfrac{p^2}{4m}$
D	p	$\dfrac{p^2}{2m}$

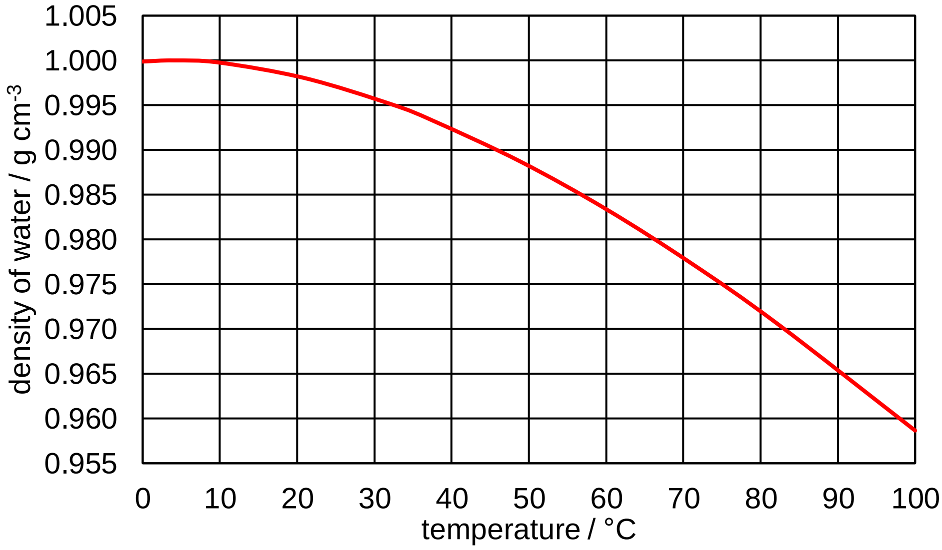
Ans: C

From conservation of momentum, total final momentum = total initial momentum = $p + 0 = p$
Since collision is elastic,
total ke after collision = total ke before collision
= initial KE of puck with mass $2m$
= $p^2 / 2(2m) = p^2 / 4m$

10 A block of volume 1000 cm^3 is attached to a newton meter by an inextensible string and is fully submerged in water of temperature 40 °C. The newton meter reads 0.149 N.



The graph below shows the relationship between the density and the temperature of water.



The temperature of the water is then changed.

What is the new temperature of the water if the reading on the newton meter changes to read 0.321 N?

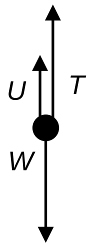
A 15 °C **B** 50 °C **C** 75 °C **D** 90 °C

Ans: C

newton meter reads tension of string

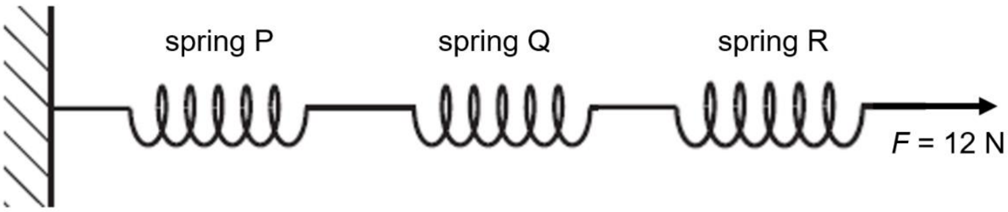
$$
\begin{aligned}
W &= U + T \\
&= \rho V g + T \\
&= \rho_{40\,^\circ\mathrm{C}} V g + 0.149 \\
&= \rho V g + 0.321
\end{aligned}
$$

$$
\begin{aligned}
\rho &= \frac{\rho_{40\,^\circ\mathrm{C}} V g + (0.149 - 0.321)}{V g} \\
&= \rho_{40\,^\circ\mathrm{C}} + \frac{-0.172}{V g} \\
&= \left(0.9925 \times 10^{-3} \times 10^{6}\right) + \frac{-0.172}{\left(1000 \times 10^{-6}\right)(9.81)} \\
&= 975 \text{ kg m}^{-3} \\
&= 0.975 \text{ g cm}^{-3}
\end{aligned}
$$



Corresponds to density at about 75°C.

11 Three light springs P, Q and R with spring constants k_P = 2.0 N m^{-1}, k_Q = 3.0 N m^{-1} and k_R = 6.0 N m^{-1} respectively are connected in series as shown below.



When a force F = 12 N is applied as shown in the diagram above, the springs extend by x_P, x_Q and x_R respectively.

What is the ratio of the extensions $x_P : x_Q : x_R$?

A 1 : 2 : 3

B 2 : 3 : 6

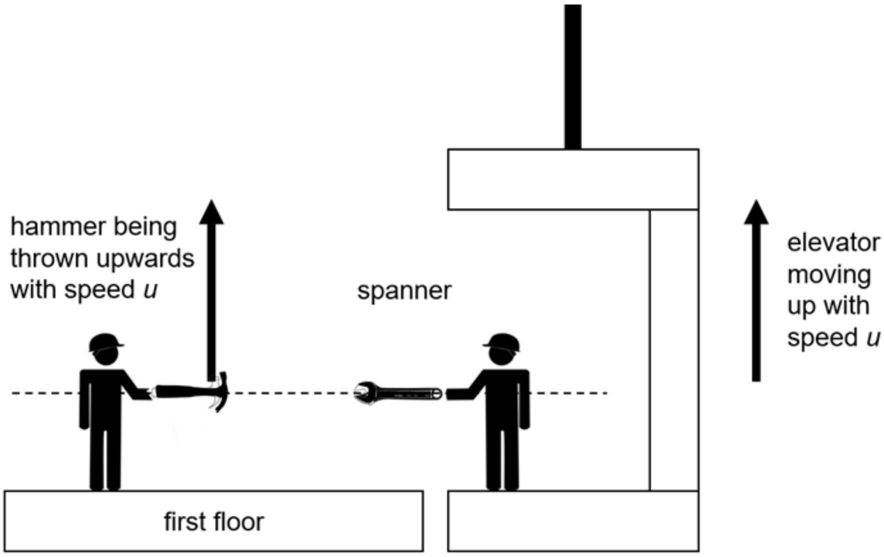
C 3 : 2 : 1

D 6 : 3 : 2

Ans: C

The 12 N force will be exerted equally on all springs as they are being connected in series.
Using Hooke's Law, $F = kx$,
x_P = 12/2.0 = 6 m
x_Q = 12/3.0 = 4 m
x_R = 12/6.0 = 2 m
Therefore answer is 3 : 2 : 1.

12 At a construction site, a workman is in an elevator moving upwards at a constant speed u. When the elevator is level with the first floor, he lets go of a spanner. At the same instant, a second workman standing on the first floor throws a hammer upwards with initial speed u. Assume that both the spanner and the hammer are being released from the same height above the first floor.



Which of the following statements correctly describes the motion of the hammer and the spanner?

A The spanner lands on the first floor before the hammer does.

B Both the spanner and hammer lands on the first floor at the same time.

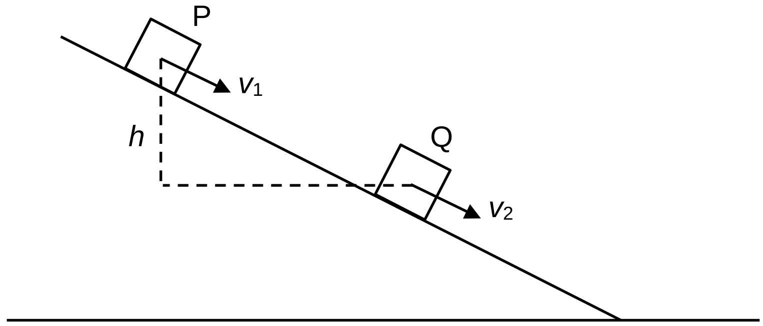
C The spanner travels a longer distance than the hammer before landing on the first floor.

D The spanner and the hammer both move upwards, but the spanner rises more slowly than the hammer.

Ans: B??

As both the hammer and spanner are released from the same vertical height and have the same initial vertical velocity relative to the first floor they will land in the first floor at the same time as they experience the same acceleration.

13 A box of mass *m* slides down a rough incline. At position P, its velocity is v_1 while at position Q, a vertical distance *h* down the incline, its velocity is v_2.



What is the expression for the energy lost due to friction in going from position P to Q?

A $\frac{1}{2}m(v_2 - v_1)^2 - mgh$

B $mgh - \frac{1}{2}m(v_2 - v_1)^2$

C $mgh + \frac{1}{2}m(v_2{}^2 - v_1{}^2)$

D $mgh - \frac{1}{2}m(v_2{}^2 - v_1{}^2)$

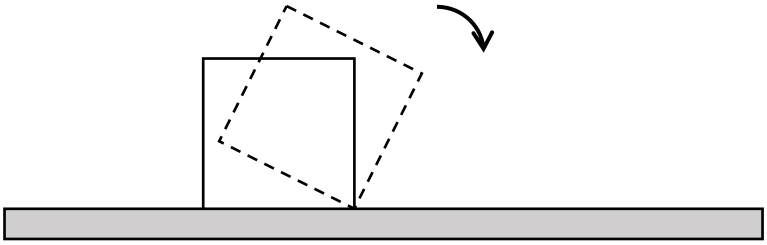
Ans: D

By COE, Gain in KE+Work Done against friction = Loss in GPE

$$\frac{1}{2}mv_2{}^2 - \frac{1}{2}mv_1{}^2 + W = mgh$$

$$W = mgh - \frac{1}{2}m(v_2{}^2 - v_1{}^2)$$

14 A uniform cube of mass m and side d rests on a horizontal surface with one of its six faces as the base. A force acts on it such that it flips over and rests on an adjacent face as the new base.



The minimum amount of work required to perform this is

A 0.21 mgd

B 0.41 mgd

C 0.71 mgd

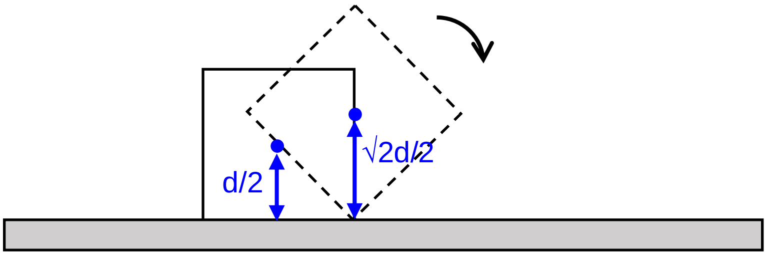
D 0.91 mgd

Ans: A

Min. work done = Gain in GPE

$$= mg\frac{\sqrt{d^2+d^2}}{2} - mg\frac{d}{2}$$

$$= 0.21$$



(B) if take $mg\sqrt{d^2+d^2} - mgd$

$= 0.41mgd$

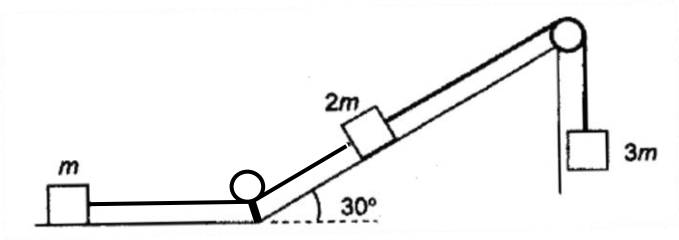
(C) if take $mg\frac{\sqrt{d^2+d^2}}{2} - mg(0)$

$= 0.71mgd$

(D) if take $mg\sqrt{d^2+d^2} - mg\frac{d}{2}$

$= 0.91mgd$

15 The diagram shows three masses of mass m, $2m$ and $3m$ connected by a light string over two light, frictionless pulleys. The objects are released from rest where mass $3m$ moves down by a distance x. What will be the total kinetic energy of the three masses?



A mgx **B** $2mgx$ **C** $3mgx$ **D** $4mgx$

Ans: B

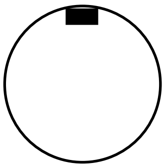
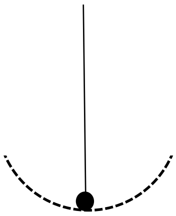
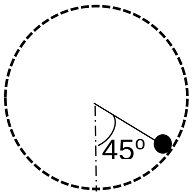
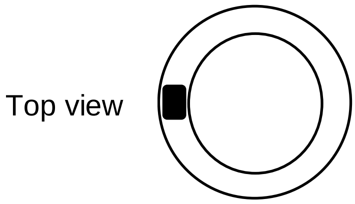
By COE, Gain in total KE+Gain in GPE by 2m $=$ Loss in GPE by 3m

$$\text{Gain in total KE} + 2mg\left(x\sin 30°\right) = 3mgx$$

$$\text{Gain in total KE} = 3mgx - mgx$$

$$= 2mgx$$

16 Which of the following is correct?

	Scenario	Centripetal Force provided by
A	Cart at the top when going around a vertical roller coaster loop 	Normal contact force of track on cart
B	Stone attached to a rope is at the bottom when swung in a vertical plane 	Tension in rope
C	Pendulum bob at an angle of 45^o to the vertical and swinging in vertical plane 	Weight of pendulum
D	Car moving along a roundabout 	Frictional force at the wheels directed towards centre of circular path

Ans: D

A car moving along a roundabout must experience a net force pointing towards the center of the circle; the centripetal force is provided by the frictional force at the wheels.

17 A car of mass m moving at a constant speed v passes over a humpback bridge of radius curvature r.

Given that the car remains in contact with the road, what is the net force exerted by the car on the road when it is at the top of the bridge?

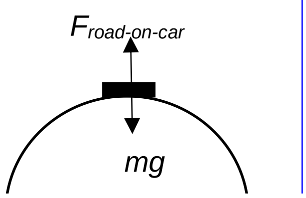
A mg **B** $\frac{mv^2}{r} - mg$ **C** $mg - \frac{mv^2}{r}$ **D** $\frac{mv^2}{r} + mg$

Ans: B

Weight of car - Force of road on car = $\frac{mv^2}{r}$

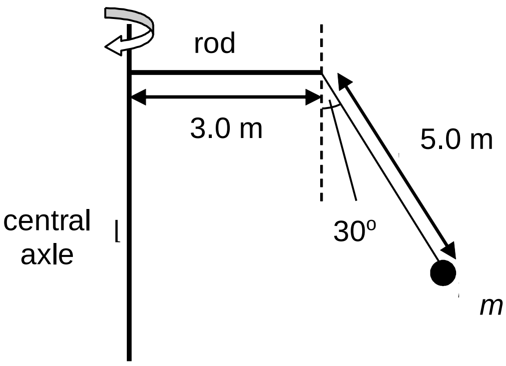
Force of road on car = Weight of car - $\frac{mv^2}{r} = mg - \frac{mv^2}{r}$

By N3L; Force of car on road = $\frac{mv^2}{r} - mg$



18 A mass m, attached to one end of an inextensible string of length 5.0 m, is made to move in a horizontal circle as the central axle and horizontal rod is rotated. In a particular circular motion, the string makes an angle of 30° with the vertical as shown below.

What is the period of the mass's motion about the central axle?



A 1.0 s **B** 3.5 s **C** 4.8 s **D** 6.2 s

Ans: D

$T\cos\theta = mg$

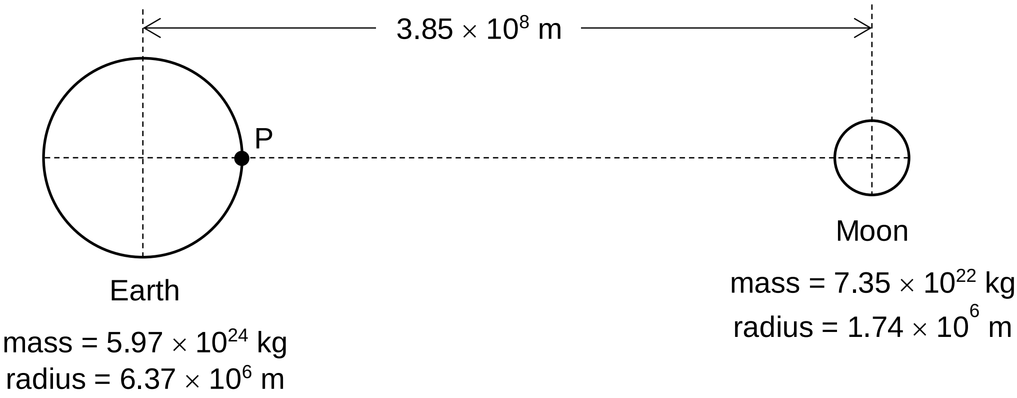
$T\sin\theta = m\omega^2 R = m\left(\frac{2\pi}{T}\right)^2 R$

$\tan\theta = \frac{m\left(\frac{2\pi}{T}\right)^2 R}{mg} = \frac{4\pi^2}{T^2 g}(3.0 + 5.0\sin 30^\circ)$

$T^2 = \frac{m\left(\frac{2\pi}{T}\right)^2 R}{mg} = \frac{4\pi^2}{g\tan 30^\circ}(3.0 + 5.0\sin 30^\circ)$

$T = 6.2$ s

19 The figure below shows a point P on the surface of the Earth that lies on the line joining the centres of mass of the Earth and the Moon which are 3.85×10^8 m apart. The masses of the Earth and the Moon are 5.97×10^{24} kg and 7.35×10^{22} kg respectively, and the radii of the Earth and the Moon are 6.37×10^6 m and 1.74×10^6 m respectively.



The resultant gravitational field strength at P is 9.81 N kg^{-1}. What percentage of this is due to the gravitational field of the Moon?

A – 20% **B** – 0.00035% **C** + 0.021% **D** + 14%

Ans: B
$g = 9.81$ N kg^{-1} (towards Earth)

$g_{Moon} = G M_{Moon} / (D - R_{Earth})^2$, D = distance between Earth and Moon
$= 3.42 \times 10^{-5}$ N kg^{-1} (towards Moon)

$g_{Moon} / g = -3.42 \times 10^{-5} / 9.81 = -0.00035\%$

20 A polar satellite orbits around the Earth such that it is able to scan the surface of the Earth from the North pole to the South pole in 55 minutes. Given that the mass of Earth is 6.0×10^{24} kg, what is the radius of the orbit of the satellite?

A 5.0×10^5 m **B** 4.8×10^6 m **C** 7.6×10^6 m **D** 2.1×10^{10} m

Ans: C
$F_G = m_s r \omega^2$, $\omega = 2\pi / T = 2\pi / (2 \times 55 \times 60) = 9.5\times10^{-4}$ s
$G M_E m_s / r^2 = m_s r \omega^2$
$r = (G M_E / \omega^2)^{1/3} = (6.67\times10^{-11} \times 6.0\times10^{24} / (9.5\times10^{-4})^2)^{1/3} = 7.6\times10^6$ m

21 An object is projected from the surface of the Earth towards the surface of the Moon. The table below shows the potential at five points along its path.

Points	P	Q	R	S	T
Distance from surface of Earth / 10^8 m	3.20	3.30	3.40	3.50	3.60
Potential / MJ kg^{-1}	–1.303	–1.284	–1.276	–1.289	–1.352

Which of the following statements is true?

A The gravitational field strength is weakest at R.

B The gravitational potential energy of the object is lowest at R.

C The gravitational force on the object is greatest at R.

D The gravitational potential gradient is greatest at R.

Ans: A
Gravitational potential is greatest at P, thus potential gradient and field strength is (near) zero.

22 The displacement in metres *s* of an oscillator can be expressed in terms of time in seconds *t* as

$$s = 5.0 \cos (4.0\pi\, t) + 2.5.$$

Which of the following correctly gives the amplitude and period of the oscillations?

	Period / s	Amplitude / m
A	0.25	2.5
B	0.50	5.0
C	2.0	7.5
D	4.0	10.0

Ans: B
$(s – 2.5) = 5.0 \cos (4.0\pi)\, t$
$x_0 = 5.0$ and $\omega = 4.0\pi \rightarrow T = 2\pi / \omega = 0.50$ s

23 Which of the following statements about oscillations is correct?

A In the absence of a driver, a damped oscillator oscillates at its natural frequency.

B A freely oscillating object does not experience any external forces.

C When an oscillator is critically damped, there is resonance when the frequency of the driver is equal to its natural frequency.

D The driver of a forced oscillation is itself an oscillator.

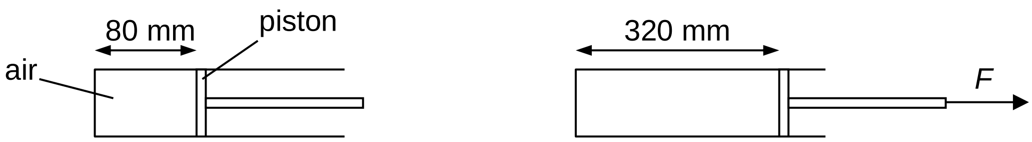
Ans: D
A. Natural frequency is the frequency of oscillation in the absence of driver and damping forces i.e. free oscillations.

B. A freely oscillating object is subjected to a restoring force that causes it to accelerate towards its equilibrium position

C. The phenomenon of critical damping is only observed in damped oscillations without a driver. The phenomenon of resonance is only observed in oscillations with a driver. Resonance occurs at a driver frequency lower than but near to the natural frequency of the oscillator when there is damping.

D. Since the driver has a frequency, it must also be an oscillator.

24 Air is enclosed in a cylinder by a gas-tight, frictionless piston of cross-sectional area 3.0×10^{-3} m^2. When atmospheric pressure is 100 kPa, the piston settles 80 mm from the end of the cylinder. The piston is then pulled out until it is 320 mm from the end of the cylinder and is held there. The temperature of the air in the cylinder returns to its original value.



What is the force *F* required to hold the piston in its new position?

A 75 N **B** 100 N **C** 225 N **D** 300 N

Ans: C
To keep the piston in place,
$F + F_{gas,\ final} = F_{atm}$
$F = F_{atm} - F_{gas,\ final}$
$F = P_{atm}A - P_{gas,\ final}A$

Note that initially,
$$P_{atm} = P_{gas,initial} = \frac{nRT}{V_{initial}} = \frac{nRT}{(80\times10^{-3})A}$$
At final state:
$$P_{gas,final} = \frac{nRT}{V_{final}} = \frac{nRT}{(320\times10^{-3})A} = \frac{1}{4}\frac{nRT}{(80\times10^{-3})A} = \frac{1}{4}P_{gas,initial} = \frac{1}{4}P_{atm}$$

Going back to the original equation we are analysing:
$F = P_{atm}A - P_{gas,\ final}A$
$= (100\ 000)(3.0 \times 10^{-3}) - (1/4)\ (100\ 000)\ (3.0 \times 10^{-3}) = 225$ N

25 A piece of metal P, of mass *m*, at 0°C, is placed into a cavity in a block of metal Q, of mass 5*m*, at 100°C. The thermal equilibrium temperature is 75°C.

Assuming that there is no heat loss to the surroundings, the ratio of the specific heat capacity of P to the specific heat capacity Q is

A 0.200 **B** 0.250 **C** 0.600 **D** 1.67

Ans: D
gain in energy of P = loss in energy of Q

$$m_P c_P \Delta T_P = m_Q c_Q \Delta T_Q$$
$$m c_P (75) = 5 m c_Q (25)$$
$$c_P / c_Q = 1.67$$

26 When an ideal monatomic gas absorbs 1000 J of heat and does 500 J of work, its temperature changes by T_1.

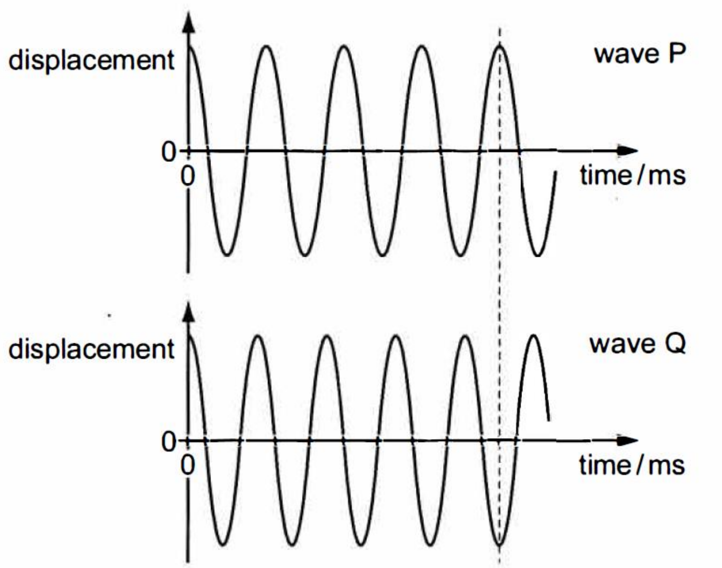
When the same gas absorbs 2000 J of heat and 500 J of work is done on it, its temperature changes by T_2.

Assuming that there is no heat loss to the surroundings, the ratio of T_1 to T_2 is

A 0.200 **B** 0.333 **C** 0.600 **D** 1.00

Ans: A
$$\Delta U_1 = Q_1 + W_1 = 1000 - 500 = 500$$
$$\Delta U_2 = Q_2 + W_2 = 2000 + 500 = 2500$$
since $U \propto T$,
$$\frac{T_1}{T_2} = \frac{\Delta U_1}{\Delta U_2} = 0.200$$

27 The diagram shows the displacement-time graphs of two pure sound waves P and Q at a point in space. The graphs have the same scales for the time axes.



The frequency of Q is 125 Hz. The waves are in phase at time $t = 0$.

At what time are the waves next in phase?

A 32 ms **B** 36 ms **C** 64 ms **D** 72 ms

Ans: D

From graphs shown,

P and Q are initially in phase at t = 0, and become out of phase next at $t = 4.5T_Q$, where T_Q is the period of wave Q.

$T_Q = 1/f_Q = 1/125$ s

Hence the next time the waves become in phase must be for another duration of $4.5\ T_Q$,

i.e. they are next in phase at time $t = 4.5\ T_Q + 4.5T_Q = 9\ T_Q = 0.072$ s

28 The loudness of a constant-frequency sound wave with initial amplitude a and intensity I increases such that its intensity is doubled.

What is the increase in amplitude in terms of a?

A a **B** $\sqrt{2}\,a$ **C** $(\sqrt{2}-1)\,a$ **D** $3\,a$

Ans: C

$I \propto a^2$

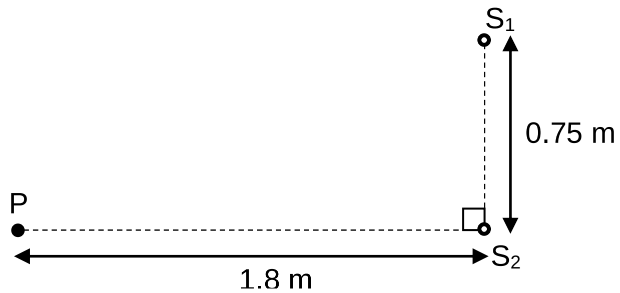
$I'/I = (a'/a)^2$

$2 = (a'/a)^2$

$a' = (\sqrt{2})\,a$

Increase in amplitude = $a' - a = (\sqrt{2} - 1)\,a$

29 Two wave generators S_1 and S_2 produce water waves of wavelength 0.30 m. They are placed 0.75 m apart in a water tank and a detector P is placed on the water surface 1.8 m from S_2 as shown.



When operated alone, each generator produces a wave at P with an amplitude A. When both generators are operating together and in phase, what is the resultant amplitude at P?

A 0 **B** $0.72A$ **C** A **D** $2A$

Ans: A

Distance between S_1 and D $= \sqrt{(0.75)^2 + (1.8)^2} = 1.95$

Path difference $= 1.95 - 1.8 = 0.15 = \frac{1}{2}\lambda$

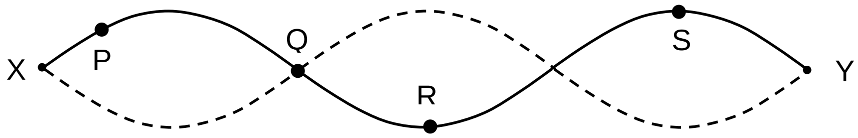
Since sources are in phase, destructive interference take place, resultant amplitude = 0

B: used $y = \frac{\lambda D}{a} = \frac{(0.30)(1.8)}{0.75} = 0.72$

C: Student don't know what's going on.

D: 1.8−2(0.75) = 0.3 = λ (hence in phase and add up amplitude)

30 A stationary wave is set up on a stretched string XY as shown. P, Q, R, S are points on the string.



Which of the following statements is incorrect?

A Points P and S are in phase.

B The distance between points Q and R is equal to one quarter wavelength.

C The amplitude of point P on the string is the same as the amplitude of point R on the string.

D The energy of point S on the string changes from kinetic energy to potential energy and back to kinetic energy twice for every period.

Ans: C

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION WITH EXAMINER'S COMMENTS**		
CLASS		TUTOR'S NAME	

PHYSICS **9749/02**

Paper 2 Structured Questions **4 October 2021**

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 8**
2	**/ 8**
3	**/ 8**
4	**/ 16**
Total	**/ 40**

This document consists of **12** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \mathrm{K} = T / {}^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 Car A is stationary at a red light. As the traffic light turns green, it accelerates forward at 2.4 m s^{-2} along a straight road. At the exact same instant, car B passes by travelling at a constant velocity. The two cars meet again after 14.0 s.

(a) Determine the velocity of car B.

$$s_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(2.4)(14.0)^2$$

$$s_2 = ut + \frac{1}{2}at^2 = v(14.0) + 0$$

$$s_1 = s_2$$

$$\frac{1}{2}(2.4)(14.0)^2 = v(14.0)$$

$$v = 16.8 \text{ m s}^{-1}$$

velocity of car B = ... m s^{-1} [3]

(b) Calculate the distance from the traffic light where the two cars meet again.

$$s_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(2.4)(14.0)^2 = 235 \text{ m}$$

$$\text{OR } s_2 = ut + \frac{1}{2}at^2 = (16.8)(14.0) = 235 \text{ m}$$

distance = ... m [2]

(c) Sketch the displacement-time graph for car A and B on Fig. 1.1 and label them as "A" and "B" respectively.

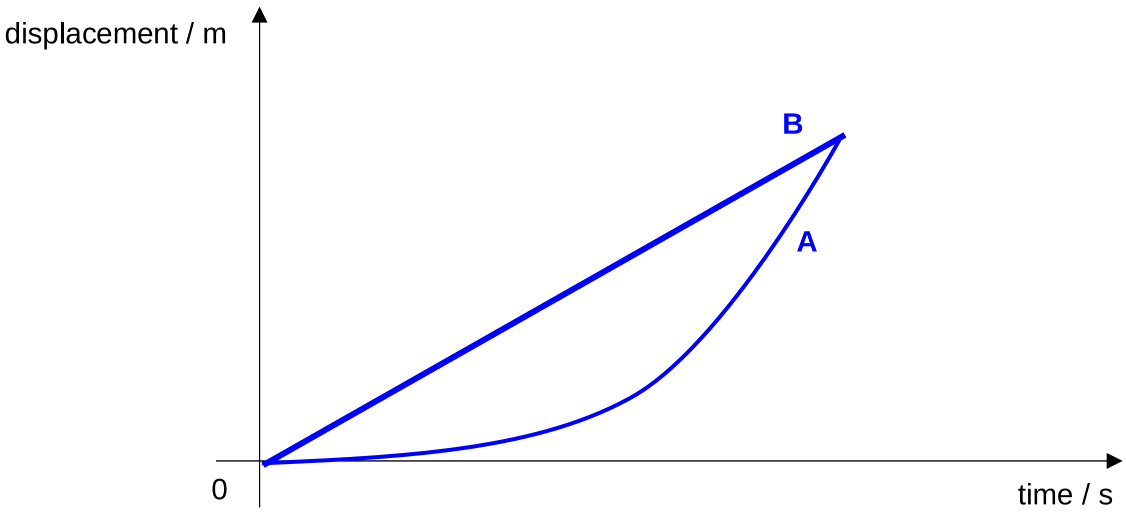


Fig. 1.1

[2]

(d) Without any further calculations, state and explain whether the average speed of car B during the 14.0 s is larger, smaller or equal to that of car A.

$\langle speed_A \rangle = \frac{Distance}{time} = \frac{235}{14.0} = 16.8$ m s^{-1} Since both cars cover the same distance over the same period of time, the average speed of car A and car B are the same.

Examiner's Comments: In explanation question, candidates are expected to show define average speed by using the term total distance, instead of total displacement. [1]

average speed by using the term *total distance*, instead of *total displacement*. [Total: 8]

2 (a) An athlete of mass 75 kg who is standing on one foot, attempts to tiptoe. The forces on the skeletal part of the foot are shown in Fig. 2.1. In this stationary position, the normal force *N* can be considered to be acting at point X. The tendon muscle exerts a tensional force *T* at point Z on the heel and makes an angle of 75° with the horizontal. The tibia exerts a contact force *C* at the ankle joint Y. The vertical and horizontal distances between the various points are given on the diagram. The weight of the foot is negligible.

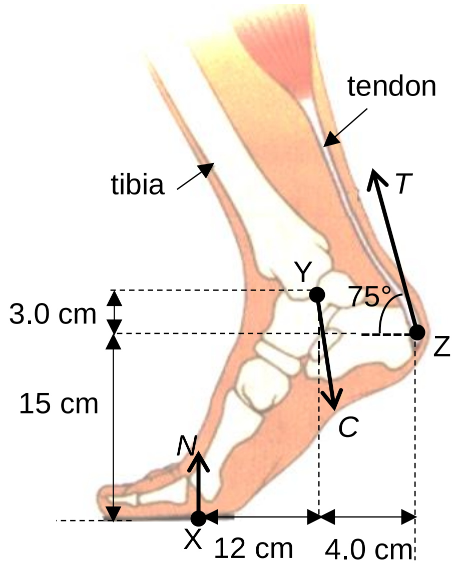


Fig. 2.1

(i) Using Newton's laws of motion, explain why the normal force *N* is equal in magnitude to the weight of the man.

From N1L, since the man remains in equilibrium, there is no net external force on the man so *N* = weight of man

Or

From N2L, since the man has no acceleration or is in equilibrium, net force on man = 0, so *N* = weight of man. [1]

Examiner's Comments:

Majority of students incorrectly used N3L, and wrongly identified weight and normal force to be an action-reaction pair. They cannot be an action-reaction pair as they are not of the same type. Weight is a non-contact force, whereas normal is a contact force. Besides, these 2 forces do not act on the same body. Students need to revise the characteristics of an action-reaction pair of forces.

Some students forgot to quote which law they are using. Even though they have explained correctly that net force on the foot must be zero, no marks is awarded as they did not state which law is being used.

(ii) By taking moments about point Y, determine the tensional force T.

Taking moments about point Y, $\sum \tau_Y = 0$
CW moments due to N and T_x = ACW moments due to T_y
$N(0.12) + T_x(0.030) = T_y(0.040)$ [1]

$Mg(0.12) + (T\cos 75°)(0.030) = (T\sin 75°)(0.040)$
$(75 \times 9.81)(0.12) = T\ [(0.040 \times \sin 75°) - (0.030 \times \cos 75°)]$

$T = 2859.83$ N
$= 2900$ N [1]

Examiner's Comments:

Majority of students who resolved T horizontally and vertically, did not realise that horizontal component of T also contributes to a clockwise moment about point Y.

Presentation needs to be improved. This is especially for those who have tried to resolve T into 2 other perpendicular directions, instead of horizontally and vertically. This is because certain angles that students wanted to solve were not labelled properly, and this makes it hard for the marker to check if it is a conceptual error or merely calculation mistake.

A popular method was to find the perpendicular distance from Y to line of action of T. This is a possible method but many were unsuccessful as they were not careful in their working. Students should use the distances provided in the question to help them solve the problem in the easiest way. For this question, vertical and horizontal distances are provided, so it will be much easier to resolve T horizontally and vertically.

T = ... N [2]

(b) Fig. 2.2 shows a man trying to remove a closed barrel of mass 200 kg and volume 0.160 m^3 from a lake. He is pulling it with an elastic cord at a constant speed up the sloped bank of a lake. A total resistive force f of 25 N acts on the barrel when it is in the lake, as it slides up the rough slope.

The slope and cord are inclined 40° to the horizontal, and the density of water in the lake is 1000 kg m^{-3}.

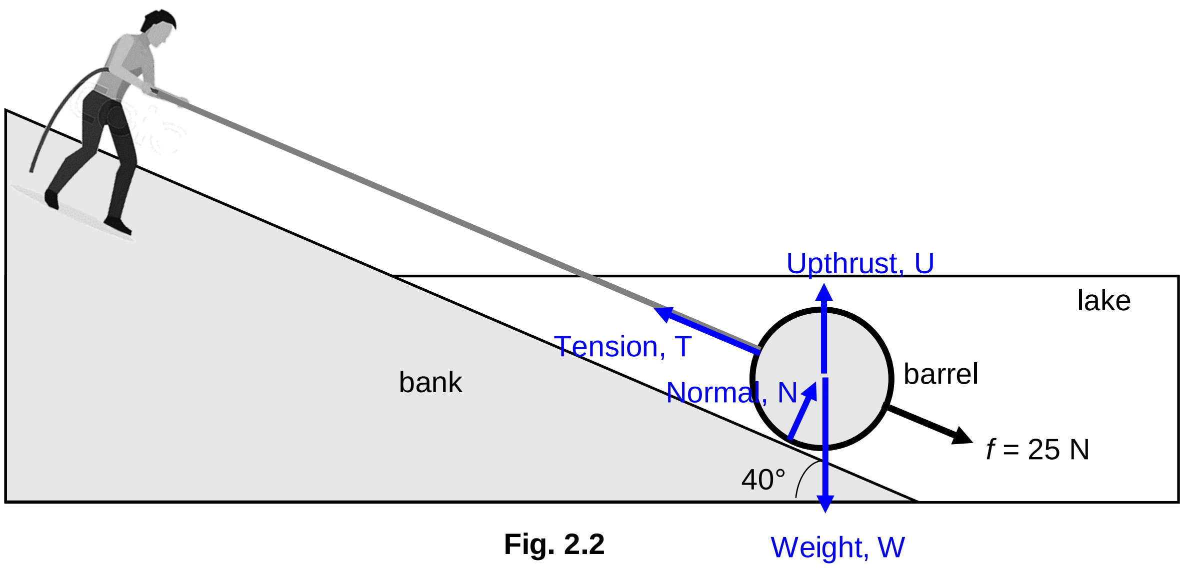


Fig. 2.2

(i) Draw, on Fig. 2.2, all the other forces acting on the barrel. Label the forces clearly. [2]

Examiner's Comments:

Majority of students were not careful and missed out some forces, especially normal contact force and Upthrust.

Upthrust should be drawn from centre of buoyancy, and vertically upwards. Some did not get these right. They should revise the section on upthrust in Forces.

Some included friction and viscous force downslope, but this is incorrect as these forces should already be incorporated in the total resistive force f already drawn out for them.

Some students drew friction in the direction upslope. This is incorrect as the barrel is sliding, not rolling, as stated in the question.

(ii) Hence, calculate the tension in the cord when the barrel is in the lake.

Taking upslope to be positive

$\sum F = 0$

$T + U\sin 40° - f - W \sin 40° = 0$

$T + (\rho_{water} V_{barrel}\, g) \sin 40° - 25 - (200\, g) \sin 40° = 0$ [1]

$T = (200 \times 9.81 \times \sin 40°) + 25 - (1000 \times 0.160 \times 9.81 \times \sin 40°)$

$= 277$ N $= 280$ N [1]

Examiner's Comments:

Many students find it challenging to resolve forces parallel and perpendicular to the slope, preferring to resolve horizontally and vertically instead. Although it is possible to do so, there is a tendency for careless mistakes as they will need 2 equations involving all 4 forces, and solve simultaneously.

Some students assume N = W in their attempt to write the equations. This is incorrect.

Presentation is a problem for many students. Sign convention and direction of resolving were not stated, which makes it very difficult for the marker to check if it were a calculation error or conceptual error in the working. BOD cannot be given for unclear working hence no marks awarded. Note that 'horizontal' direction is not the same as 'along the slope', and 'vertical' direction is not the same as 'perpendicular to slope'. Instead, x & y-directions can be used to denote these directions, but even when used, these has to be indicated clearly at least on the diagram.

tension = ... N [2]

(iii) Suggest why the extension of the cord increases when the barrel is completely removed from the lake.

When the barrel is removed from the water, no more upthrust acts on it (or the decrease in upthrust is more than the decrease in drag force on the barrel).

(For $\sum F = 0$), Tension must increase hence extension increases.

[1]

Examiner's Comments:

Many students were not accurate in their explanation. Students are not awarded any marks if any incorrect or inaccurate statement which reflects conceptual error are given in their answer (incorrect statements include 'net force increase or decrease', or missing forces), even if the two points above in the solution are written.

Note that net force cannot change as the barrel is always in equilibrium even when it leaves the water. Many students wrote down net force changing.

It is incorrect to say that downwards or downslope forces changes, as these forces which are the weight component parallel to slope and resistive forces remain the same.

It is incorrect to say horizontal component of upthrust or weight changes, as these forces always have zero horizontal component.

Note that weight of barrel does not change. Some students state that net force of weight and upthrust gives the 'net weight' of the barrel. There is no such thing as 'net weight', just weight which is W=mg.

Although it is true that resistive force should decrease because no more drag force, but simply saying only this occurs is wrong, because it cannot lead to the conclusion that extension of cord increases. In fact, if only this occurs, extension should decrease, which is not the observation given in the question.

3 A small disc of mass 30.0 g is placed on a turntable at a distance 15.0 cm from the axis of rotation as shown in Fig. 3.1. The maximum frictional force between the disc and the turntable is 0.18 N.

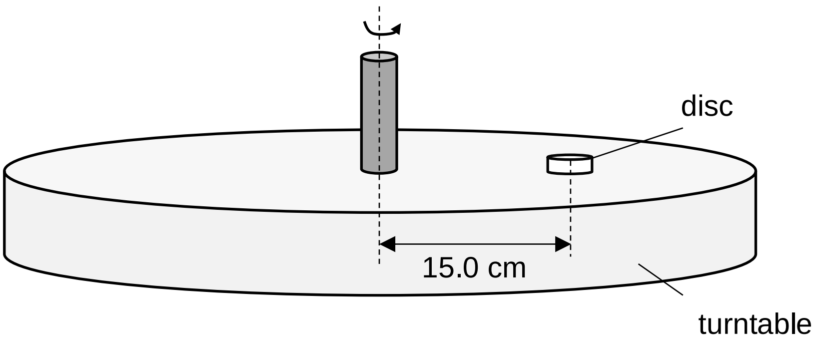


Fig. 3.1

(a) Use Newton's laws of motion to explain why a body moving with uniform speed in a circle must have a resultant force acting towards the centre of the circle.

....

....

....

Since the direction of the body is changing, by Newton's 1st Law, a resultant force must act on the body. [B1] ....[2]

OR

The speed of the body is constant but its direction is constantly changing. This implies that velocity is changing and hence the object experiences an acceleration due to a resultant force acting on it. By Newton's second law there must be a net force acting on it. [B1]

Why does this force point to the center:

In order for the speed of the body to remain constant, the resultant force must be perpendicular to the motion or velocity (ie the force has no component along the direction of motion to increase or decrease the speed). [B1]

OR

There is no change in kinetic energy of the body (because speed is constant). This means that there is no work done by the resultant force, which implies that the force is perpendicular to the motion (or velocity). [B1]

Hence, there is a centripetal force on body which points towards the centre of the circle.

Examiner's Comments:

The question explicitly stated to use Newton's laws of motion to explain which many students did not. Many just stated that because the object is traveling in circular motion, hence there must be a force perpendicular to the direction of motion. This does not explain why this force in perpendicular in the first place, and not explicitly invoking Newton's laws in their explanation.

Student must realise that for many 'explain' questions, you must always fall back to theory, and also use the proper physics terms wherever possible (regardless whether the questions asks you to use any specific concept or not).

(b) Calculate the maximum angular velocity ω of the turntable for the disc to remain in a circular path of radius 15.0 cm.

The frictional force provides the required centripetal force for the disc to move in a circle.

$$\text{friction} = mr\omega^2$$

$$\omega = \sqrt{\frac{\text{friction}}{mr}} = \sqrt{\frac{0.180}{(0.0300)(0.150)}}$$

$$= 6.32 \text{ rad s}^{-1}$$

Examiner's Comments:

This part was well done, except those who were totally clueless about the equation for centripetal force.

Mistakes made were mainly due to carelessness, forgetting to convert the values to SI units.

ω = ... rad s^{-1} [2]

(c) Hence calculate the frequency of rotation of the turntable.

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi} = \frac{6.32}{2\pi}$$

$$= 1.01 \text{ Hz}$$

Examiner's Comments:

Well done. A couple of students do not round off correctly. In physics we do not truncate our values. We round off!

frequency = ... Hz [1]

(d) State and explain what happens to the disc if the frequency of the rotation of the turntable is increased.

When the frequency and thus angular velocity of the turntable is increased, the required centripetal force to maintain circular motion increases. [B1]

Since the centripetal force required now exceeds the maximum frictional force, [B1]

the disc will slide off the turntable. [B1]

**If a student says that the disc moves towards the centre, no credit awarded. Immediate zero.

Note:

- The sliding motion is not tangential to the original path as radial frictional force still exists (unlike cutting the string of a pendulum, where tension becomes zero). [3]
- Once sliding takes place, the disc continues to move further away from the centre until it falls off the turntable as there is no position where Fc $\leq$ fmax (because as r↑, Fc↑). [Total: 8]

Examiner's Comments:

Many students do understand the concepts, but are unable to express their ideas correctly. When the angular velocity increases, the friction increases until the maximum is reached. Students tend to write that the "centripetal force is now larger than the maximum friction, and hence…." which is technically incorrect, as the centripetal force is provided by friction.

Many students wrote good explanations for a start but tragically ended off with stating the disc moves inwards. Logic should be engaged when attempting questions like these. When the disc is already spinning with friction barely holding it in place, how would the disc on its own be able to move inwards?

4 Radiation is a significant component of thermal energy transfer in buildings, especially for sun-exposed surfaces and regions of large temperature differences. Most countries have building regulations that contain instructions about limiting heat transfer in order to reduce the amount of air-conditioning required.

In order to calculate energy transfer, a thermal transmittance coefficient or U-value, U, is measured for each type of building component and is given by the equation:

$$U = \frac{P}{A\Delta T}$$

where P is the rate of energy transfer through the component in W,
A is the surface area of the component through which energy transfer occurs in m^2, and
ΔT is the air temperature difference between each side of the structure in K.

The values of U of three building components are given below in Fig. 4.1:

Component	**U / W m^{-2} K^{-1}**
Single-glazed window	5.6
Double-glazed window	3.2
Uninsulated roof	1.9
Thermal insulation (50 mm)	1.4

Fig. 4.1

A house has windows of total area 24 m^2 and a roof of area 60 m^2. During the winter period, the owner heats the house for 250 hours per month on average to a temperature that is 14 K above that of the air outside.

(a) (i) Show that 1 kWh is equivalent to 3.60×10^6 J.

$1 \text{ kWh} = 1000 \times 3600 = 3.60 \times 10^6 \text{ J}$ (shown)

Examiner's Comments:
Poorly done. Many candidates forget about what they have learnt about in their O Levels on kWh

[1]

(ii) Calculate the amount of energy lost in a month through single-glazed windows.

$$U = \frac{P}{A\Delta T} \rightarrow P = UA\Delta T$$

$$E = Pt = UA\Delta Tt$$

$$E = 5.6 \times 24 \times 14 \times 250 \times 3600$$

$$E = 1.69 \times 10^9 \text{ J}$$

Examiner's Comments:
Poorly done. Quite a significant number of candidates are not sure of which area to use in their calculations. More time ought to be spend on understanding the question before doing calculation haphazardly.

... J [2]

(iii) By replacing single-glazed windows with double-glazed windows, calculate the monthly savings given that electricity costs 0.25 dollars per kWh.

$\Delta E = \Delta U A \Delta T t = (5.6 - 3.2) \times 24 \times 14 \times 250 \times 3600 \div (3.6 \times 10^6)$

$\Delta E = 2.02 \times 10^2$ kWh

savings $= 2.02 \times 10^2 \times 0.25 = 50.4$ Dollars

Examiner's Comments:
Generally well done. Candidates are able to come out with clear presentation for their calculations. Candidates who have gotten the previous parts wrong will be awarded ECF if their working demonstrates clear understanding of what they are doing.

savings = ... dollars [3]

(b) The roof is insulated with two 50 mm thick layers of thermal insulation on each side to reduce heat transfer as shown in Fig. 4.2 below.

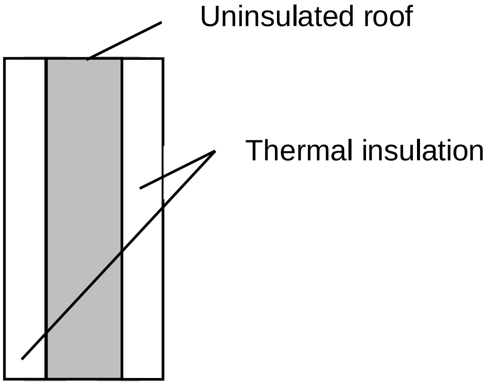


Fig. 4.2

To calculate the rate of heat transfer P through such a roof, a composite U-value, U_c, has to be used. U_c can be expressed in terms of the U-values of the individual materials by the equation:

$$\frac{1}{U_C} = \frac{1}{U_1} + \frac{1}{U_2} + ...$$

(i) Using the above equation, show that the rate of heat transfer P through the roof with thickness of thermal insulation of 50 mm on each side is 430 W.

$$\frac{1}{U_C} = \frac{1}{1.4} + \frac{1}{1.9} + \frac{1}{1.4}$$

$$U_C = 0.512$$

$P = U A \Delta T = 0.512 \times 60 \times 14 = 430$ W (shown)

Examiner's Comments:
Generally well done. Some candidates however forget that they need to reciprocate the numerical value to obtain U_c

[2]

(ii) Complete Fig. 4.3 below for the different values of thickness *t*. [2]

***t* / mm**	***U* / W m^{-2} K^{-1}**	***P* / W**
25	0.806	**677**
50	0.512	430
75	0.375	315
100	**0.296**	248
125	0.244	205
150	0.208	175
175	0.181	152
200	0.160	135

Examiner's Comments:
Well done by majority. Some however rounded off their answers wrongly unfortunately.

Fig. 4.3

(iii) Some corresponding values of P and t for the data in Fig. 4.3 are plotted on the graph of Fig. 4.4.

`

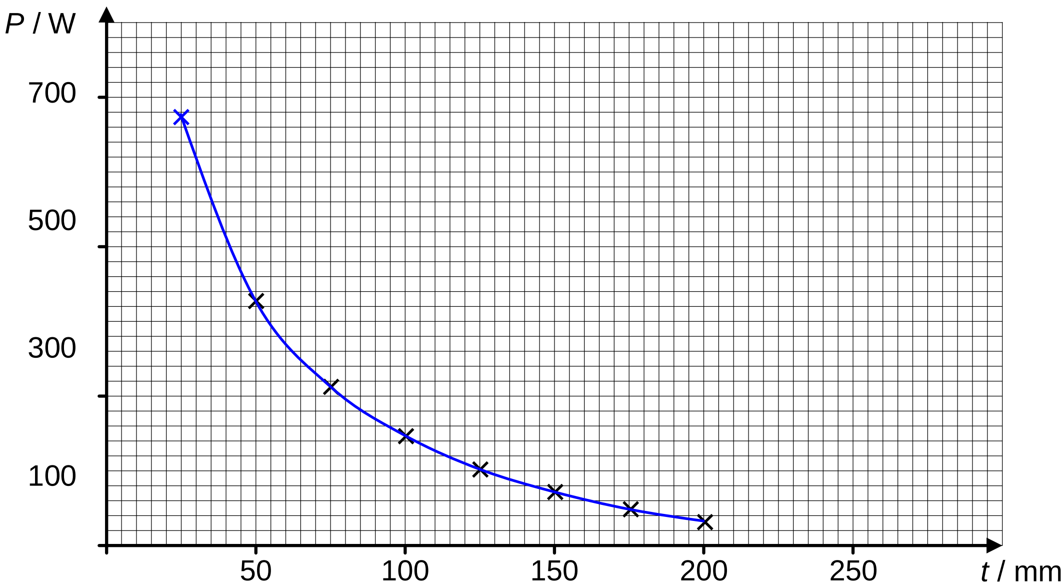


Fig. 4.4

On Fig. 4.4,

1. plot the point corresponding to thickness *t* = 25 mm.

2. draw the best-fit line for all the plotted points. [2]

(iv) Explain why the rate of heat transfer for a thickness of 250 mm thermal insulation on each side cannot be accurately determined from Fig. 4.4.

Since the graph is not a straight-line, extrapolation should be avoided when it is difficult to predict the trend.

....[1]

Examiner's Comments:
Generally well done. Most candidates are able to deduce that extrapolation should be avoided. However, some did not score credit in their answers as they are unclear about the idea they are trying to convey. Furthermore answers such as graph scaling problems are not being accepted.

(c) External work is required to get energy to flow from a cold reservoir to a hot reservoir. A heat pump is such a device, which applies external work W to extract an amount of heat Q_C from a cold reservoir, and delivers heat Q_H to a hot reservoir, as shown in Fig. 4.5 below.

Thermal efficiency e of a heat pump is defined as the ratio of W to Q_H during one cycle of the process. W, which is equivalent to $(Q_H - Q_C)$, maintains a particular temperature difference between the hot and cold reservoirs.

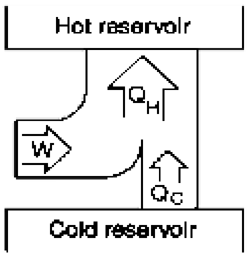


Fig. 4.5

The coefficient of performance COP of a heat pump is given by the equation:

$$\text{COP} = \frac{1}{e}$$

Fig. 4.6 shows the relationship between thermal efficiency, e, of an **ideal** heat pump and the temperature of the hot reservoir, T_h, for a temperature difference of 27 K.

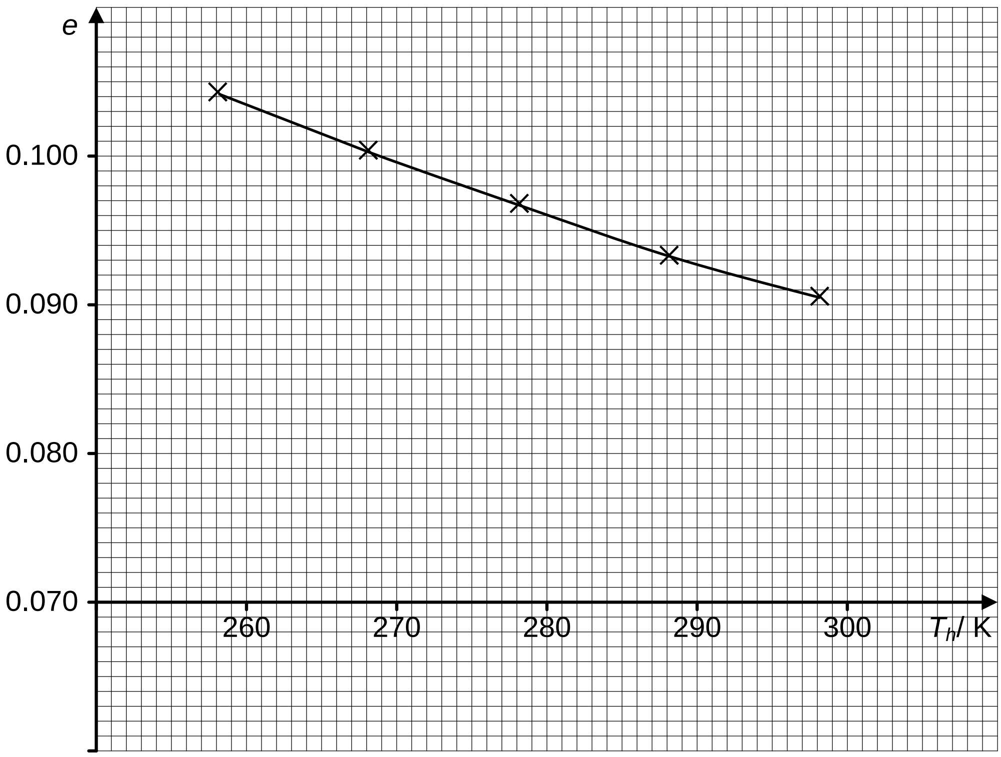


Fig. 4.6

The house loses energy at a rate of 5.00 kW when the interior temperature is 287 K and the outside temperature is 260 K.

(i) Using Fig. 4.6, calculate the COP for an ideal heat pump.

From graph, $e = 0.0938$ [1] (accept 0.0936 to 0.0939)

$$COP_{ideal} = \frac{1}{e} = 10.66$$

COP = ... [1]

Examiner's Comments:
Generally well done. Most candidates are able to get the value of *e* from the graph. However, some forget to reciprocate the value.

(ii) Assuming that a heat pump operates with a coefficient of performance that is 60% of the ideal value, calculate the electric power needed by the heat pump to maintain the interior temperature at 287 K.

$$COP_{\text{heat pump}} = 0.60 \times 10.66 = 6.40 = \frac{Q_H}{W} \quad [1]$$

$$P = \frac{W}{t} = \frac{Q_H}{COP_{\text{heat pump}}} \times \frac{1}{t} = \frac{5000}{6.40} \times \frac{1}{1} \quad [1]$$

$P = 782$ W [1]

W [2]

Examiner's Comments:
Poorly done. Mostly unattempted. Those that attempt make careless mistake by forgetting COP is 60% of ideal value.

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: **SOLUTION WITH EXAMINER'S COMMENTS**

CLASS:

TUTOR'S NAME:

PHYSICS 9749/03

Paper 3 Longer Structured Questions

28 September 2021

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and tutor's name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 10**
3	**/ 6**
4	**/ 10**
5	**/ 12**
6	**/ 12**
Section B	
7	**/ 20**
8	**/ 20**
Total	**/ 80**

This document consists of **24** printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^{\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 In the study of materials, tensile stress, σ, in a wire is defined as the normal force applied per unit cross-sectional area. Tensile strain, ε, is the ratio of extension to the natural length.

The property of the material, Young's modulus E, is the ratio of stress over strain.

$$E = \frac{\sigma}{\varepsilon}$$

(a) Determine the base units of E.

$E = \dfrac{\sigma}{\varepsilon}$

$[E] = [\dfrac{\sigma}{\varepsilon}] = \mathrm{N\,m^{-2}}$

$= \mathrm{kg\,m^{-1}\,s^{-2}}$ [1]

Show knowledge that ε has no units. [1]

base units = ... [2]

Examiner's Comments:

Use of [ ] is necessary to denote unit of quantity.

Must demonstrate knowledge that strain has no unit.

(b) An experiment is performed to determine the Young's modulus E of a thin wire of steel. The following measurements were obtained:

Force applied	(200 ± 5) N
Diameter	(4.0 ± 0.2) mm
Strain	$(1.5 \pm 0.5) \times 10^{-5}$

Calculate

(i) the uncertainty of stress $\Delta\sigma$ in the wire,

$$\sigma = \frac{F}{A} = \frac{F}{\pi D^2} = \frac{200}{\pi(\frac{4.0 \times 10^{-3}}{2})^2} = 1.5915 \times 10^7\ \mathrm{N\,m^{-2}} \quad [1]$$

$$\Delta\sigma = \left(\frac{\Delta F}{F} + \frac{2\Delta D}{D}\right) \times \sigma = \left(\frac{5}{200} + \frac{2 \times 0.2}{4.0}\right) \times 1.5915 \times 10^7 = 0.2 \times 10^7\ \mathrm{N\,m^{-2}} \quad [1]$$

Examiner's Comments:

Common mistake in finding area eg πr or $4\pi r^2$.

Initial value of σ should not be round-off; this is only done when the value of $\Delta\sigma$ is determined.

$\Delta\sigma$ = ... unit .... [2]

(ii) the Young's modulus E of the material and its associated uncertainty.

$\varepsilon = (1.5 \pm 0.5) \times 10^{-5}$

$E = \sigma / \varepsilon = (1.5915 \times 10^{7} / 1.5 \times 10^{-5}) = 1.061 \times 10^{12}\ \mathrm{N\,m^{-2}}$ [1]

$$\Delta E = \left(\frac{\Delta\sigma}{\sigma} + \frac{\Delta\varepsilon}{\varepsilon} \right) \times E$$

$$= \left(\frac{0.2}{1.6} + \frac{0.5}{1.5} \right) \times 1.061 \times 10^{12} = 0.5 \times 10^{12}\ \mathrm{N\,m^{-2}} \quad [1]$$

$E = (1.1 \pm 0.5) \times 10^{12}\ \mathrm{N\,m^{-2}}$ [1]

E = ... ± .... unit .... [3]

Examiner's Comments:

Incorrect substitution of fractional uncertainty of strain eg using extensive string of numbers.

Premature rounding of value of E.

Unable to display E and ΔE to same power of ten.

(c) **(i)** State and explain which measurement may be improved to most effectively reduce the uncertainty of Young's modulus ΔE.

The measurement of strain may be improved. [1]

The fractional uncertainty of strain contributes the most to uncertainty of Young's modulus. [1]

.... [2]

(ii) Suggest the instrument that may be used.

Strain guage. Vernier scale (not callipers). Micrometer screw gauge. (allowed due to scope of syllabus). [1] [1]

[Total: 10]

2 The driving force F_D (in N) required for a car of mass 1000 kg to move at a constant speed v (in m s^{-1}) on a flat road is given by

$$F_D = 100\,v^2 + 150.$$

(a) Suggest why, even though a driving force is applied, the car moves with a constant speed.

There are forces resisting the motion of the car exerted by the road and the air. The sum of these forces with the driving force is zero. [1]

Examiner's Comments:

The net frictional force by the road on the car is actually in the forward direction. Without this forward friction, the tyres will skid against the surface of the road and not move the car forward. Thus, simply stating "friction from the road" will not earn a mark. There must be a mention of the existence of forces "resisting / opposing motion".

(b) Show that the driving force required for the car to move at a constant speed of 60 km h^{-1} is 28 kN.

v = 60 km h^{-1} = 60 × 1000 / 3600 = 16.7 m s^{-1}

F_D = 100 × 16.7^2 + 150 = 2.8 ×10^4 N

Examiner's Comments:

The conversion of the speed from km h^{-1} to m s^{-1} should be presented clearly i.e. **not** a simple division by 3.6.

[1]

(c) Calculate the acceleration required for the car to increase its speed from 60 km h^{-1} to 78 km h^{-1} in 5.0 s.

a = (v – u) / t

= (78 – 60) × 1000 / 3600 / 5.0

= 1.0 m s^{-2}

acceleration = ... m s^{-2} [1]

(d) Calculate the driving force required for the car moving at 60 km h^{-1} to produce the acceleration calculated in **(c)**.

$F_D + (-R) = m\,a$ where $R = 28 \times 10^3$ N

$F_D = 1000 \times 1.0 + 28 \times 10^3 = 2.9 \times 10^4$ N

Examiner's Comments:

Question clearly stated to find acceleration at the speed of 60 km h^{-1}, but many students used the final speed of 78 km h^{-1} in their solution.

driving force = ... N [2]

(e) Explain why the car may never reach its target speed of 78 km h^{-1} with the driving force calculated in **(d)**.

As the car accelerates, the total resistance force increases, so resultant force and acceleration of the car decreases. The acceleration of the car may decrease to zero before the target speed is reached. [2]

Examiner's Comments:

Most students simply stopped at 'acceleration decreases'. In order for the car to never reach the target speed, the acceleration must decrease to zero.

(f) The driving force on the car, initially moving at 60 km h^{-1}, is increased to 30 kN as it begins to climb up a slope inclined at 18° to the horizontal. Calculate the initial acceleration of the car as it begins to climb up the slope.

$F_D + (-R) + (-W \sin\theta) = m\,a$

$30 \times 10^3 - 28 \times 10^3 - 1000 \times 9.81 \times \sin 18° = 1000\,a$

$2000 - 3000 = 1000\,a \rightarrow a = -1.0$ m s^{-2} = 1.0 m s^{-2} (deceleration)

acceleration = ... m s^{-2} [3]

[Total: 10]

3 A 50 W transmitter emits microwaves of frequency 10 GHz uniformly in all directions, as shown in Fig. 3.1. A receiver is initially at point O which is 500 m from the transmitter, and detects microwaves of an amplitude of 15 cm. The receiver is then moved 300 m to point P.

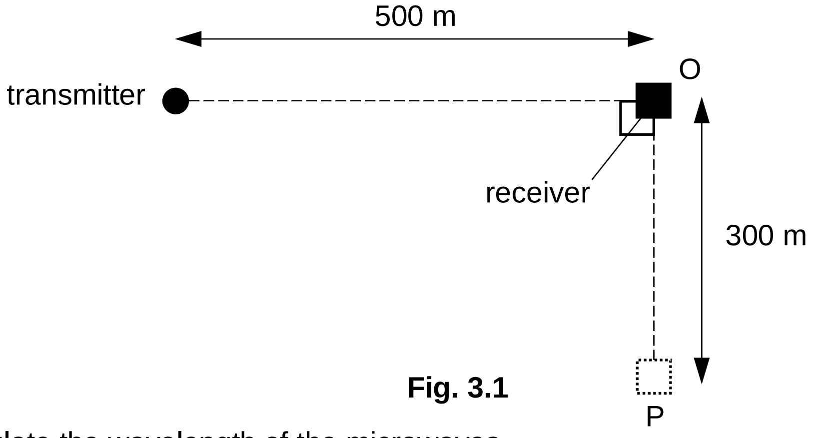


Fig. 3.1

(a) Calculate the wavelength of the microwaves.

$$\lambda = \frac{c}{f} = \frac{3.0\times10^{8}}{10\times10^{9}} = 0.030 \text{ m}$$

wavelength = ... m [1]

(b) Determine the intensity of the microwaves at P.

distance between transmitter and P $= \sqrt{500^2 + 300^2}$

$= 583$ m

Intensity at P $= \dfrac{P}{4\pi r^2}$

$= \dfrac{50}{4\pi(583)^2}$

$= 1.17\times10^{-5}$ W m^{-2}

Examiner's Comments:

Quite a number of students did not interpret the diagram correctly and mistook the positions of O, P and the transmitter.

intensity at P = ... W m^{-2} [2]

(c) Show that the amplitude A of the microwaves at a point is inversely proportional to the distance r between the transmitter and that point.

Since Intensity $I = \dfrac{P}{4\pi r^2}$, $I \propto \dfrac{1}{r^2}$

and $I \propto A^2$

$A^2 \propto \dfrac{1}{r^2}$

$\therefore A \propto \dfrac{1}{r}$

Examiner's Comments:

Because this is a 'show' question with the final answer given, the last step before the final answer i.e. $A^2 \propto 1/r^2$ must be shown.

[2]

(d) Hence, determine the amplitude of the microwaves detected by the receiver at P.

Since $A \propto \dfrac{1}{r}$,

$$\frac{A_o}{A_P} = \frac{r_P}{r_o}$$

$$\frac{15}{A_P} = \frac{583}{500}$$

$$A_P = \frac{r_o}{r_P} A_o$$

$$= \frac{500}{583}(15)$$

$$= 12.8 \text{ cm}$$

amplitude = ... cm [1]

[Total: 6]

4 **(a)** State the *principle of superposition*.

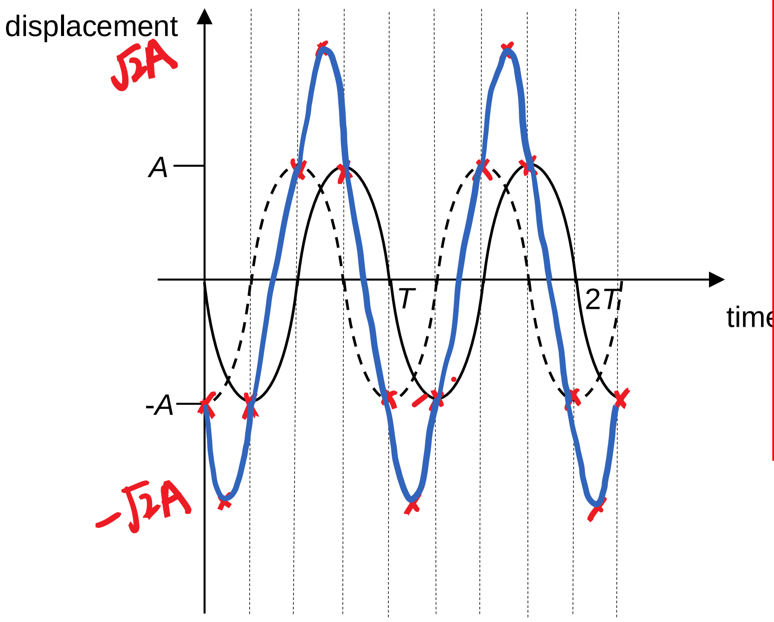
When two waves meet, the resultant displacement is the vector sum of the displacements due to each individual wave.

[1]

Examiner's Comments:

It was already highlighted in lecture that the keyword is *displacement* and not *amplitude*.

(b) Two sources of waves with amplitude A and period T meet $\frac{\pi}{2}$ rad out of phase at point P as shown in Fig. 4.1.



Examiner's Comments:

It is useful to take the vector sum of the displacement of the two graphs (apply Principle of Superposition) and mark out the points as shown in red. Then draw a smooth curve joining the points as shown in blue.

Fig. 4.1

(i) State the time, in terms of T, at which the two waves first have the same displacement.

$t = \frac{T}{8} = 0.125\,T$

time = ... T [1]

(ii) Determine the displacement of the resultant waveform, in terms of A, at the time stated in **(b)(i)**.

$x_1 = -A \sin \omega t = -A \sin \frac{2\pi}{\mathrm{T}}\left(\frac{T}{8}\right) = -A \sin \frac{\pi}{4} = -\frac{A}{\sqrt{2}}$

Therefore displacement of resultant wave = $2\left(-\frac{A}{\sqrt{2}}\right) = -\sqrt{2}A$

Examiner's Comments:

Candidates studied the chapter in isolation and did not realize that the waveform can be expressed in the general equation for SHM.

resultant displacement = ... A [2]

(iii) By applying the principle of superposition, sketch and label, on Fig. 4.1, the variation of resultant displacement at P with time. [3]

(c) Stationary waves can be produced by the superposition of progressive waves when a guitar string is plucked. The side view of the guitar is shown in Fig. 4.2. The guitar string can produce different musical notes by pressing the string at different distances L from the far end.

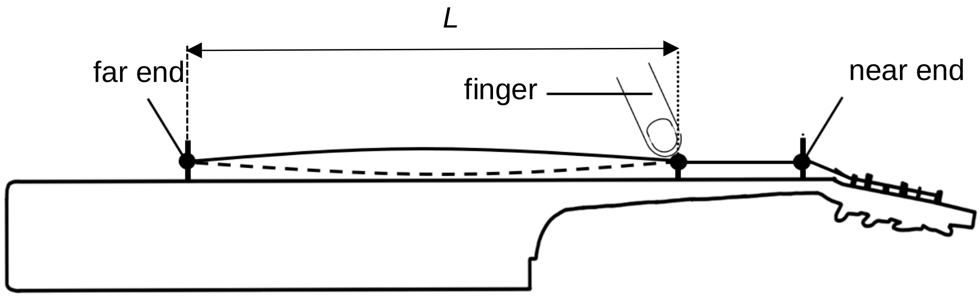


Fig. 4.2

Assuming that the speed of the wave remains constant at 425 m s^{-1}, calculate the change in L when a guitarist changes from playing a note with a fundamental frequency of 247 Hz to a note with a fundamental frequency of 262 Hz.

$$L = \frac{\lambda}{2} = \frac{v}{2f}$$

$$\text{change in } L = \frac{v}{2}\left(\frac{1}{f_1} - \frac{1}{f_2}\right)$$

$$\text{change in } L = \frac{425}{2}\left(\frac{1}{247} - \frac{1}{262}\right) = 0.0493 \text{ m (3sf)}$$

Examiner's Comments:

Candidates should begin by drawing the waveform for fundamental frequency to deduce that L = half a wavelength. They can then form two separate equations for each fundamental frequency.

change in L = ... m [3]

[Total: 10]

5 **(a)** State the *First Law of Thermodynamics*.

The increase in internal energy of a system is sum of heat supplied to system and work done on system.

Examiner's Comments: [1]

Common mistakes in using the term "change in internal energy" instead of increase. Many candidates are unsure about work done "on" versus "by" system. The term "thermal energy" cannot be used interchangeably with "internal energy".

(b) A monoatomic ideal gas is enclosed in an air-tight cylinder with a movable piston, as shown in Fig. 5.1.

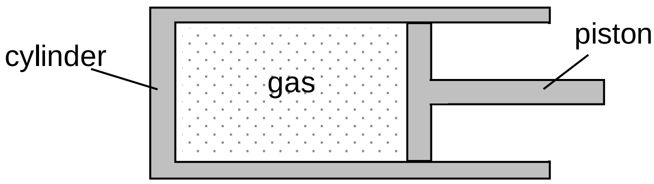
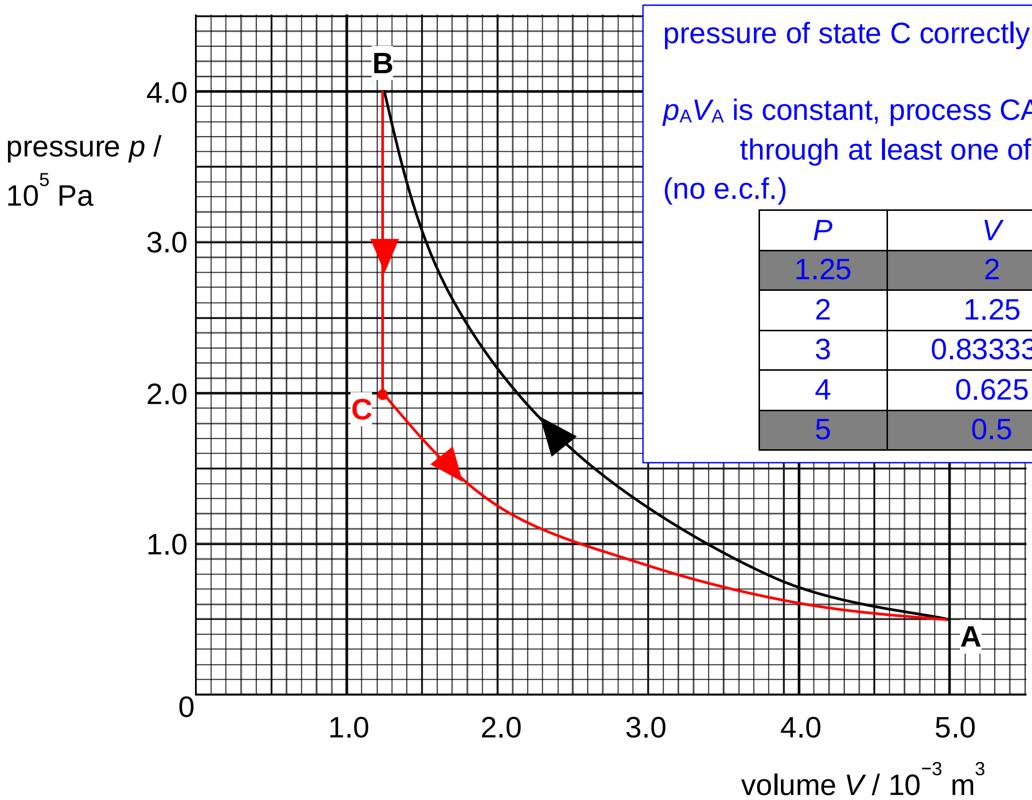


Fig. 5.1

The gas is compressed as it transits from state A to B very quickly as shown in Fig. 5.2.



pressure of state C correctly plotted

$p_A V_A$ is constant, process CA must pass through at least one of below:
(no e.c.f.)

P	V
1.25	2
2	1.25
3	0.833333
4	0.625
5	0.5

Fig 5.2

(i) Determine the internal energy of the gas at state A.

$$U = \frac{3}{2}NkT = \frac{3}{2}pV$$

$$= \frac{3}{2}\left(0.5\times10^{5}\right)\left(5.0\times10^{-3}\right)$$

$$= 375 \text{ J}$$

internal energy = ... J [2]

Comments:

Common mistakes includes forgetting the factor of 3/2 in the equation for internal energy. A number of candidates calculated change in internal energy instead of internal energy. POT error is also very commonly observed.

(ii) The gas then goes through two more processes:
State B → C: The gas is cooled while the piston is kept at the same position.
State C → A: The gas expands at constant temperature slowly.

Determine the pressure of the gas at state C.

process CA is isothermal so C is at same temperature as A

$p_C V_C = p_A V_A$

$p_C = \frac{p_A V_A}{V_C} = \frac{(0.5\times10^5)(5.0\times10^{-3})}{1.25\times10^{-3}}$

$= 200\ 000$ Pa

pressure = ... Pa [2]

Comments:

Mainly well done. Very clear indication of those who understand and those who did not understand. Poor presentation of answers was observed in quite a number of response given.

(iii) With reference to the processes in **(b)(ii)**, complete the *p*-*V* diagram in Fig. 5.2. Label state C. [2]

Comments:

Very poorly done. A number of candidates did not take note of important points that the graph should cut when a graph with grids are given to them resulted in the lost of marks.

(iv) Explain why the change in internal energy of the gas from state A to state B is equal to the area under the *p*−*V* graph as shown in Fig. 5.2.

Area under the *p*-*V* graph gives the work done on the gas, W. As the gas goes from state A to state be in a short time, there is insufficient time for heat exchange to take place. Using 1st Law of thermodynamics, ΔU = Q + W. As Q = 0, hence ΔU = W

[3]

Examiner's Comments:

Very good distinguisher. Candidates that did well in this question layered their response clearly describing and explaining the process behind to earn full credit. Majority of the response did not earn full credit due to the lack of description of the lack of time that resulted in the process to be an adiabatic process.

(v) Without further calculations, sketch, on Fig. 5.3, the variation of pressure *p* with temperature *T* as the gas undergoes energy changes from state B to C to A. Label the values of pressure of gas at states A, B and C.

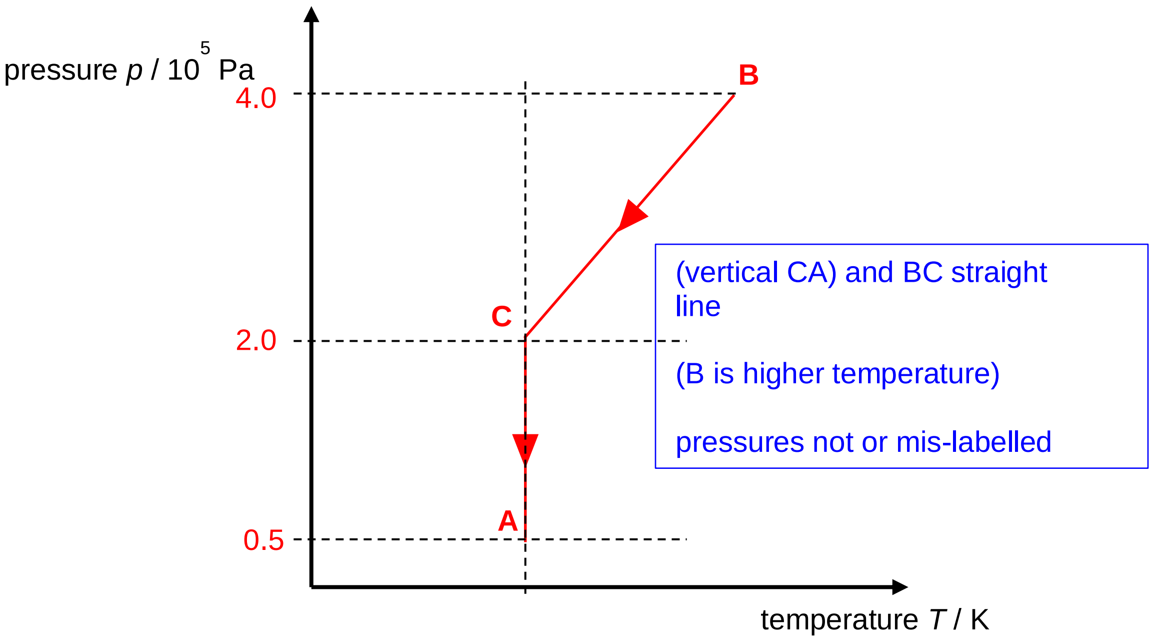


Fig. 5.3

[2]

Examiner's Comments:

Very poorly done. A huge variety of answers are obtained for this question. A number of responses failed to earn full credit as the pressure values are not being labelled as instructed by the question.

[Total: 12]

6 Static friction can be defined as the frictional force which exist between a stationary object and the surface it is in contact. The magnitude of static friction that an object experiences can vary over a range of values. It can be affected by factors such as the mass of the object, the magnitude of the external force that is exerted on the object and the texture of the surface that it is in contact with. The maximum static friction can be defined as the magnitude of the force the surface exerts on the stationary object just before the object starts to move.

When an object is placed on a circular disc and the disc starts to spin about its centre, the static friction provides the centripetal force to keep the mass on the same location on the disc. The mass can be observed to start slipping when the angular velocity of the disc exceeds a certain value, ω_{min}.

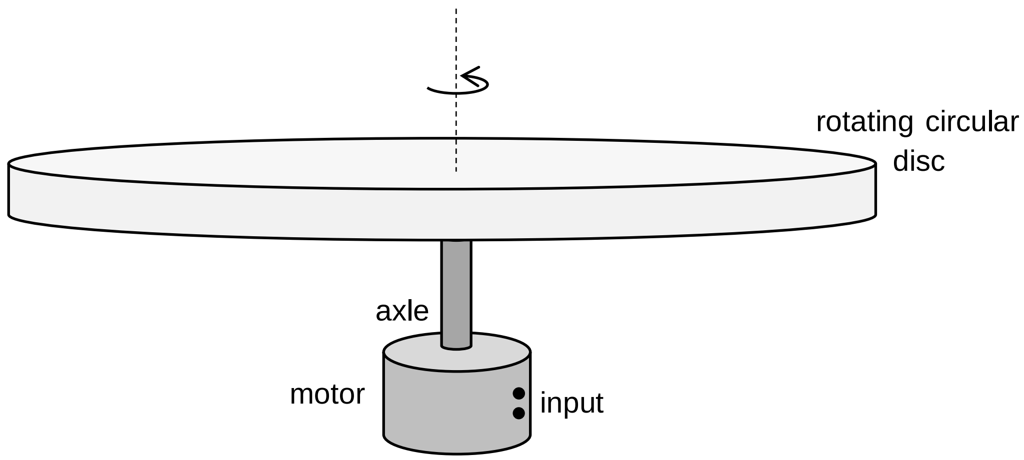
The relationship between the minimum angular velocity of the disc, ω_{min}, and the mass of the object, m, may be written in the form

$$\omega_{\text{min}} = k\, m^n$$

where k and n are constants.

Design an experiment to investigate the relationship between the minimum angular velocity ω_{min} and the mass of the object m and determine the value of k.

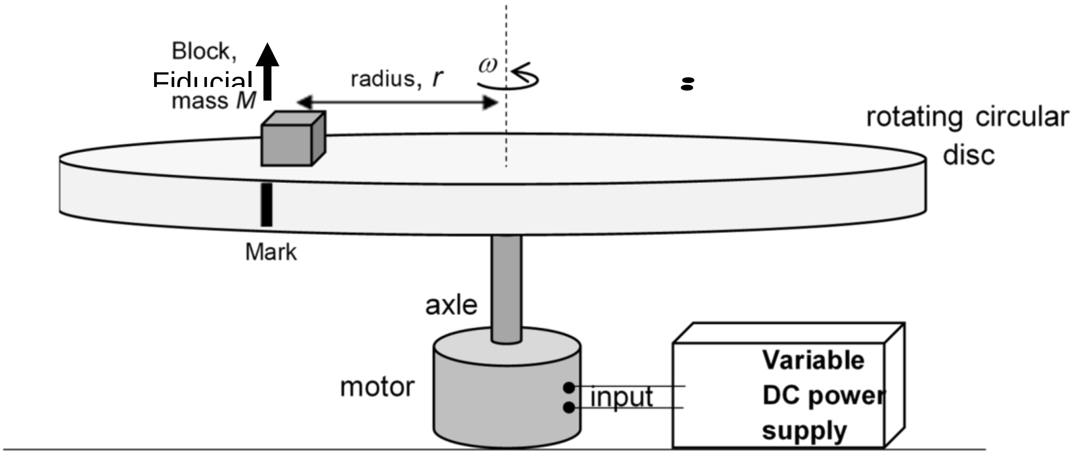
You are provided with a motor which has an axle that is attached to the centre of a circular disc. The motor has a variable power supply to vary angular velocity. You may also use any of the other equipment usually found in a physics laboratory.



You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how the minimum angular velocity is measured
(d) the control of variables
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Diagram



Procedure

1) Set up apparatus as shown above.

2) Use an electronic balance to measure the mass, M of the block.

3) Use a ruler to measure the distance, r of the block from the axle of the circular disc.

4) The motor is turned on and power varied until the block is observe to just about to slip.

5) By looking at the mark, count the number of cycles, N the circular disc make in a time t measured with a stopwatch.

6) The angular velocity ω is obtain by = $2\pi N/t$.

7) Steps 2) – 6) were repeated to obtain six more values by adding standard masses, m_s on top of the block.

8) The total mass placed on circular disc is $M_T = M + p\,m_s$. Where p is the the no. of standard mass.

9) A table of M_T /kg and its corresponding ω / rad s^{-1} was obtained.

10) Plot a graph of lg ω vs lg M_T.

11) A straight line validate the relationship. Determine the vertical intercept.

12) Vertical intercept = lg k. The value of k = $10^{\text{vertical intercept}}$

Additional details

- Preliminary readings eg varying the speed of circular disc were obtained to determine the onset of slippage. Small increments of speed is necessary.
- Multiple values of ω were obtained for the same M_T. Value(s) that were significantly different from the rest was discarded and the average is determined.
- The mark was positioned near the block to allow ease of observation (of slippage) and counting of the no of revolutions.
- The position of the block was outline with a pen for better determination of slippage.

Control of variables

The block should be placed at a fixed distance r from the axle.

The texture of block/mass in contact with disc is the same.

Accuracy/safety

Appropriate measures eg covered foot wear/screen to prevent harm from falling objects.

Transparent screen to protect from projectile.

Mark Scheme

Diagram (D)		
- must include DC circuit to power the motor - r must be labelled on the disc - Penalty if mass is placed at center.	1	Max 1
Basic Procedure (B)		
Vary the angular velocity of the disc until the mass/block **<u>just slip off.</u>** Obtain the time and number of revolution at this condition. Determine the angular velocity. Penalty if mass is secured such that it is not allowed to slip. Penalty if shape of mass (eg ball) allows tendency to slip.	1	Max 2
Vary the weight of the mass for at least six sets.	1	
Measurements (M)		
Count the number of revolutions made and measure the time using a stopwatch.	1	Max 2

Weigh the mass of the weights using a weighing scale	1	
Controlled variable (C)		
Distance *r* from the axle. Expressly mentioned. Penalty if mass is placed at center.	1	Max 2
Same base texture of mass/block to ensure constant coefficient of static friction	1	
Analysis (A)		
$\omega = kM_T{}^n$ $\lg\omega = n\lg(M_T) + \lg k$ where n is the gradient and $\lg k$ is the vertical intercept Plot a graph of lg ω vs lg M_T.	1	Max 2
lg *k* is the vertical intercept. The value of *k* = $10^{\text{vertical intercept}}$	1	
Additional Details (AD)		
Ensure that the distance is from the centre of axle to centre of the block/mass to ensure a more accurate reading of *r*	1	Max 3 out of which max 1 for safety
Mention way to improve accuracy in recording the timing of time, eg via the use of a light gate with datalogger, etc	1	
Ensure the timing for the revolutions is long enough to minimize the random error when taking the timing.	1	
Ensure the block/standard masses are placed on top of each other such that the line joining cg is a vertical line perpendicular to the plane of circular disc.	1	
Means to observe onset of slippage eg outline block. eg outline shape of object on circular disc.	1	
Use of fiducial marker to observe number of revolutions.	1	
Preliminary experiment to determine appropriate distance from axle, angular velocity and mass.	**1**	
Use spirit level to ensure that the circular disc is level.	**1**	
Safety (S)		

Wear safety footwear to prevent mass from hitting foot.	1	
Place shielding around the setup to prevent the mass to hitting people after slipping from the disc	1	

Examiner's Comments:

Use of computer to vary speed of circular disc is vague and does not display thinking.

Many students mentioned relationship but didn't continue to determine *k*.

Use of goggles is limited to eye protection and does not adequately protect the user.

Determination of ω_{min} at onset of slippage is not explicitly mentioned; usually a cursory mention of determining ω_{min}.

Marks are not awarded for dubious method (eg non-slipping condition) to determine ω_{min}.

Incorrect usage of power supply – it does not display angular velocity/ power/ speed/frequency.

Marks not awarded for mass placed at center of rotating dics. The mass with not slip because the rotation axis pass through its center of mass.

Section B

Answer **one** question from this Section in the spaces provided.

7 **(a)** **(i)** Define *gravitational potential* at a point.

Gravitational potential at a point is the work done per unit mass by an external force in bringing a small (test) mass from infinity to that point.[B1] Do not accept: work done on a unit mass.

[1]

(ii) The gravitational potential ϕ at a distance r from an isolated point mass m is given by the expression

$$\phi = -\frac{Gm}{r}$$

where G is the gravitational constant.

Explain why gravitational potential is negative.

Since gravitational potential at infinity is zero [B1], and because gravitational force is attractive in nature [B1], the direction of the external force is opposite to the direction of displacement of the mass [B1]. Hence by definition, the gravitational potential is negative.

[3]

(b) The Earth and Moon can both be assumed to be isolated uniform spheres of masses 6.0×10^{24} kg and 7.3×10^{22} kg respectively. The radius of Earth is 6.4×10^{6} m and the radius of the Moon is 1.7×10^{6} m.

The variation with displacement x of the gravitational potential ϕ between the surface of the Moon and the surface of Earth along the line joining their centres is shown in Fig. 7.1. Q is the point at which the gravitational potential is maximum.

(i) The gravitational potential on the surface of the moon at point P is -3.9×10^{6} J kg^{-1}. Show that the distance D between the centres of the Earth and Moon is 3.9×10^{8} m.

$$\phi_{\text{m,surface}} = -\frac{GM_{\text{m}}}{r_{\text{m}}} + \left(-\frac{GM_{\text{E}}}{x - r_m}\right)$$

$$= -G\left(\frac{M_{\text{m}}}{r_{\text{m}}} + \frac{M_{\text{E}}}{x - r_m}\right)$$

$$-3.9 \times 10^{6} = -(6.67 \times 10^{-11})\left(\frac{7.3 \times 10^{22}}{1.7 \times 10^{6}} + \frac{6.0 \times 10^{24}}{x - 1.7 \times 10^{6}}\right)$$

$$x = 3.88959 \times 10^{8} = 3.9 \times 10^{8} \text{ m}$$

[1] proper substitution for ϕ due to Moon

[1] proper substitution for ϕ due to Earth

[2]

Examiner's Comments:

Some students mistook D to be the distance between the surfaces. D is distance between the centres of the bodies.

Presentation of working is very poor. Equation with formulas should be shown first, and then substitution clearly shown. Several students simply wrote down an equation with only D as the unknown, or used other distances with symbols that were not defined in the beginning.

Since this is a showing question, students could have worked backwards to obtain the answer, which makes proper presentation even more crucial. Students should take note of this even if they were not penalised this time round.

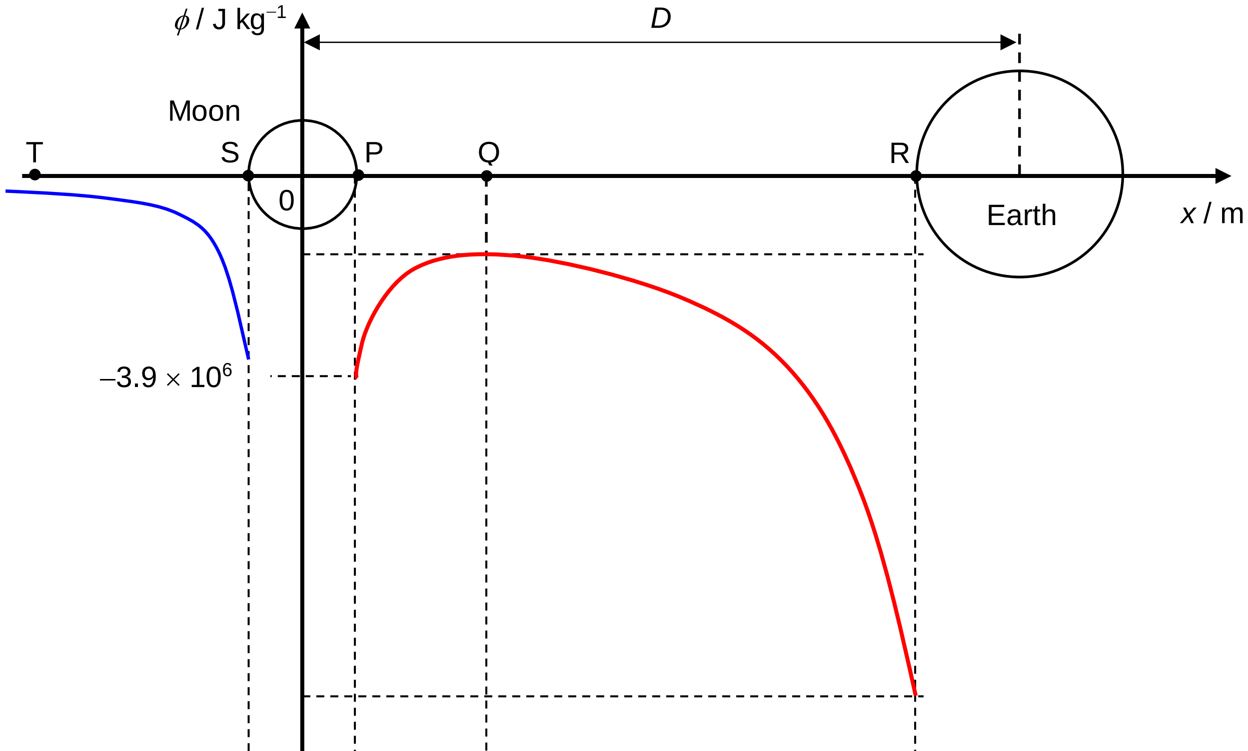


Fig. 7.1
(not to scale)

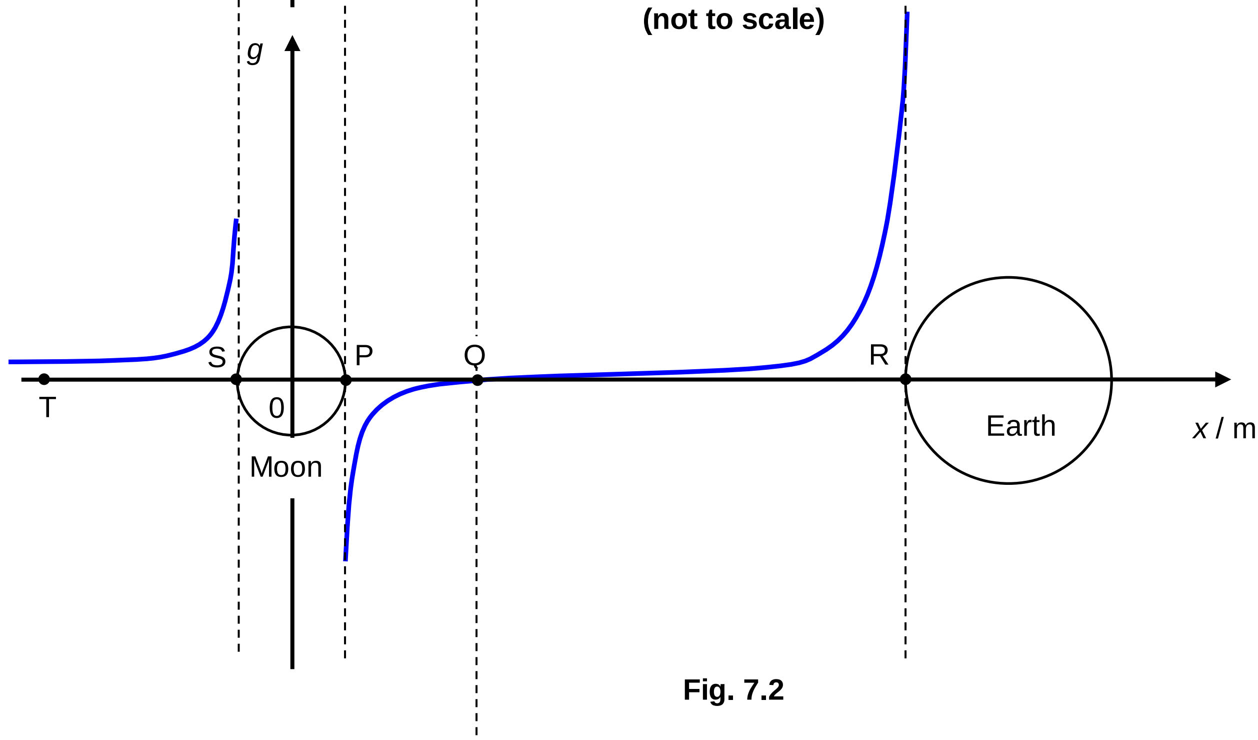


Fig. 7.2

(ii) Using Fig. 7.1, state and explain the motion, if any, of an object when it is released from rest at point Q.

At position of maximum potential the gradient is zero. As $g = -\dfrac{d\phi}{dr}$, the gravitational field strength (or gravitational force) due to Earth and Moon acting on the object is zero.

Hence objection will remain at rest / stationary.

Examiner's Comments:

Students should take note of the following:

Graph needs to be used i.e. features of a graph, for this case the gradient.

Gradient of the potential-x graph is not rate of change (by default, rate of change means with respect to time)

Gradient of graph is gravitational field strength, not gravitational force.

Potential due to moon and earth are not equal at Q.

Q is a point, not an object.

Students use gravitational field strength and force interchangeably, which is incorrect. Note that gravitational field strength is a quantity associated with the field at point Q, whereas gravitational force is exerted on an object at point Q. Similarly for gravitational potential and potential energy.

(iii) Show that the distance between Q and the centre of the Earth is 3.5×10^8 m.

Let d be the distance from Earth where potential is maximum.
At position of maximum potential, g = 0

$$\frac{GM_{Earth}}{d^2} - \frac{GM_{moon}}{((3.9\times10^8)-d)^2} = 0$$

$$\frac{M_{Earth}}{d^2} = \frac{M_{Moon}}{((3.9\times10^8)-d)^2}$$

$$\sqrt{\frac{M_{Moon}}{M_{Earth}}} = \frac{((3.9\times10^8)-d)}{d}$$

$$\sqrt{\frac{7.3\times10^{22}}{6.0\times10^{24}}} = \frac{((3.9\times10^8)-d)}{d}$$

$$= \frac{3.9\times10^8}{d} - 1$$

$$d = 3.51256\times10^8 = 3.5\times10^8 \text{ m}$$

Must show full substitution.

[2]

Examiner's Comments:

For point Q, many students somehow equated the potential due to the Earth = potential due to Moon.

Please define your variables that you use. Many used R_e and R_m.

Students are reminded to look at earlier parts to get a hint as to what is going on, which is that g = 0 at point Q. All substitutions must be shown as getting the correct formula does not indicate that you know exactly the values to use. Students who attempted to solve using the quadratic equation method, you need to show why you rejected the other solution.

When the question requires you to use a value that was "shown" in the earlier part, i.e. (b)(i),

(iv) A scientific instrument of mass 100 kg was projected at a velocity *v* from point R on the surface of the Earth towards point P on the surface of the Moon, along the line joining their centres. The instrument reached the surface of the Moon with kinetic energy 1.5×10^8 J.

1. State the energy changes that take place from the instant the instrument is projected from R to the instant just before it hits P.

By the principle of conservation of energy, the <u>decrease in the kinetic energy</u> of the module goes into <u>the increase in potential energy of the instrument till point Q.</u>
Beyond Q, the <u>decrease in potential energy leads to the increase of kinetic energy</u>.
[B1] Correct transition point
[B1] Correct energy conversions for both segments. All energy gains and losses must be described to be awarded the mark.
using "PE", "KE" in the answers (minus 1 mark)
[2]

Examiner's Comments:

The question specifically asked for the object going from R to P. In other words, it went from R to Q to P. For energy changes, you should always refer to increase/decrease in energies. Most if not all students just used "converted".

Note that for this case, the KE at Q is non-zero. The question does not mention anything about it, so you cannot assume. For structured question, please answer in full sentences.

For such questions, we do not consider friction, neither do we talk about atmosphere, which does not extend very far from the Earth surface (and definitely negligible when considering the distances between the Earth and the Moon.

2. The gravitational potential at R is -6.3×10^7 J kg^{-1}.

Calculate the velocity *v* at which the instrument is projected.

Considering KE and PE of instrument on both surface of Earth and Moon, and using conservation of energy,
(idea should be reflected in statement or clearly in working, but not marked for)

$$KE_{Earth} + PE_{Earth} = KE_{Moon} + PE_{Moon}$$

$$KE_{Earth} - KE_{Moon} = PE_{Moon} - PE_{Earth}$$

$$\frac{1}{2}mv_{Earth}^2 - 1.5\times10^8 = m(\phi_{Moon} - \phi_{Earth}) \quad \text{[C1]}$$

$$\frac{1}{2}(100)v_{Earth}^2 = 1.5\times10^8 + (100)(-3.9\times10^6 - (-6.3\times10^7)) \quad \text{[M1]}$$

$$v_{Earth} = 1.10\times10^4 \text{ m s}^{-1} \quad \text{[A1]}$$

(those with incorrect solutions):
[C1] Calculation of change in GPE ($m\Delta\phi$) - alternatively
[M1] Final substitution

v = ... m s^{-1} [3]

Examiner's Comments:

This was so badly done, considering that a similar type question was set for the lecture test 2. The potentials for both surfaces of the Earth and Moon was already given, and from there using $m\phi$ you can obtain the potential energies. Where ϕ is the potential due to both Earth and Moon. Presentation wise, you cannot simply use GMm/R, and conveniently replace it by ϕ.

Using the normal method of conservation of energy, you can obtain the answer. Nowhere is it mentioned that the object is a satellite (hence NO circular motion!), neither is the instrument projected to infinity!

(c) (i) On Fig. 7.1, sketch, without further calculations, a graph to show the variation of gravitational potential ϕ with displacement x along the line ST, paying attention to the potential at point S. [1]

(ii) On Fig. 7.2, sketch, without further calculations, a graph to show the variation of the resultant gravitational field strength g with displacement x along the line TR

1. between PR, [3]

2. between ST. [1]

[Total: 20]

(i) [B1] Correct shape and magnitude on surface of moon must be smaller than -3.9×10^6 J kg^{-1}. (i.e. less negative than -3.9×10^6 J kg^{-1})

(ii) 1. [B1] Correct shape
[B1] |g| at surface of Moon smaller than that of |g| at surface of Earth
[B1] correctly intersection point at Q, with point of inflection properly drawn
2. [B1] Correct shape on the positive y axis.

(minus 1 if there is a gap. Allowed for e.c.f.)

Examiner's Comments:

(i) Many did not consider the magnitude of the potential at the point, when the question attempted to direct your attention to it.
(ii) 1. Many students had their graphs flipped around. Note that you need to take reference to the conventions as shown in the ϕ–r graph. g is a vector, hence the signs (+ or −) gives you the direction of the gravitational field. 2. Many sketched this curve on the bottom quadrant instead.

8 Fig. 8.1 shows a setup consisting of a light inextensible string attached to a spring at one end, and is wound around a frictionless moveable pulley. The top ends of the string and spring are fixed to the ceiling. The pulley is supporting a block which is resting in equilibrium.

The spring has spring constant k and the block has mass M. The mass of the pulley and spring are negligible.

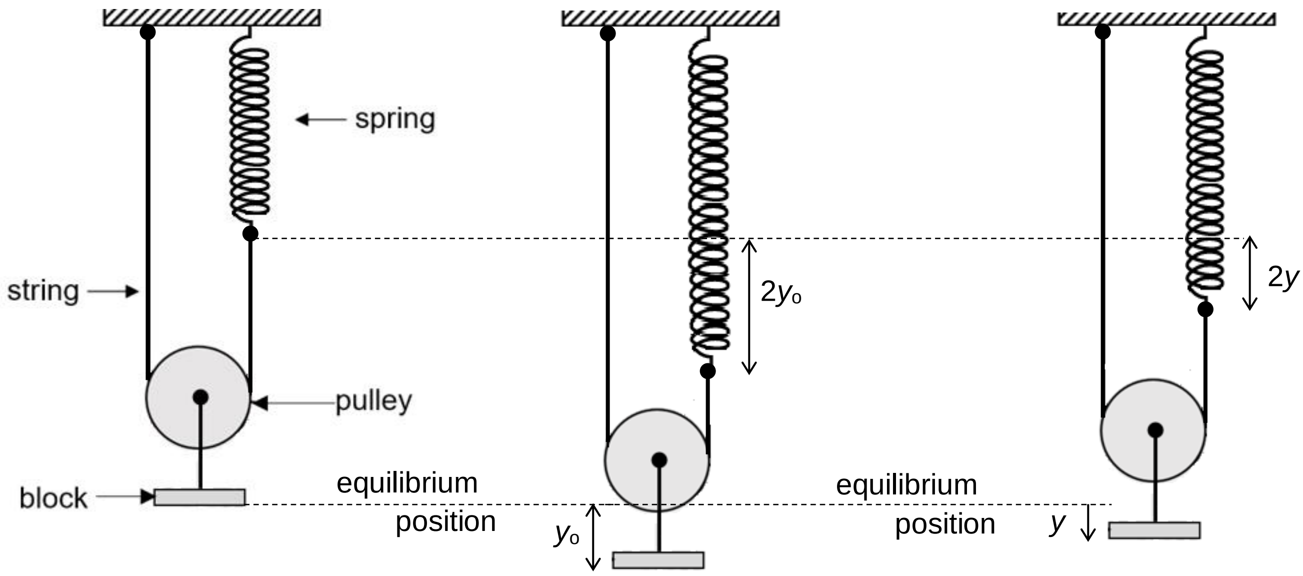


Fig. 8.1 **Fig. 8.2** **Fig. 8.3**

As shown in Fig. 8.2, the block is displaced vertically downwards from the equilibrium position by a distance y_o, resulting in a further extension of the spring by $2y_o$. It is then released from rest and subsequently oscillates with simple harmonic motion.

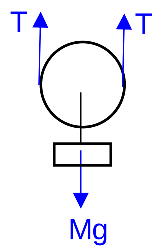
At an instant, the displacement from the equilibrium position is y as shown in Fig. 8.3.

(a) (i) Derive an expression for the extension of the spring when the block is in equilibrium, in terms of k, M and g.

At equilibrium, Mg = 2T

= 2(ke)

e = Mg/(2k) [1]



[1]

Examiner's Comments:

Poorly done. Many incorrectly wrote down Mg/k. They drew the FBD wrongly or did not draw the FBD at all, thus not realising that there are actually 2 tensional forces upwards, not just one. Some did not realise that the 2 tensional forces are equal (as they are acting along the same taut string wound around a frictionless pulley).

There are others who got the final correct expression but were not awarded the mark because of wrong method or incorrectly presented. For instance, equation such as Mg = k(2y) is not accepted as it implies the extension of the spring at equilibrium is '2y', yet the expression for 'y' is derived instead, and will incidentally give the correct expression for extension of spring at equlibrium.

(ii) By considering the net force on the block and using the expression in **(a)(i)**, show that the acceleration a of the block at displacement y from its equilibrium position is given by

$$a = -\frac{4k}{M}y.$$

When displaced by y downwards,

Taking downwards to be positive,

$\sum F = Mg - 2T$ -------- (1) [1]

When block is displaced by y downwards, the spring is further extended by $2y$ from Fig. 8.3, (since the string is inextensible)

Hence $T = k(e+2y)$ ------- (*) [1]

Sub (*) into (1),

$Ma = Mg - 2k(e+2y)$

$= Mg - 2ke - 4ky$

$= -4ky$ using (i)

$a = -(4k/M)y$ (shown)

[2]

Examiner's Comments:

Poorly done. Many students tried to bluff their way through this question, using vague expressions in their presentation.

Students should take hints from the question, and apply the usual method of using two N2L equations, one at equilibrium and one at a general displacement of the block, to derive the expression.

(b) For the oscillations to remain simple harmonic when the block reaches the top position, the distance y_o by which it is initially lowered cannot exceed half of the extension of the spring in **(a)(i)**. Explain why.

The distance y_o is the amplitude of the oscillation [1]

From equilibrium to top position, the decrease in extension of the spring is twice the displacement of the block OR From equilibrium to top position, block is displaced by y_o and extension of spring is reduced by $2y_o$ [1]

[3]

Since string cannot become slack/tension cannot reduce to zero before block reaches the top position [1], in order to just reduce the spring's extension to zero at the top position, extension at equilibrium position must be twice of y_o i.e. maximum y_o should be half the extension at equilibrium position.

Examiner's Comments:

Poorly done. Many tried to use the idea of spring exceeding the limit of proportionality. However there is no information from the question that suggests this has occurred.

Some incorrectly explained that the spring will be compressed at the top position and hence shm cannot continue. This statement is wrong because firstly, the mass is directly attached to the string, not the spring, so the spring cannot be compressed. Secondly, even if the mass were attached directly to the spring, and the spring becomes compressed, shm can still proceed.

(c) The spring constant k is 50 N m^{-1}, the mass M of the block is 500 g and the distance y_o is 1.0 cm.

(i) Determine

1. the period of oscillation of the block,

$$\omega = \sqrt{\frac{4k}{M}}$$

$$\frac{2\pi}{t} = \sqrt{\frac{4k}{M}} \qquad [1]$$

$$t = 2\pi\sqrt{\frac{M}{4k}} = 2\pi\sqrt{\frac{0.500}{4(50)}}$$

$$= 0.314$$

$$= 0.31\text{s} \qquad [1]$$

period = ... s [2]

Examiner's Comments:

Many students can obtain the answer. However they chose a longer method which shows weak conceptual understanding.These students solved for maximum acceleration first using the given equation in (ii) before substituting into the defining equation for shm to find ω.

Better students identified ω in terms of the constants directly i.e. ω = √(4k/M) by comparing the same two equations, without the need to use the amplitude value or solve for max acceleration.

2. the time taken for the block to reach a displacement of 0.50 cm above its equilibrium position from the moment of release,

Taking downwards as positive,

$y = y_o \cos\omega t, \quad where \ \ \omega = \sqrt{\frac{4k}{M}}$

$y = 1.0\cos\left(\sqrt{\frac{4\times 50}{0.500}}\right)t$

$-0.50 = 1.0\cos\left(\sqrt{\frac{4\times 50}{0.500}}\right)t$ [1]

$t = 0.10$ s [1]

time = ... s [2]

Examiner's Comments:

Poorly done. Many students cannot get the correct equation, because they either ignored the initial amplitude position of the mass <u>below</u> the equilibrium position, or the displaced position of the mass <u>above</u> its equilibrium position. So many had the negative sign missing.

Some were unsure of how to solve for an inverse cosine of a negative number.

Students should sketch the diagram of the motion so they can double check if their final answer for t makes sense or not (t should be between T/4 and T/2)

3. the maximum kinetic energy of the block.

Max KE $= \frac{1}{2}M\omega^2 y_o^{\,2}$ [1]

$= \frac{1}{2}M\left(\frac{4k}{M}\right)y_o^{\,2}$ or $= \frac{1}{2}\mathrm{M}(\frac{2\pi}{T})^2 y_o^{\,2}$

$= 2ky_o^{\,2}$ $\qquad = 2(0.500)(\frac{2\pi}{0.314})^2(0.010^2)$.

$= 2\times 50\times(0.010^2)$ $\qquad = 0.010$ J [1]

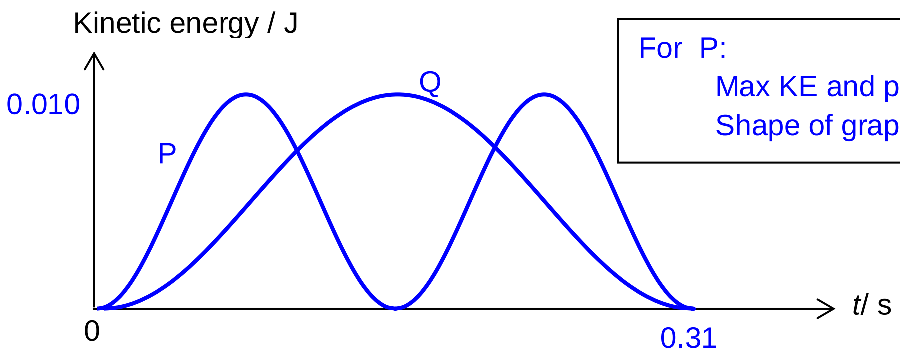
$= 0.010$ J [1]

Examiner's Comments:

This was fairly well done for those who attempted. Common errors included forgetting to square either ω or amplitude, and forgetting to convert units.

maximum kinetic energy = ... J [2]

(ii) 1. Using the values obtained in **(c)(i)**, sketch a labelled graph, on Fig. 8.4, to show the variation with time t of kinetic energy of the block from the moment of release for one period. Label this graph P. [2]



For P:
Max KE and period values
Shape of graph

Fig. 8.4

2. The block is replaced with another of mass 4M and the experiment is repeated. Sketch, on Fig. 8.4, the graph obtained for this second block. Label this graph Q. [3]

For Q: period $t = 2\pi\sqrt{\dfrac{M}{4k}}$, so $t \propto \sqrt{M}$ → Hence new t is doubled [1]

Max KE = ½ M (4k/M) y_o^2 = 2k y_o^2, ∴Max KE is independent of mass & remains unchanged [1]

Shape of graph [1]

Examiner's Comments:

1. Badly done. Many forgot that for energy graphs, the frequency is doubled. Students should attempted to imagine the motion of the object when sketching such curves. Many somehow took time t = 0 to be at max KE, when the question said otherwise. The question specifically stated to sketch the graph for <u>one</u> period.
   Students must take note of the curvatures of their graphs at the start and end of their sketches.
2. Most if not all were clueless with regard to this part. No calculations or working were to be seen on the script. Always look back at the equations given to obtain hints. Probably less than 15 in the whole cohort got this part correct. Well done if you did!

(d) A small motor is now introduced to the same setup in **(c)** as shown in Fig. 8.5. The motor is attached to the bottom of the block and switched on to drive the oscillations.

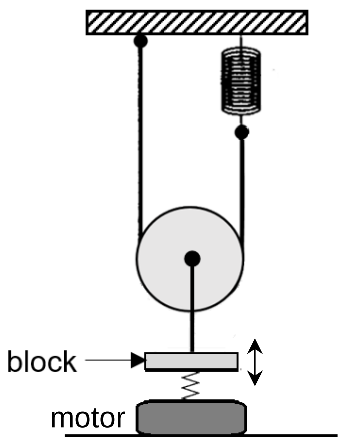


Fig. 8.5

The frequency of the motor is slowly increased until maximum amplitude is achieved.

(i) Determine the frequency at which this occurs.

Resonance frequency = natural frequency

$$\omega = 2\pi f \quad \therefore f = \frac{1}{2\pi}\sqrt{\frac{4k}{M}} \qquad [1]$$

$$= \frac{1}{2\pi}\sqrt{\frac{4(50)}{0.500}} = 3.2\,\text{Hz} \qquad [1]$$

frequency = ... Hz [2]

Examiner's Comments:

This was well done. Most used f = 1/T which was also accepted.

(ii) Suggest a reasonable way to reduce the amplitude achieved at the frequency obtained in **(d)(i)**.

Ways to change natural frequency of system:
Change spring to one of a different spring constant.
Change block to another one with a different mass. [1]

Ways to increase damping:
Change block to another with greater surface area
Immerse block in fluid
etc

[Total: 20]

End of Paper

Examiner's Comments:

Most managed to get credit for this. If pure damping is what you want to achieve, one should use a 'light' card to increase the surface area, so as to not change the mass of the system.

If one wants to change the natural frequency, then just increase mass.

If it is mentioned that damping is to be achieved, but with increasing mass – the mismatch of concepts warrants no credit. This would be a classic case of "saying less is more" especially when writing too much becomes a contradiction.

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**

CLASS		TUTOR'S NAME	

PHYSICS

9749/01

Paper 1 Multiple Choice

30 September 2019

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class, Centre number and index number in the spaces at the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **18** printed pages.

1 Express the gravitational potential, ϕ, in S.I. base units.

A kg m^2 s^{-2} **B** kg m^2 s^{-3} **C** kg m^3 s^{-2} **D** m^2 s^{-2}

Ans: D

$$[\phi] = \left[-\frac{GM}{r}\right]$$
$$= \frac{N\,m^2\,kg^{-2}\,kg}{m}$$
$$= \frac{kg\,m\,s^{-2}\,m^2\,kg^{-2}\,kg}{m}$$
$$= m^2\,s^{-2}$$

2 The acceleration due to gravity near the surface of Earth, *g*, was determined by measuring the time taken *t* for a ball to travel a distance *h* vertically when released from rest. In one experiment, the following measurements for *t* and *h* were obtained:

h = (41.30 ± 0.01) m
t = (2.9 ± 0.2) s

Which of the following would result in the greatest improvement in precision of the value of *g*?

A Measuring the height, *h*, to a precision of 0.1 cm.

B Measuring the time, *t*, to a precision of 0.01 s

C Taking the average of multiple measurements of *h*.

D Taking the average of multiple measurements of *t*.

Ans: B

Using $s = ut + \frac{1}{2}at^2$,

$$h = 0 + \frac{1}{2}gt^2$$
$$g = \frac{2h}{t^2}$$

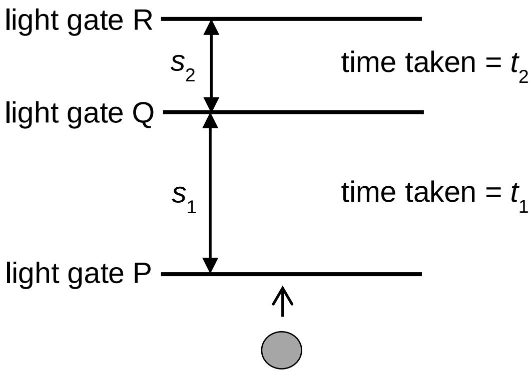
3 A stopwatch is used to measure the time a sprinter takes to run a distance of 100 m. The recorded time for the run is 10.0 s. Assuming that the uncertainty due to human reaction time in pressing the stopwatch each time is 0.2 s, what is the lowest possible average speed of the runner?

A 9.6 m s^{-1} **B** 9.8 m s^{-1} **C** 10.0 m s^{-1} **D** 10.2 m s^{-1}

Ans: A

Since start timing there is an uncertainty of 0.2 s, and stop timing there is an uncertainty of 0.2 s, total uncertainty in timing is 0.2 + 0.2 = 0.4 s. Thus, 100/10.4 = 9.6 m s^{-1}.

4 An object is thrown vertically upwards and passes through three light gates P, Q and R as shown.



The object has a speed u when it passes P. It takes a time of t_1 to move up a distance s_1 between P and Q, and then takes a time t_2 to travel a distance s_2 between Q and R. The object reaches its highest point exactly at R.

If the acceleration due to gravity is g, what is the distance ($s_1 + s_2$) in terms of g, t_1 and t_2?

A $g(t_1+t_2)$ **B** $g(t_1+t_2)^2$ **C** $\dfrac{g(t_1+t_2)^2}{2}$ **D** $\dfrac{(t_1+t_2)^2}{2g}$

Ans: C

Using $v^2 = u^2 + 2as$,

$$0 = u^2 - 2g(s_1+s_2) --- (1)$$

Using $\mathrm{v} = u + at$,

$$0 = u - g(t_1+t_2)$$

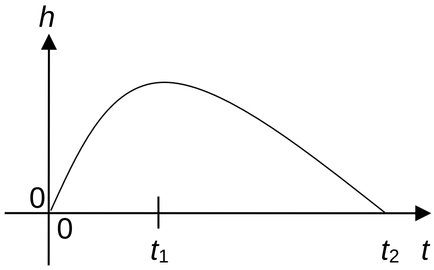
$$u = g(t_1+t_2) --- (2)$$

Sub (2) into (1),

$$0 = g^2(t_1+t_2)^2 - 2g(s_1+s_2)$$

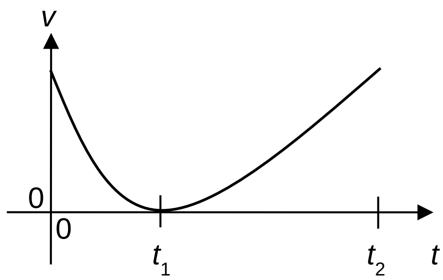
$$(s_1+s_2) = \frac{g(t_1+t_2)^2}{2}$$

5 A ball is thrown vertically upwards and returns along the same path. The graph shows how its height h above the ground varies with time t.

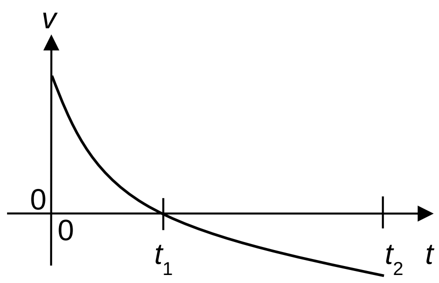


Which graph shows the variation with time t of the velocity v of the ball?

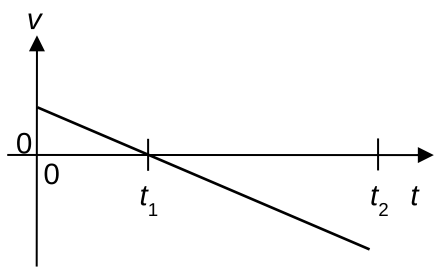
A



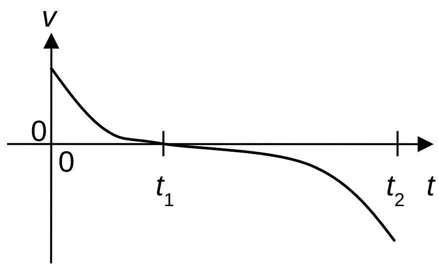
B



C

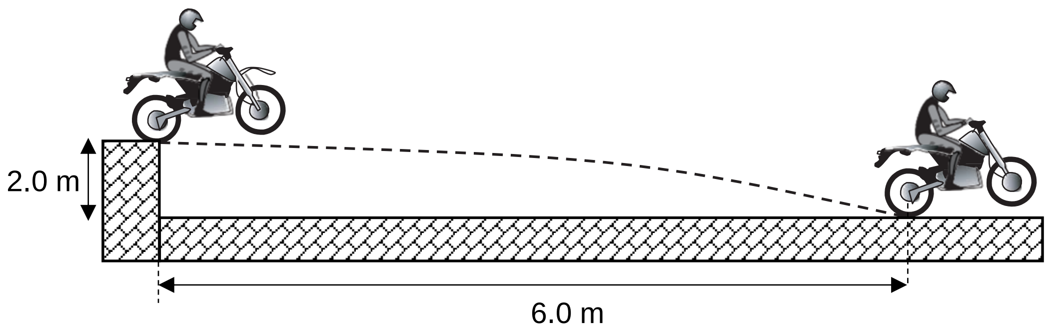


D



Ans: B
Gradient of displacement time graph represents velocity.

6 A stunt-rider takes off horizontally from a point 2.0 m above the ground, landing 6.0 m away as shown. Air resistance is negligible.



What was the speed of the stunt-rider at take-off?

A $6.3\ \text{m s}^{-1}$ **B** $9.4\ \text{m s}^{-1}$ **C** $9.9\ \text{m s}^{-1}$ **D** $15\ \text{m s}^{-1}$

Ans: B

Using $s_y = u_y t + \frac{1}{2}gt^2$

$$2 = 0 + \frac{1}{2}gt^2$$

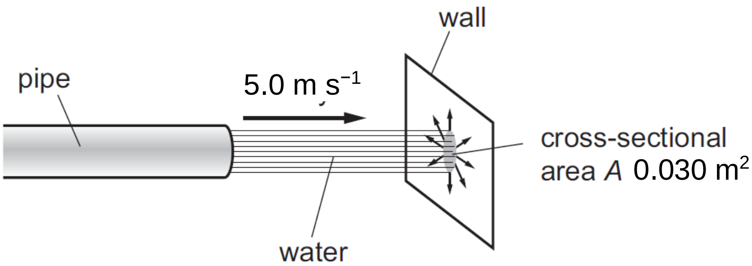
$$t = \sqrt{\frac{4}{g}}$$

Using $s_x = u_x t + \frac{1}{2}a_x t^2$

$$6 = u_x\left(\sqrt{\frac{4}{g}}\right) + 0$$

$$u_x = 9.4\,m\,s^{-1}$$

7 Water flows out of a pipe with a speed of 5.0 m s^{-1} and hits a wall, forming a cross-sectional area of 0.030 m^2 before it falls vertically downwards. The density of water is 1030 kg m^{-3}.



An engineer adjusts the flow valve, causing the water to flow at speed v, and the force exerted on the wall by the water was halved.

What is the value of v?

A 1.3 m s^{-1} **B** 2.5 m s^{-1} **C** 3.5 m s^{-1} **D** 7.1 m s^{-1}

Ans: C

F on wall per unit time $= \rho A v^2$

Using ratio to solve,

$$\frac{F}{\left(\frac{F}{2}\right)} = \frac{\rho A v_1^2}{\rho A v_2^2}$$

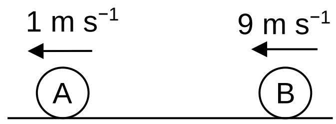
$$\frac{v_1^2}{v_2^2} = 2$$

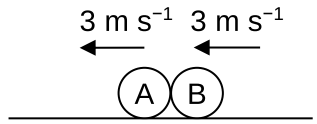
$$v_2 = \sqrt{\frac{5^2}{2}} = 3.5\,m\,s^{-1}$$

8 Two objects A and B of mass 1.0 kg and 3.0 kg respectively collide head-on elastically on a horizontal, frictionless surface as shown. The initial velocities of both objects before the collision are shown in the diagram below.

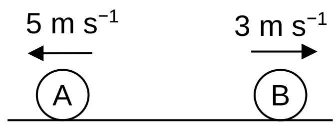
Which of the following diagrams showing the final velocities of both objects after the collision is correct?

A **B**

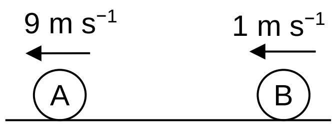




C



D



Ans: D

By COLM,

$m_A u_A + m_B u_B = m_A v_A + m_B v_B$

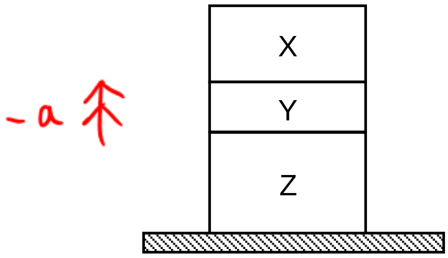
$(1)(3) + (3)(-5) = v_A + 3v_B$

$v_A + 3v_B = -12$

By inspection, $v_A = -3\,m\,s^{-1}, v_B = -3\,m\,s^{-1}$ OR $v_A = -9\,m\,s^{-1}, v_B = -1\,m\,s^{-1}$

Since it is elastic collision, they must move off separately. Hence D.

9 Three crates X, Y and Z of masses *3m, m* and *5m* respectively, are stacked on top of one another on the floor of a lift which is moving upwards but decelerating, and their common acceleration is *a*.



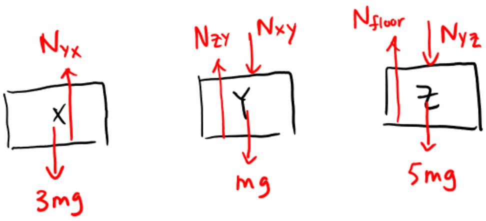
What is the magnitude of the force exerted by crate Y on crate Z during this acceleration?

A $4mg + 4ma$

B $4mg + 5ma$

C $4mg - 4ma$

D $4mg - 5ma$



Ans: C

Draw the free body diagram of X, Y and Z. Then apply N2L and N3L to the relevant masses to find the required force.

For X:

$N_{YX} - 3mg = -3ma$

$N_{YX} = 3mg - 3ma$

$|N_{YX}| = |N_{XY}|$

For Y:

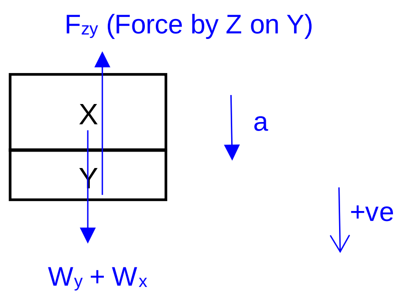
$N_{ZY} - N_{XY} - mg = -ma$

$N_{ZY} = mg - ma + N_{XY}$

$= mg - ma + (3mg - 3ma)$

$= 4mg - 4ma$

$|N_{YZ}| = |N_{ZY}|$



Method 2:
Consider FBD of X & Y:

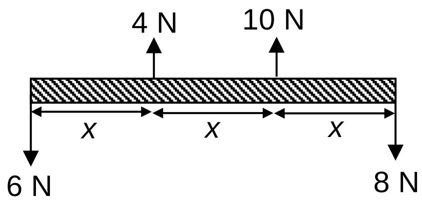
$W_x + W_y - F_{zy} = (4m)a$

$F_{zy} = (3m)g + mg - (4m)a$
$= 4mg - 4ma$

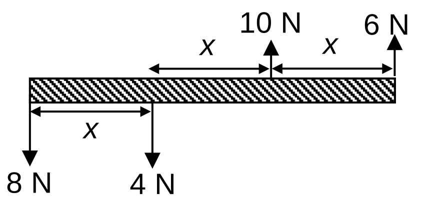
10 The force diagrams below show all the forces acting on a beam of length $3x$, which is at rest initially.

Which force system experiences only rotational motion of the beam, without any linear acceleration?

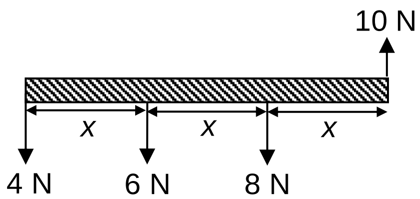
A



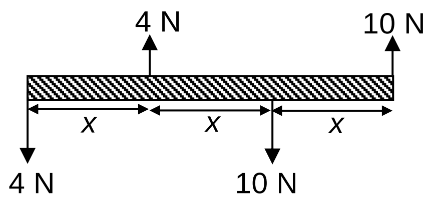
B



C

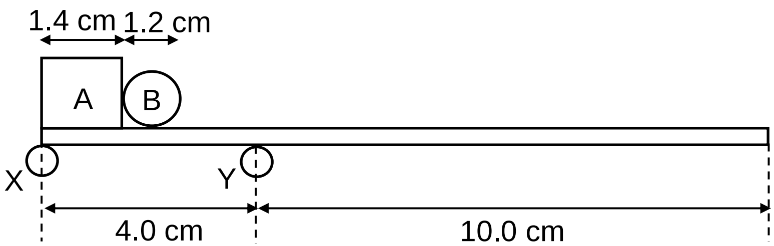


D



Ans: D
Since there is no linear acceleration, the net force must be zero. Thus, options B and C are ruled out.
Since there is rotational motion, the total moment must be non-zero. Suppose we take the end on the left as the pivot.
For A, the net clockwise moment = $8(3x) - 4(x) - 10(2x) = 0$ (no rotation)
For D, the net clockwise moment = $10(2x) - 4(x) - 10(3x) = -14x$ (rotation)

11 A beam of negligible mass is supported by two rods X and Y. A block A of mass 200 g and a ball B of mass 100 g rest on the beam as shown. Both A and B have uniform density.

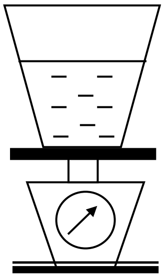


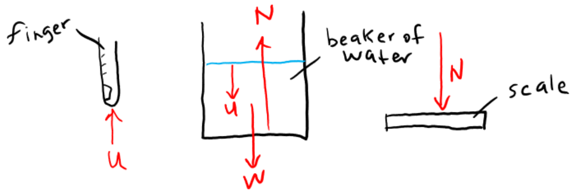
If ball B starts to roll to the right, what is the distance it has moved when the beam just loses contact with rod X?

A 6.6 cm **B** 8.0 cm **C** 8.6 cm **D** 9.4 cm

Ans: C
Loses contact with X → $R_x = 0$. The beam is still in equilibrium though, so taking Y as the pivot, B has to roll to the right of Y to produce CW moment, in order to maintain equilibrium, because A produces ACW moment.
Let the distance of B from Y be d.
Taking moments about Y,
$0.2g \times 3.3 = 0.1g \times d$
$d = 6.6$ cm (careful, this is not the answer!)
total distance moved by B = 6.6 + (4 – 1.4 – 1.2 + 0.6) = **8.6 cm**

12 A cup half-filled with water resting on a weighing scale registers a reading W. When a boy dips his finger into the water without touching the base, the reading of the weighing scale is W'.





Which of the following statements is correct?

A $W' = W$ because the water has not overflowed from the beaker.

B $W' < W$ because the water exerts an upthrust on the boy's finger.

C $W' > W$ because the water exerts an upthrust on the boy's finger and the boy's finger exerts a force on the water equal to the upthrust by the water on his finger.

D $W' > W$ because the weight of the boy's finger is added to that of the water.

Ans: C
When the finger is placed in the water, the finger experiences an upthrust by the water upwards and the water experiences a force by finger downwards. Drawing the FBD of the beaker of water, in the vertical direction, $N = W + U$, where N is the normal force the scale exerts on the beaker. Since $N = W'$, then $W + U = W'$, hence $W' > W$.

13 A 1.0 kg ball is released from a certain height. When it is 0.70 m above the floor, its potential energy is exactly equal to its kinetic energy. What is the speed of the ball just before it hits the floor?

A 3.7 m s^{-1} **B** 5.2 m s^{-1} **C** 14 m s^{-1} **D** 27 m s^{-1}

Ans: B
At h = 0.70 m above the ground, qn, says GPE = KE, meaning that $\frac{1}{2}mv_1^2 = (1)(9.81)(0.7)$.
Applying COE from position 1 (h = 0.7m) to position 2 (h = 0),
$\frac{1}{2}mv_1^2 + mgh = \frac{1}{2}mv_2^2$
$(1)(9.81)(0.7) + (1)(9.81)(0.7) = \frac{1}{2}(1)v_f^2$
$v_2 = 5.2$ m s^{-1}

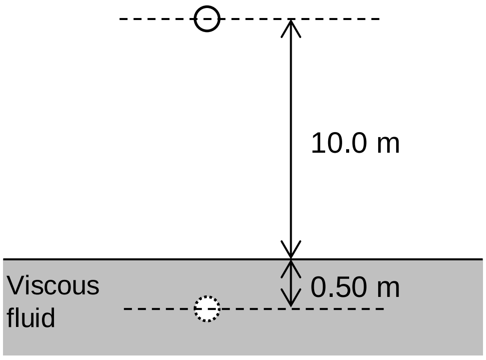
14 A car of mass m is accelerated horizontally from rest to a speed v by a constant force F. How much work is done on the car during this acceleration?

A $\frac{1}{2} Fv$ **B** Fv **C** mv **D** $\frac{1}{2} mv^2$

Ans: D

Work done by force F increases the kinetic energy of the car.
Hence Work done = $\frac{1}{2}$ mv^2 – 0
= $\frac{1}{2}$ mv^2

15 A small object is dropped from a height of 10.0 m above the surface of a viscous fluid as shown in the diagram below. The mass of the object is 1.0 kg and the viscous fluid offers a constant retarding force of 160 N.

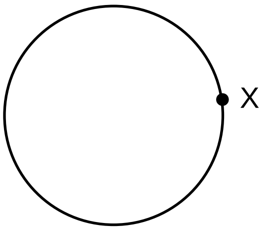


What is the speed of the object after it has moved 0.50 m into the viscous fluid?

A 6.0 m s^{-1} **B** 6.8 m s^{-1} **C** 13 m s^{-1} **D** 14 m s^{-1}

Ans: B
Apply COE from the initial position to its final position in the fluid,
$mg(10.5) = 160(0.5) + \frac{1}{2} mv^2$
$v = 6.8$ m s^{-1}

16 An object moves in a circular path of radius 0.80 m at an angular speed of $\frac{2\pi}{3}$ rad s^{-1}.



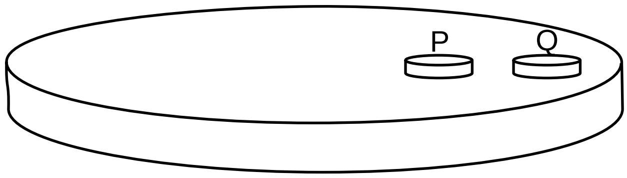
What is its distance travelled from a point X, 6.0 s after passing X?

A 0.80π m **B** 1.6π m **C** 3.2π m **D** 4.0π m

Ans: C

$$s = r \times d\theta$$
$$= 0.80 \times \frac{2\pi}{3} \times 6$$
$$= 3.2\pi\ m$$

17 Two identical coins P and Q rest on a flat, rough turntable.



The turntable starts from rest and spins about its vertical axis through its centre at an increasing rate. When the turntable reaches a certain rate of rotation, one of the coins begins to slide.

Which of the following statements best explains why this happens?

A P begins to slide because it has less friction.

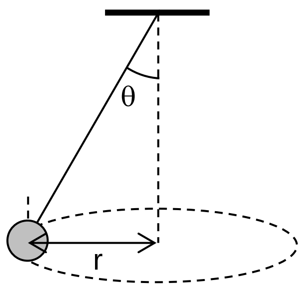
B Q begins to slide because it has less friction.

C Q begins to slide because it has a larger angular velocity.

D Q begins to slide because it is moving with a larger radius.

Ans: D
Friction depends on the coefficient of static friction (material-on-material dependent) and the normal force, hence friction on P and Q are the same since they are identical.
P and Q are rotating at the same angular velocity of the turntable.
As Q is at a larger radius away from the axis of rotation, it experiences a larger centripetal force than P (by $F_c = mr\omega^2$), hence there is a tendency to exceed the limit of maximum friction that holds Q in place, hence Q tends to slide off the turntable.

18 A pendulum bob is suspended from the ceiling by a light inextensible string. It is set to whirl in a horizontal circle of radius *r* such that the cord is inclined at an angle θ to the vertical.



What is the period of rotation of the pendulum?

A $\sqrt{\dfrac{4\pi^2 r}{g}}$ **B** $\sqrt{\dfrac{4\pi^2 r}{g\tan\theta}}$ **C** $\sqrt{\dfrac{4\pi^2 r}{g\sin\theta}}$ **D** $\sqrt{\dfrac{4\pi^2}{rg\tan\theta}}$

Ans: B

$$T\sin\theta = mr\omega^2 \quad ---(1)$$

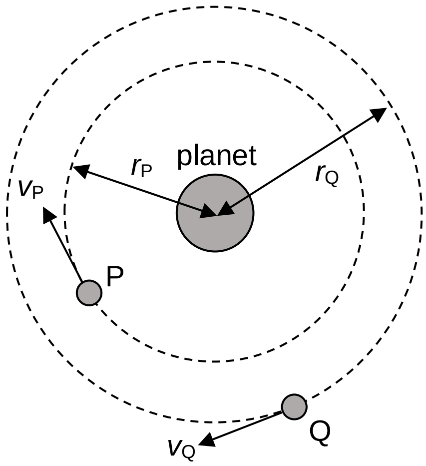
$$T\cos\theta = mg \quad ---(2)$$

$$(1)\div(2),\quad \tan\theta = \frac{r\omega^2}{g}$$

$$T^2 = \frac{4\pi^2 r}{g\tan\theta}$$

$$T = \sqrt{\frac{4\pi^2 r}{g\tan\theta}}$$

19 Two moons P and Q move in circular orbits about a planet as shown below.



Moon P has an orbital radius r_P of 1.4×10^8 m and linear speed v_P. Moon Q has an orbital radius r_Q of 2.3×10^{10} m and linear speed v_Q.

What is the ratio $\dfrac{v_P}{v_Q}$?

A 6.1×10^{-3}

B 7.8×10^{-2}

C 13

D 160

Ans: C

Gravitational force provides the centripetal force. Let mass of planet be M, mass of moon P be m_P and mass of moon Q be m_Q.

For P:

$$\frac{GMm_P}{(r_P)^2} = \frac{m_P (v_P)^2}{r_P}$$

$$v_P = \sqrt{\frac{GM}{r_P}}$$

For Q:

$$\frac{GMm_Q}{(r_Q)^2} = \frac{m_Q (v_Q)^2}{r_Q}$$

$$v_Q = \sqrt{\frac{GM}{r_Q}}$$

Using ratio,

$$\frac{v_P}{v_Q} = \sqrt{\frac{r_Q}{r_P}} = \sqrt{\frac{2.3\times10^{10}}{1.4\times10^{8}}} = 13$$

20 Star X of mass 2M and Star Y of mass M perform circular motion about their common centre of mass under their mutual gravitational attraction. Ignoring the effects of any other bodies, what is the ratio $\dfrac{\text{centripetal force acting on X}}{\text{centripetal force acting on Y}}$?

A 0.5 **B** 1 **C** 2 **D** 4

Ans: B
Centripetal force acting on X = centripetal force acting on Y = gravitational force of attraction between them

21 A stationary object is released from a distance 6*R* from the centre of the Earth which has radius *R* and mass *M*.

Which one of the following expressions gives the speed of the object upon hitting the Earth?

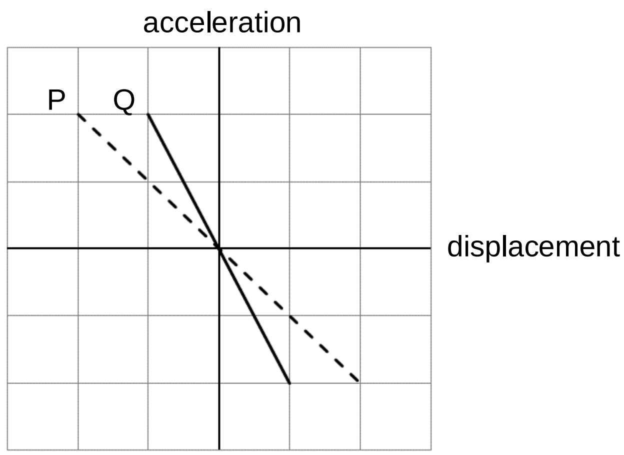
A $\sqrt{\dfrac{GM}{R}}$ **B** $\sqrt{\dfrac{GM}{5R}}$ **C** $\sqrt{\dfrac{5GM}{2R}}$ **D** $\sqrt{\dfrac{5GM}{3R}}$

Ans: D
By conservation of energy, $KE_i + GPE_i = KE_f + GPE_f$

$$0+\left(-\frac{GMm}{6R}\right)=½mv^2+\left(-\frac{GMm}{R}\right)$$

$$v=\sqrt{\frac{5GM}{3R}}$$

22 The figure below shows the acceleration-displacement graphs of two oscillators P and Q. The amplitude and period of P are x_0 and T respectively.

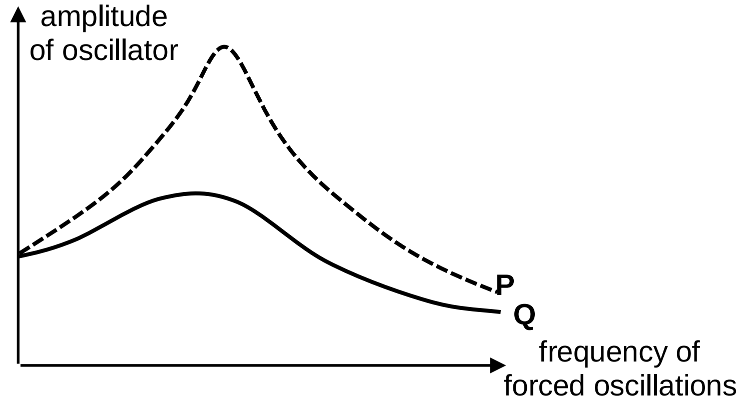


Which of the following correctly gives the amplitude and period of Q?

	amplitude	period
A	x_0	$2\,T$
B	x_0	$T / 4$
C	$x_0 / 2$	$T / \sqrt{2}$
D	$x_0 / 2$	$T / 2$

Ans: C
The gradient of the acceleration-displacement graph represents ω^2. The 'end points' of the line represents the values of maximum displacement, i.e. amplitude.

23 The graphs below show the frequency responses of two identical oscillators P and Q when subjected to forced oscillations by the same driver but two different levels of damping.



Which of the following statements is correct?

A The natural frequency of P is higher than that of Q.

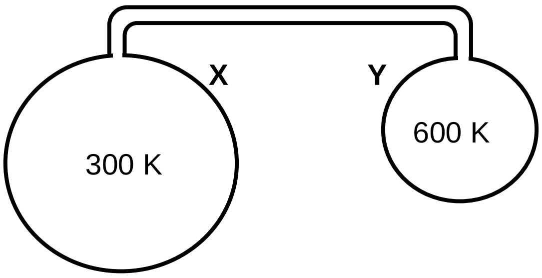
B The damping on P is heavier than that on Q.

C P and Q oscillate at different frequencies when the driver is disengaged.

D P exhibits resonance and Q does not.

Ans: C
Since P and Q are identical oscillators, they must have the same natural frequency.
The damping on Q is heavier than P.
Both P and Q exhibit resonance.

24 The volume of bulb X is twice that of bulb Y. They are filled with the same ideal gas and are connected by a narrow tube, as shown. A steady state is established with bulb X held at 300 K and bulb Y at 600 K. If there are n moles of gas in bulb X, how many moles of gas are there in bulb Y?



A ¼ n **B** ½ n **C** n **D** $2n$

Ans: A
Since the gases are connected, p is the same on both sides.
Using ratio and $pV = nRT$,

$$\frac{n_x}{n_y} = \frac{\frac{p(2V)}{RT}}{\frac{pV}{R(2T)}} = \frac{\frac{2pV}{RT}}{\frac{pV}{2RT}} = 4$$

$$n_y = \frac{1}{4} n_x$$

25 An ideal gas with a mass of 1.60 kg exerts a pressure of 1.00×10^5 Pa in a container of volume 0.500 m^3.

What is the root-mean-square speed of the gas molecules?

A 250 m s^{-1}

B 286 m s^{-1}

C 300 m s^{-1}

D 306 m s^{-1}

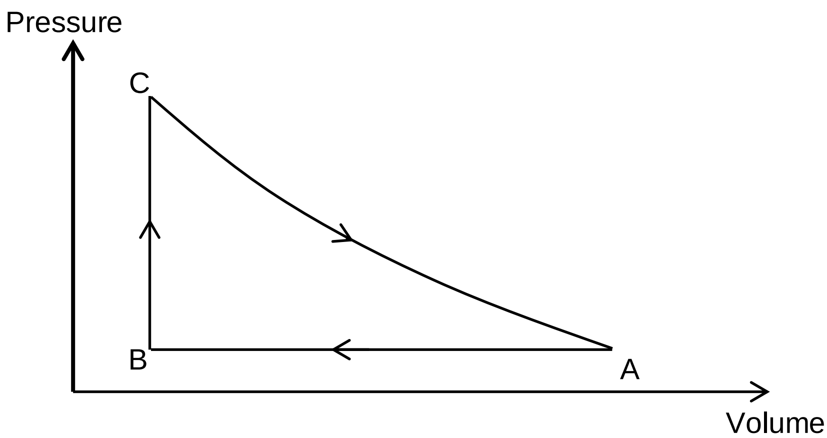
Ans: D

$$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$$

$$1 \times 10^5 = \frac{1}{3}\left(\frac{1.6}{0.5}\right)\langle c^2 \rangle$$

$$\sqrt{\langle c^2 \rangle} = \sqrt{93750} = 306\, m\, s^{-1}$$

26 An ideal gas undergoes a cycle of changes A → B → C → A, as shown below.



During the process, heat is supplied to the gas as shown in the table.

Process	Heat supplied / kJ
A → B	– 15.0
B → C	+ 20.0
C → A	0

The efficiency of the gas engine is defined as follows:

$$\text{efficiency} = \frac{\text{net work done in a cycle}}{\text{heat supplied to gas from process B} \rightarrow \text{C}}$$

The efficiency of the gas engine is

A 0.25 **B** 0.30 **C** 0.50 **D** 0.75

Ans: A
Since $\Delta U = Q + W$ and for a cyclic process, $\Delta U = 0$, thus $|\text{net heat}| = |\text{net work done}|$

$$\eta = \frac{|\text{net } W|}{Q_{BC}} = \frac{|\text{net } Q|}{Q_{BC}} = \frac{|-15.0 + 20.0|\,kJ}{20.0\,kJ} = 0.25$$

Note: The net work done is the area enclosed by the graph, i.e. area ABC.

27 The least distance between two points of a progressive transverse wave which have a phase difference of $\pi/3$ rad is 0.050 m. If the frequency of the wave is 500 Hz, what is the speed of the wave?

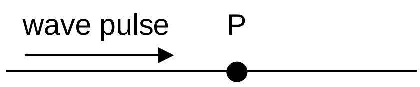
A 75 m s^{-1} **B** 150 m s^{-1} **C** 250 m s^{-1} **D** 1670 m s^{-1}

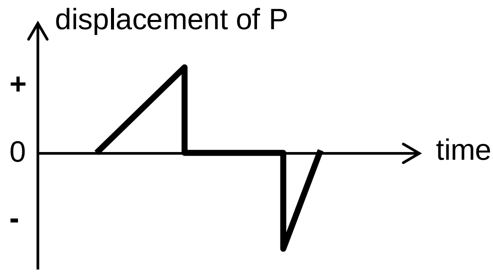
Ans: B

$$\Delta\phi = \frac{\Delta x}{\lambda}(2\pi)$$
$$\frac{\pi}{3} = \frac{0.05}{\lambda}(2\pi)$$
$$\lambda = 0.3m$$

$$v = f\lambda = 500 \times 0.3 = 150\,m\,s^{-1}$$

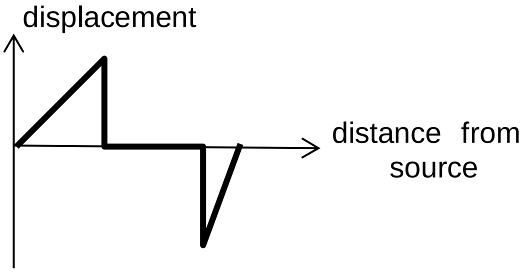
28 A wave pulse is travelling to the right as shown in the diagram below. The graph on the right shows the variation with time of the displacement of a particle P as the pulse passes it.



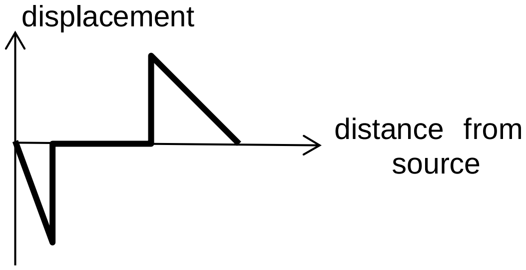


Which one of the following graphs represents the variation of the displacement with positions of the particles along the path of the wave pulse at a certain instant?

A

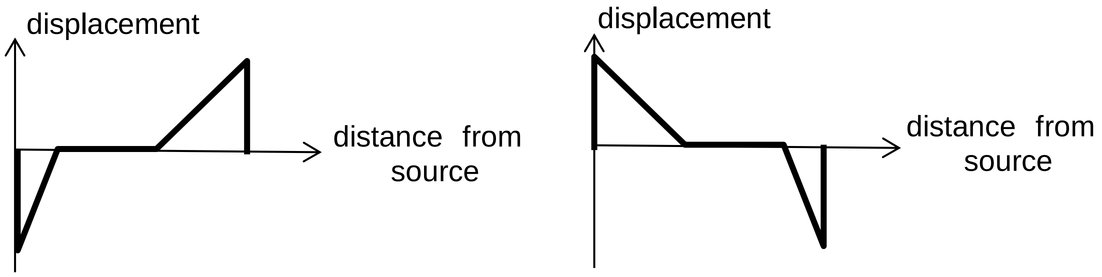


B



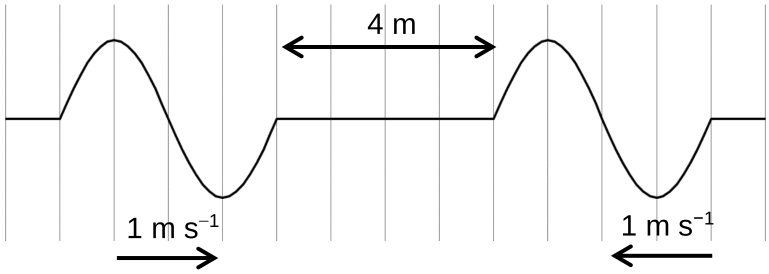
C

D



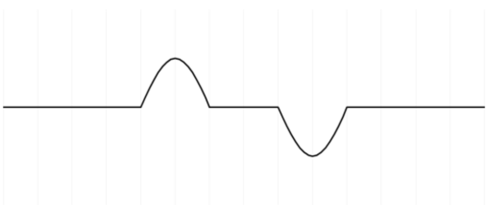
Ans: B
Note: The displacement-time graph tracks the motion of a single particle P. To deduce the shape of the dispalcement-distance graph, which applies for all particles, we have to deduce how the particles leading ahead of P would have been displaced. Since the wave is travelling to the right, particles leading P will be to the left of P. From the displacement-time graph of P, let's consider a time into the future of the motion of P, we see that P will have an initial positive displacement (i.e. displaced to the right in the future), and its subsequent displacements will therefore follow the shape of the wave pulse as indicated in the displacement-time graph. This implies that the nearest particles leading P (particles just to the left of P) would have experienced an initial positive displacement first (i.e. displaced right), before P does. Hence, the shape of the displacement-distance graph would be a reflection (i.e. mirror-image) about the vertical axis.

29 The figure below shows two waves, each of wavelength 4 m, moving towards each other on a string with speeds of 1 m s^{-1}.

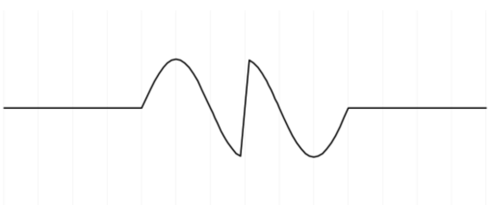


Which of the following shows the string after 3 s?

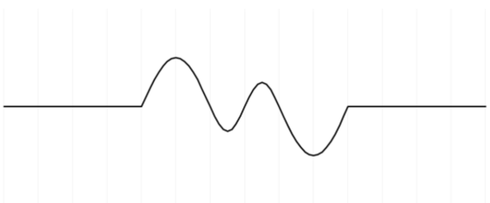
A



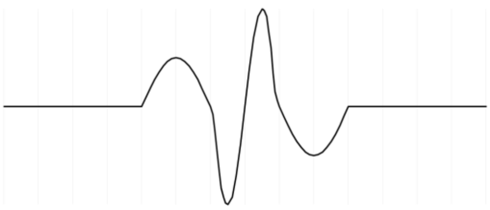
B



C



D



Ans: A

Sketching the waves at t = 3 s later, the crest of the wave on the left would have moved 3 spaces, and the crest of the wave on the right would have also moved 3 spaces. By using the principle of superposition, the resultant waveform would be A.

30 When a continuous tone of frequency 130 Hz is played close to a taut string of 60 cm, the string vibrates as shown below.

What is the speed of the wave in the string?

A zero **B** 26 m s^{-1} **C** 52 m s^{-1} **D** 78 m s^{-1}

Ans: C
String is taut at 60 cm implies distance between the two fixed ends is 0.60 m.
The arrangement of nodes (N) and antinodes (A) along the string would be N A N A N A N.
Hence $3\lambda/2 = 0.6$.
$\lambda = 0.40$ m.
$v = f\lambda = 130 \times 0.4 = 52$ m s^{-1}.

End of Paper

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: **SOLUTION**

CLASS

TUTOR'S NAME

PHYSICS

9749/02

Paper 2 Structured Questions

30 September 2019

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 7**
2	**/ 8**
3	**/ 9**
4	**/ 16**
Total	**/ 40**

This document consists of **10** printed pages.

[Turn over

For Examiner's Use

1 **(a)** State two differences between *random* and *systematic* errors.

Random errors have no fixed pattern, while systematic errors have a fixed pattern

Random errors have an equal chance of over- or under-estimating the true value, while systematic errors consistently over- or under-estimate the true value.

[answers must compare/contrast the two types of errors rather than just state the definitions.] [2]

Not accepted:

"errors have … of being larger/smaller than true value" (errors ~~have~~ lead to **measurements** being […])

"errors scattered about true reading"

(b) **(i)** When determining period T directly using a stopwatch, it is good practice to measure the time taken for a large number of oscillations rather than for one oscillation.

Explain why this should be done.

The uncertainty in the period T is reduced when the total time for a large number of oscillations is divided by number of oscillations to obtain the average period of oscillation.

Not accepted:

"uncertainty is spread out over […]" [1]

"reduce human error" / "reduce error due to human reaction"

(ii) Fig. 1.1 shows a simple pendulum consisting of a mass m attached to a light inextensible string of length L. The pendulum is secured to a fixed point, and undergoes oscillations when displaced sideways by a small angle θ.

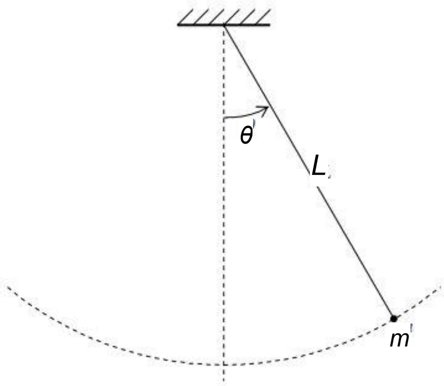


Fig. 1.1

The acceleration of free fall g and the period of oscillation T are related according to the following equation:

$$T^2 = 4\pi^2 \frac{L}{g}$$

Given that L = (50.0 ± 0.2) cm, and the time for 20 oscillations t_{20} = (28.2 ± 0.2) s, determine g with its associated uncertainty.

$$T = \frac{28.2}{20} = 1.41 \qquad \Delta T = \frac{\Delta t_{20}}{20} = \frac{0.2}{20} = 0.01$$

$$g = 4\pi^2 \frac{L}{T^2} \qquad \frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T}$$

$$= 4(3.14)^2 \frac{0.500}{1.41^2} \qquad = \frac{0.2}{50.0} + 2\frac{0.01}{1.41} = 0.004 + 0.014 = 0.018$$

$$= 9.9186 \qquad \Delta g = 9.9186(0.018)$$

$$= 0.18 \approx 0.2$$

(g ± Δg) = ... m s^{-2} [4]

[Total: 7]

For Examiner's Use

2 A water wheel, which is used to generate electricity for a village, has eight buckets equally spaced around its circumference as shown in Fig. 2.1.

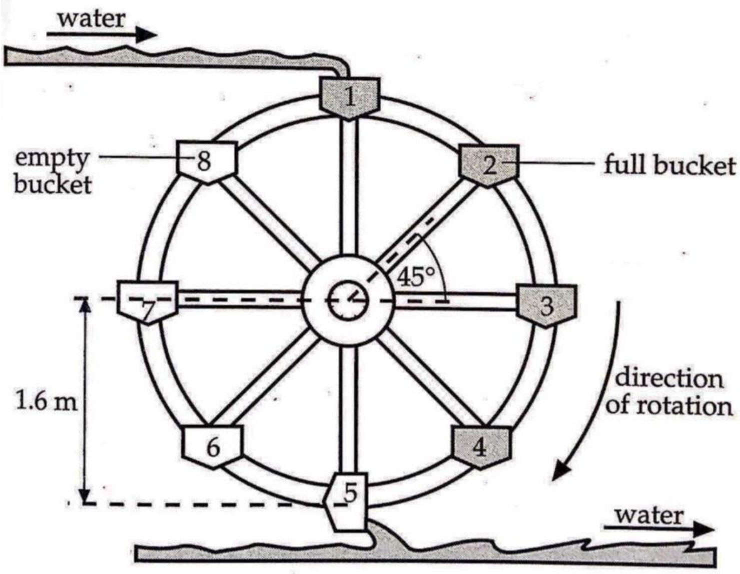


Fig. 2.1

The distance between the centre of each bucket and the centre of the wheel is 1.6 m. When a bucket is at the highest point, the bucket is filled with a mass of 40 kg of water. The wheel rotates at a constant speed and the bucket is emptied at its lowest point.

(a) Define the *moment* of a force.

The moment of a force about a pivot is the product of the force and the perpendicular distance from the pivot to line of action of the force.

....[1]

(b) State the bucket number that provides the largest moment about the axle of the wheel.

number = ...3........... [1]

(c) Calculate, for the wheel in the position shown in Fig. 2.1, the total moment due to the weight of the water in the buckets about the centre of the axle of the wheel.

Moment due to bucket 2
= Moment due to bucket 4
= W x d_1
= 40(9.81)(1.6 cos 45°)
= 443.95 Nm

Moment due to bucket 3
= W x d_2
= 40(9.81)(1.6)
= 627.84 Nm

Total Moment due to bucket 2, 3 and 4
= 443.95 x 2 + 627.84
= 1520 Nm

moment = ... N m [3]

For Examiner's Use

(d) Calculate the loss in gravitational potential energy of water in bucket number 1 as it moves from the top to the bottom.

Loss in GPE
$= mg\Delta h$
$= 40(9.81)(3.2)$
$= 1260$ J

loss = ... J [1]

(e) Hence, determine the total loss in gravitational potential energy of water in the buckets for one complete revolution.

Total Loss in GPE
$= 8 \times mg\Delta h$
$= 10\ 000$ J

loss = ... J [1]

(f) State how the principle of conservation of energy is applicable as the water wheel rotates.

Gravitational Potential energy of the buckets is converted to electrical energy for the village.
Cannot mention kinetic energy since the water wheels rotates at constant speed.

....[1]

[Total: 8]

3 Bobsledding is an Olympic winter sport in which teams of two or four crews make timed runs down an ice track in a bobsled. The team with the fastest timed run wins. In one part of the journey, the bobsled moves in a circular path along a banked curve, as shown in Fig. 3.1. Friction is assumed to be negligible.

Students have to demonstrate clear understanding of these 2 pts:
1) Need to explain clearly how a resultant force arises from a change in direction → change in velocity → an acceleration (stating of N2L is not necessary but good to have)
2) Need to explain why this resultant force does not cause a change in linear speed (merely stating 'textbook answers' that centripetal force is the resultant force which acts towards the centre does not indicate true understanding and application to the qn.)

Fig. 3.1

(a) When the bobsled travels at constant speed in a circular path along the track in Fig. 3.1, it experiences a resultant force. Explain how a resultant force acts on the bobsled even though it is travelling at constant speed.

When the bobsled travels in a circular path, its **direction is constantly changing**, hence there is a **change in velocity and thus an acceleration** [1] By N2L, this acceleration causes a *resultant* force to act on the bobsled. Since the bobsled travels at constant speed, the **resultant force and acceleration has to be perpendicular to the direction of motion** (i.e. radial component), so as not to have any tangential component to cause a change in speed. [1] [2]

(b) Explain why it is necessary for the track to be banked.

There is negligible friction for the bobsled to turn. Due to banking, (horizontal component) of the **normal force is able to provide the centripetal force for the bobsled to turn.** [1] [1]

(c) Fig. 3.2 shows the top view of two horizontal curves of radius r and $2r$, which form part of the track. The tracks are banked at the same angle θ as shown in Fig. 3.3. The safe speed for the bobsled to turn around the curve of smaller radius is v.

Students have to identify and specify the correct force that provides the centripetal force for the bobsled to turn in the absence of friction. Merely stating the consequences of not banking the track, e.g. bobsled will slide off and crash, does not show clear understanding of a fundamental concept that a centripetal force is necessary for an object to undergo circular motion.

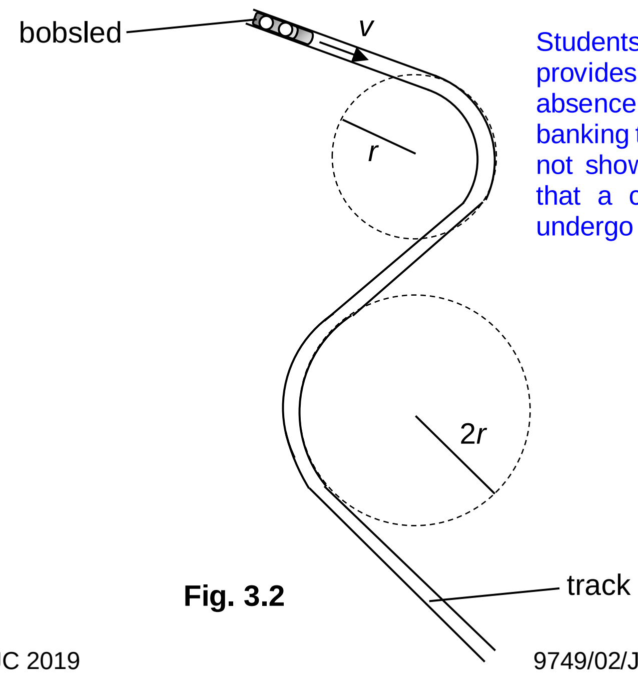


Fig. 3.2

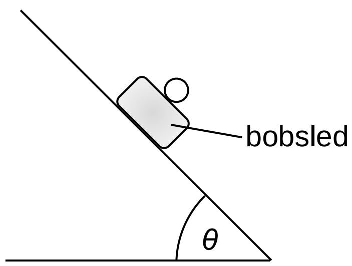


Fig. 3.3

(i) Derive an expression for the safe speed, v, for the curve of smaller radius, in terms of θ, r and g, where g is the acceleration due to gravity.

$$\sum F_c = ma_c$$

$$N \sin\theta = \frac{mv^2}{r} \quad ---(1)$$

$$\sum F_y = 0$$

$$N \cos\theta = mg \quad ---(2)$$ [1] for both eqn. seen or implied

$$\tan\theta = \frac{v^2}{rg}$$ [1] for correct manipulation

$$v = \sqrt{rg\tan\theta}$$ [1] ans. from incorrect method/working scores NO marks

v = ... [3]

(ii) Hence determine, in terms of v, the safe speed v' for the bobsled to turn about the curve of larger radius.

$$\frac{v}{v'} = \frac{\sqrt{rg\tan\theta}}{\sqrt{2rg\tan\theta}}$$

$$v' = \frac{\sqrt{2rg\tan\theta}\, v}{\sqrt{rg\tan\theta}} = \sqrt{2}v \quad \text{OR} \quad 1.41v$$ [1] allow e.c.f. from (c)(i)

v' = ... [1]

(iii) In the actual Olympics bobsled track, the banking angle θ, defined as the angle the tangent to the curve makes with the horizontal, is not constant but varies as shown in Fig. 3.4. When coming around a turn, the bobsled crew will intentionally "climb the track", which is to go higher up the track. State and explain the reason for doing this.

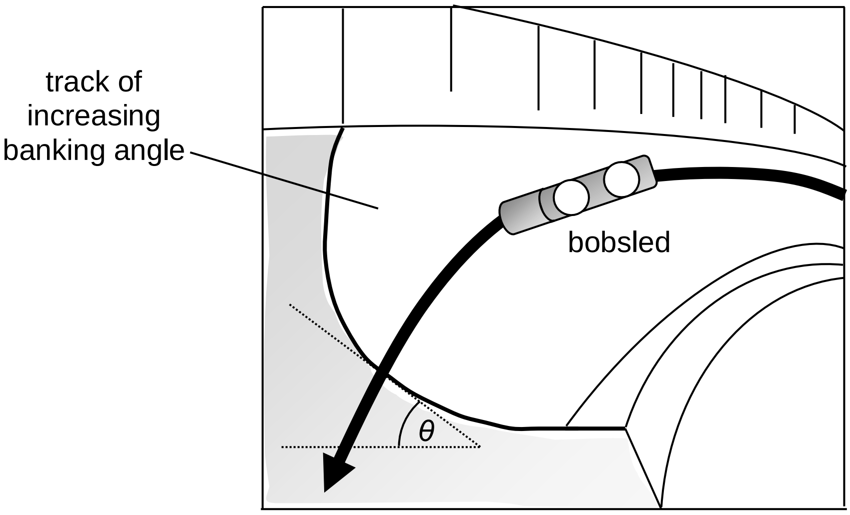


Fig. 3.4

This allow the bobsled to take the **turn at a higher (safe) speed** [1], since higher up the curve, the **greater the banking angle *θ* and/or *r*, and the greater the centripetal force** [1] provided from the horizontal component of the normal force. [2]

(allow e.c.f. if they made reference from v in (c)(i), ignore reasons from energy considerations, but give for higher speed)

[Total: 9]

For Examiner's Use

4 This question is about a space shuttle used to take tourists to the 'edge of space'.

(a) Fig 4.1 shows the variation with height *h* above the Earth's surface of pressure *P*.

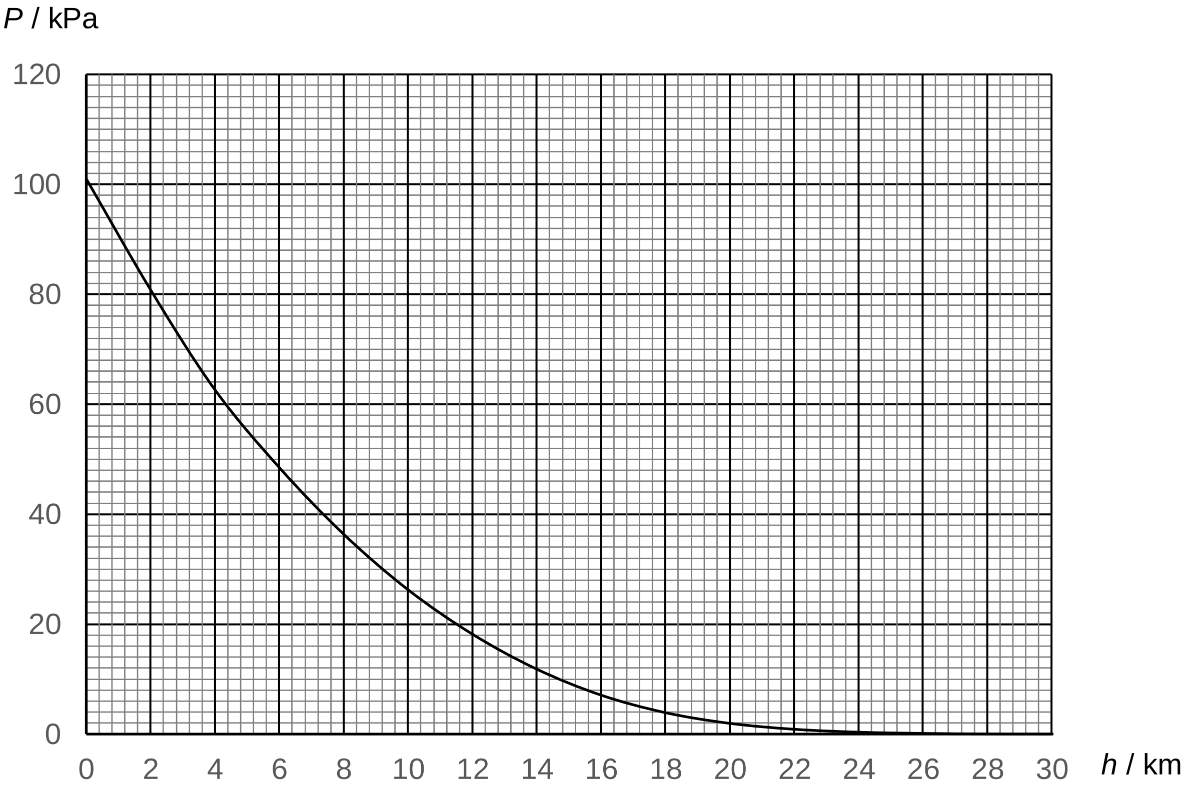


Fig 4.1

(i) Using Fig 4.1, suggest how the density of air varies with height *h*.

(From P = (24000 – h) ρ g, gradient of the graph is proportional to the density.)

Since gradient becomes gentler (decreases) [1] , hence the density decreases [1] [2]

Comments:

- Many students used the formula P = hρ g to explain that density has to decrease when h increases because from Fig 4.1, pressure P decreases with increasing h. However, the 'h' in the formula is depth, not height from surface of Earth as defined in the question. So this argument is not accepted.

- Explanations using proportionality between P and density is also not accepted, because there are assumptions made about constant depth (when P = = hρ g is used) or constant temperature or mass of air (when ideal gas equation is used).

- Some students used the phrase 'Pressure decreases at a decreasing rate when height increases'. This is accepted as a description of gradient getting gentler. However, in general 'rate' is usually taken with respect to time, so students are discouraged to use this phrase in future when the quantity on the horizontal axis is not time.

- Many students used the argument that decrease in pressure implies less number of particles per unit volume and hence density drops. However, there is an assumption made that average speed of particles is the same (ie constant temperature), so this is not accepted.

(ii) The space shuttle, carrying three people, is taken to a suitable height above the Earth's surface on the back of a carrier craft. At this height where the air pressure is only 25% of that at the surface of the Earth, the space shuttle is released from the carrier craft.

Using the graph in Fig 4.1, determine the height *h* above the earth's surface where pressure is 25% of that at the surface.

25% of pressure at surface ~ 25 kPa [1] Height range accepted = 10 km to 10.4 km [1]

h = ... km [2]

(iii) Suggest and explain an advantage of releasing the space shuttle at the height in **(ii)** instead of at the Earth's surface.

At a height of 10 km above the surface, the gradient of the graph and hence density of the air is much less than that at the surface, thus less drag is experienced by the shuttle, and hence acceleration of the shuttle is higher upon release/less force required to launch shuttle/less energy and fuel required [1] [1]

(b) Fig. 4.2 shows the variation with the height h near the Earth's surface of the gravitational potential ϕ.

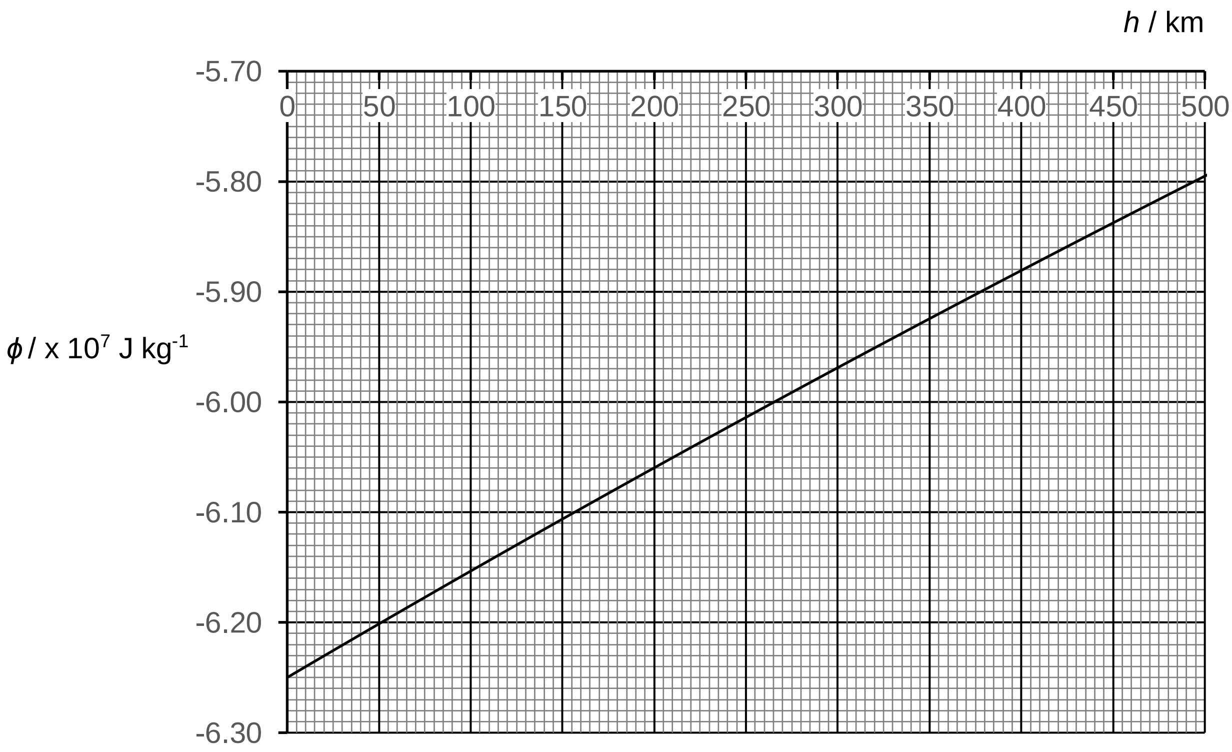


Fig 4.2

Using Fig 4.2,

(i) State the feature of the graph that shows that the gravitational field strength is non-uniform over the range of the flight from h =0 to 500 km.

Graph is not linear/gradient of graph is not constant or decreasing. [1] ....

.... [1]

(ii) Calculate the energy required by the space shuttle of mass 3800 kg to rise from the Earth's surface to 500 km above the surface.

Energy required= $m(\Delta V_g)$ = $3800 \times (-5.795-(-6.250)) \times 10^7$ or $3800 \times (-5.79-(-6.250)) \times 10^7$ [1]
$= 1.73 \times 10^{10}$ J [1] $= 1.75 \times 10^{10}$ J [1]

If POT 10^7 missing, answer mark not awarded.

energy required = ... J [2]

(iii) Estimate the gravitational field strength at a height of 300 km above the Earth's surface.

Find gradient of tangent to the curve at h = 300 km
$g = (-5.80 - (-6.14)) \times 10^7 / (490 - 110)$ Working for gradient [1]
= 8.95 Answer [1]

Range accepted: $8.6 \text{ N kg}^{-1} < g < 9.4 \text{ N kg}^{-1}$

Comments: Determining the mass of Earth (in order to use the formula $g = GM/r^2$) using estimated values of g at the surface and radius of Earth is not accepted.

gravitational field strength = ... N kg^{-1} [2]

(c) When the shuttle is 300 km above the Earth's surface, the engines of the space shuttle exert a vertical thrust of 74 kN, radially away from the Earth. Calculate the acceleration on the shuttle at this instant. You may neglect the effect of resistive forces in your calculation.

Net force = vertical thrust – weight of the shuttle
$= 74 \times 10^3 - (g \times 3800)$ g value from (biii) [1]

Net acceleration a = Net force / mass = $(74 \times 10^3 - (g \times 3800)) / 3800 = 10.5 \text{ m s}^{-2}$ [1]

Range accepted: $9.47 \text{ ms}^{-2} < a < 11.5 \text{ ms}^{-2}$

Comments: if value of g used is 9.81 ms^{-2}, no marks awarded.

acceleration = ... m s^{-2} [2]

For Examiner's Use

(d) With the engines turned off, the space shuttle continues to travel radially away from the Earth in very thin atmosphere. Explain any change in the speed of the space shuttle.

p.e. gain = k.e. loss [1], and lower k.e. ⇒ lower speed [1]

OR

Gravitational force on space shuttle or acceleration of space shuttle opposes motion. [1]
so speed decreases [1]

[2]

Comments:

- 'Thin' atmosphere implies that air resistance is negligible. But many students still assume there is drag force on the shuttle.
- Many students assume that gravitational force acting on the shuttle is close to zero, and with no thrust and drag force, there is hence no resultant force and the shuttle moves with constant speed. This is not accepted as the distance from Earth is not given, and cannot be assumed to be so far from Earth such that gravitational force reduces to zero.
- Many students assume the shuttle is in circular motion, giving the formula for KE to be GMm/2r. However the question clearly states that the shuttle is travelling radially away from the Earth, hence no marks will be given.
- The argument that total energy increase with distance is also not accepted since the engines are off, hence no energy input.

(e) Towards the end of the journey when the shuttle returns to Earth, the space shuttle descends nearer the Earth's surface where atmospheric pressure is high. State and explain whether the people in the cabin of the shuttle experience weightlessness.

- Force of air resistance acting on shuttle causes decrease in acceleration of shuttle. Passenger's acceleration also decreases and hence <u>acceleration of passenger is less than g</u> [1]
- Astronaut requires a <u>normal contact force from the shuttle</u> (so that he also accelerates at less than g). Hence no weightlessness. [1]

[2]

[Total: 16]

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**
CLASS	
TUTOR'S NAME	

PHYSICS

9749/03

Paper 3 Structured Questions

3 October 2019

2 hour

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Sections A and C.
Answer **1 out of 2** questions in Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

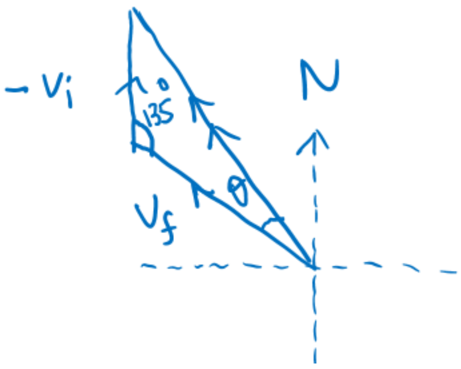
For Examiner's Use	
1	/ 12
2	/ 12
3	/ 12
4	/ 12
5	/ 20
6	/ 20
7	/ 12
Total	/ 80

This document consists of **22** printed pages.

Section A

Answer **all** the questions in the spaces provided.

1 (a) An aerial drone is used to take videos of an amusement park for an advertising company. Determine the magnitude and direction of the increase in velocity when the drone, which has been moving due south at 6.00 m s^{-1}, changes direction and moves north-west at 8.00 m s^{-1}.



$(\Delta v)^2 = 6^2 + 8^2 - 2(6)(8)\cos 135^o$ [1] for method/working

$\Delta v = \sqrt{167.882251}$

$= 12.95693833$

$= 13.0\ ms^{-1}$ [1] for correct magnitude

$\dfrac{6}{\sin\theta} = \dfrac{12.95693833}{\sin 135^o}$

$\theta = 19.1^o$

direction $= 90^o - 45^o - 19.1^o$

$= 25.9^o$ W of N [1] for correct direction

$\equiv 64.1^o$ N of W

Allow for graphical method (scale drawing)

magnitude = ……………………… m s^{-1}

direction = …………………………………………………………

[3]

(b) At the shooting range in the amusement park, players win a prize if they manage to hit a moving target with a bow and arrow. The player stands at O which is 10.0 m away from T, where the target is initially. The player shoots the arrow 2.00 s after the target starts to move at a constant velocity of 12.0 m s^{-1} away from T. Assume that air resistance is negligible.

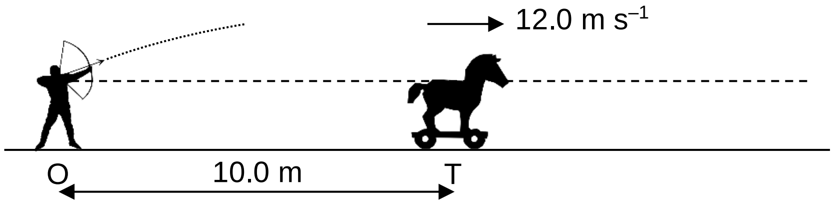


Fig. 1.1

(i) Explain why, in order for the arrow to hit the target, the player has to aim the arrow at an angle above the target, and not directly at the target.

Gravitational force acting on the arrow provides a downward acceleration which changes its vertical velocity. [1]

Aiming the arrow at an angle above allows the arrow to travel in a projectile motion such that the arrow travels up before descending and hits the target. [1] [2]

For Examiner's Use

(ii) Calculate the distance between the player and target when the arrow leaves the bow.

distance = 10 + (2 x 12) = 34.0 [1] m [1]

(iii) The arrow leaves the bow at an angle of 30.0° above the horizontal with an initial velocity of 32.0 m s^{-1}. Show that the time of flight for the arrow to return to the same horizontal level as it left the bow is 3.26 s.

$$s_y = u_y t + \frac{1}{2}a_y t^2$$

$$0 = (u\sin\theta)t - \frac{1}{2}gt^2$$

$$t = 0 \quad or \quad \frac{2u\sin\theta}{g}$$

$$\therefore t = \frac{2(32\sin 30^o)}{9.81} = 3.26s \quad (\text{shown})$$ [1]

[1]

(iv) Hence, determine whether the player is able to win a prize.

For the arrow to hit the target, it must travel the same distance from O as the target in the same time duration after leaving the bow.

range of arrow, $d = (u\cos\theta)t$

$$= \frac{(u\cos\theta)(2u\sin\theta)}{g}$$

$$= (32\cos 30^o)(3.26)$$

$$= 90.3\,m$$ [1]

dist. travelled by target, $d = 34 + 12t$

$$= 34 + 12\left(\frac{2u\sin\theta}{g}\right)$$

$$= 34 + 12(3.26)$$

$$= 73.1m$$ [1]

Since the distances are not equal (90.3 m $\neq$ 73.1 m), arrow will not hit the target. [1]

Whether the arrow is rising or falling, air resistance always opposes the motion. Air resistance also depends on the speed of the moving object; the greater the speed, the greater the air resistance. With air resistance, as the arrow rises, magnitude of acceleration will be more than 9.81 m s^{-2} and will gradually decrease to 9.81 m s^{-2} at maximum height, where it is instantaneously at rest. As the arrow falls, magnitude of acceleration will gradually decrease from 9.81 m s^{-2} to zero, provided it manages to reach terminal velocity before hitting the ground.

[3]

(v) In reality, air resistance is not negligible.
State how air resistance affects the change in acceleration in the vertical direction, if any, as the arrow

1. rises, and

As the arrow rises, acceleration decreases. [1] [1]

2. falls.

As the arrow falls, acceleration decreases. [1] [1]

For Examiner's Use

2 **(a)** State the *principle of conservation of linear momentum.*

In the absence of external forces, the total momentum of bodies in a system remains constant.

[1]

(b) A pellet of mass 40 g is launched towards a stationary trolley of mass 1.0 kg. It has a velocity of 12.0 m s^{-1} at an angle of 60.0° below the horizontal just before it lands on the trolley, as shown in Fig. 2.1. The pellet sticks to the trolley and moves off horizontally after impact.

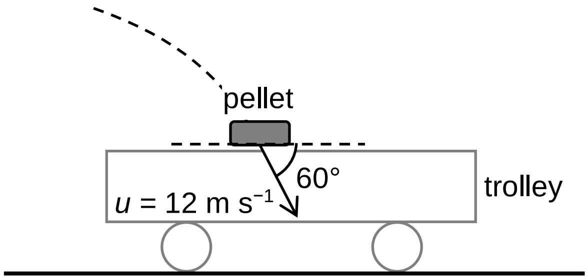


Fig. 2.1

(i) Explain why the momentum of the pellet and trolley is not conserved in the vertical direction.

There is an external force exerted vertically on the trolley by the ground (normal contact force),

hence the principle of conservation of linear momentum does not apply to the system of pellet and trolley in the vertical direction / hence momentum of the pellet and trolley is not conserved in the vertical direction. [1]

(ii) Show that the final horizontal velocity of the pellet and trolley is 0.23 m s^{-1}.

$$m_1u_1 + 0 = (m_1 + m_2)v$$
$$(0.040)(12\cos 60°) = (1.040)v$$
$$v = 0.231 \text{ (shown)}$$

[1]

(iii) If the time of collision with the trolley is 0.15 s, calculate the average horizontal force exerted on the pellet upon collision with the trolley.

Pellet: $v_i = 6.0, v_f = 0.23$

$\Delta p = m(v_f - v_i)$ [1]

$= 0.040(0.23 - 6.0)$

$= -0.23$ kg m s^{-1} [1]

Horizontal force: $F_x = \dfrac{\Delta p}{t}$

$= \dfrac{-0.23}{0.15}$

$= 1.54$ N (direction not required) [1]

horizontal force = ... N [3]

(iv) Show that the change in momentum of the pellet in the vertical direction is 0.416 kg m s^{-1}.

Before collision, $u_y = -12\sin 60°$

Upon collision, $\Delta v_y = v_y - u_y$

$= 0 - (-12\sin 60°)$

$= 10.39$

$\Delta p_y = m\Delta v_y$

$= (0.040)(10.39)$

$= 0.416$ kg m s^{-1} (upwards)

[1]

(v) Determine the average vertical force exerted by the trolley on the pellet.

Average vertical resultant force, $\langle F \rangle_y = \dfrac{\Delta p}{t}$

Resultant vertical force on pellet $\langle F \rangle_y = N_{tp} - W_p$

$$\frac{\Delta p_y}{t} = N_{tp} - mg$$

$$N_{tp} = \frac{\Delta p_y}{t} + mg$$

$$= \frac{0.416}{0.15} + (0.040)(9.81)$$

$$= 2.773 + 0.392$$

$= 3.2$ (1 d.p.) <3.165 full precision>

average vertical resultant force = ... N [2]

(vi) Hence, determine the magnitude of average force exerted by the trolley on the pellet.

Average force on pellet $\langle F \rangle = \sqrt{F_y^{\,2} + F_x^{\,2}}$

$$= \sqrt{3.17^2 + 1.54^2}$$

$$= \sqrt{10.05 + 2.37}$$

$= 3.5$ N

magnitude of average force = ... N [1]

(c) If the trolley in **(b)** is now given a small initial velocity to the right, and the same pellet is launched such that it hits the trolley with the same speed and angle of impact, explain why the increase in velocity of the trolley will be smaller than 0.23 m s^{-1}.

If the trolley has an initial velocity, the **final velocity** of pellet and trolley would be higher (in **a(ii)**) and hence the **change in horizontal momentum would be smaller** (in **a(iii)**). [1]

Hence, the change in velocity of the trolley (final − initial) will be smaller than 0.23 m s^{-1} (the value from (a)), as (change in) **velocity is proportional to** (change in) **momentum**. [1]

....[2]

3 T is a point source of microwaves which transmits waves of frequency 0.60 MHz uniformly in all directions. A and B are identical microwave receivers placed equidistant on either side of T, as shown in Fig. 3.1.

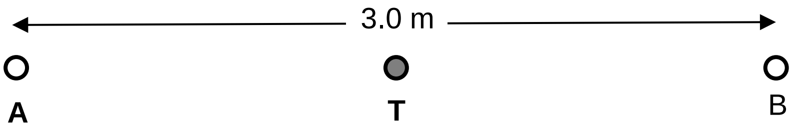


Fig 3.1

The distance between A and B is 3.0 m, and the intensity of the wave received by each of them is 74 mW m^{-2}.

(a) Explain what is meant by the *intensity* of a wave.

The intensity of a wave is the rate of flow of energy per unit area perpendicular to the direction of the wave.

....[1]

(b) Calculate the power of source T.

$P = I \times A = 74\times10^{-3} \times 4\pi\,(1.5^2) = 2.1$ W

power = ... W [2]

(c) T is moved 0.50 m towards B. Calculate the ratio of

$$\frac{\text{amplitude of wave at A}}{\text{amplitude of wave at B}}.$$

$I = P / A \propto 1 / r^2$

$I \propto x_0^2$

$x_0 \propto 1 / r \rightarrow x_A / x_B = r_B / r_A = 1.0 / 2.0 = 0.50$

ratio = ... [3]

(d) The waves emitted by T are polarised in a vertical plane.

(i) Explain why microwaves can be polarized.

They are electromagnetic waves which are transverse waves.

....

....[1]

(ii) Calculate the percentage loss in intensity if a receiver is orientated with its axis off the vertical by an angle of 10°.

$I_0' = I_0 \cos^2 10^o$

$I' / I = 0.985^2 = 0.970$

% loss = 1 – 0.970 = 0.030 = 3.0%

percentage loss = ... [3]

(e) A second source U identical to T is located on the opposite side of B at an equal distance. When U begins transmitting together with T, the amplitude at B drops to zero. Deduce why this is so.

The waves from U and T form a stationary wave between them.

B is located at a node. OR

The waves from U and T meet at B with a phase difference of π.

....[2]

Destructive interference occurs at B.

For Examiner's Use

4 An oscillator comprising a mass and two light springs shown in Fig. 4.1 has a mass of 0.50 kg. It is displaced from its equilibrium state and released. As a result, it performs simple harmonic motion about its equilibrium position.

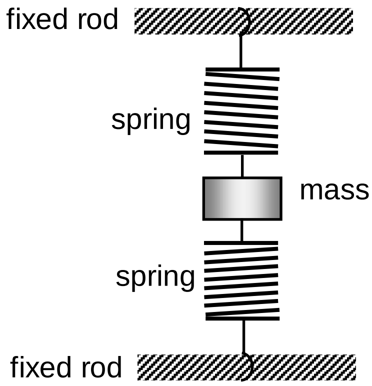


Fig. 4.1

The kinetic energy of the oscillator varies with its displacement from its equilibrium position as shown in Fig. 4.2.

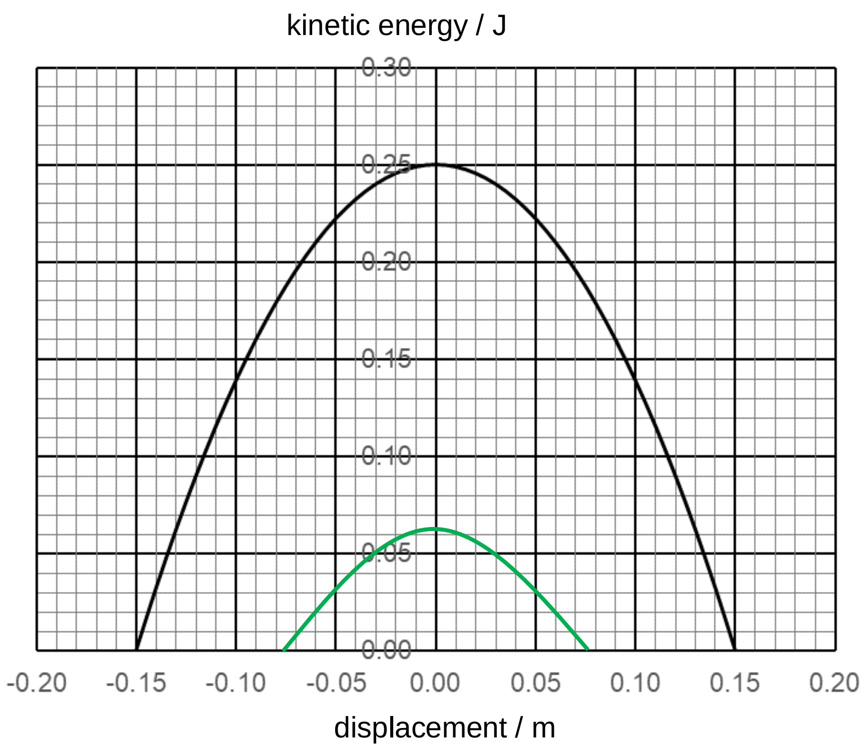


Fig. 4.2

(a) Explain what is meant by *simple harmonic motion*.

Motion in which the acceleration is proportional in magnitude and opposite in direction to the displacement from a fixed point.

....[2]

For Examiner's Use

(b) Determine the speed of the oscillator when it is **(i)** at its equilibrium point, and **(ii)** furthest from its equilibrium point.

At equilibrium: $E = 0.25\ J = ½\ m\ v^2$

→ $v = (0.25 / 0.5 / 0.50)^{1/2} = 1.0\ m\ s^{-1}$

At furthest point: $E = 0$ → $v = 0$

speed at equilibrium point = ... $m\ s^{-1}$

speed at furthest point = ... $m\ s^{-1}$

[3]

(c) Determine the natural frequency of the oscillator.

$v_0 = \omega\ x_0$ → $\omega = 1.0 / 0.15 = 6.7\ rad\ s^{-1}$

$f = \omega / 2\pi = 6.7 / 2\pi = 1.1\ (1.06)\ Hz$

natural frequency = ... Hz [3]

(d) A student explains that the shape of the graph in Fig. 4.2 is as shown because elastic potential energy is converted to kinetic energy and back as the oscillator oscillates. Comment on the validity of his explanation.

Not correct. Total potential energy, made up of elastic and gravitational PE, is converted to kinetic energy and back. (There is conversion of PE from one form to the other.) [2]

(e) Using the axes in Fig. 4.2, sketch a graph of kinetic energy against displacement for the oscillator if its amplitude is halved. Indicate the values of the intercepts on both axes. [2]

For Examiner's Use

Section B

Answer **ONE** question from this section.

5 The table shows how the gravitational potential varies at three points above the surface of an unknown planet of radius 1.25×10^5 m.

Height above surface of planet / 10^5 m	Gravitational potential / 10^3 J kg^{-1}
0	- 15.0
1.75	- 6.25
6.25	- 2.50

(a) State what is meant by *gravitational potential* at a point.

The gravitational potential at a point in a field is defined as the work done per unit mass by an external agent in bringing a test mass from infinity to that point. [1]

(b) Show, using the data above, that the potential is inversely proportional to the distance from the centre of the planet.

Height above surface of planet / 10^5 m	Gravitational potential / 10^3 J kg^{-1}	Distance from centre of planet / 10^5 m	$\phi r/10^8$
0	- 15.0	1.25	-18.8
1.75	- 6.25	3.00	-18.8
6.25	- 2.50	7.50	-18.8

Since ϕr = constant [1] , this implies ϕ is inversely proportional to r.

[2]

(c) Determine the mass of the planet.

$\phi = -GM/r$

$-15.0 \times 10^3 = -6.67 \times 10^{-11} M / (1.25 \times 10^5)$

$M = 2.81 \times 10^{19}$ kg

mass = ... kg [1]

(d) Hence determine the gravitational field strength at the surface of the planet.

$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11} \times 2.81 \times 10^{19}}{(1.25 \times 10^5)^2} =$ 0.120 N kg^{-1}

gravitational field strength at surface = ... N kg^{-1} [2]

For Examiner's Use

(e) It is suggested that a space vehicle could land on the planet to search for valuable minerals. The planet is spinning and the time for one rotation is 5.0 hours.

The space vehicle of mass 3.0×10^4 kg is located on the equator of the planet at a distance of 1.25×10^5 m from the centre, as shown in Fig. 5.1.

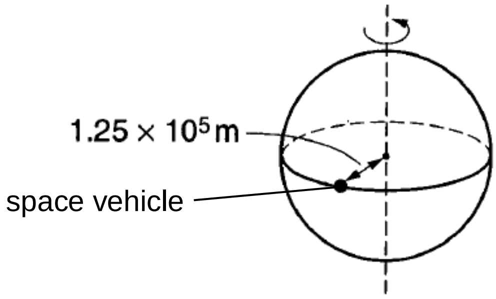


Fig. 5.1

(i) Calculate the centripetal force needed to keep the vehicle on the surface of the planet.

$F_c = mrw^2 = mr\left(\frac{2\pi}{T}\right)^2 = 3.0 \times 10^4 \times 1.25 \times 10^5 \times \left(\frac{2\pi}{5.0\times60\times60}\right)^2$

= 457 N

centripetal force = ... N [2]

(ii) Hence deduce quantitatively whether the vehicle will stay on the surface of the rotating planet.

Gravitational force acting at surface on vehicle,

$F_g = mg = 3.0 \times 10^4 \times 0.120 = 3600\ N$

Since $F_g > F_c$ $\Rightarrow$ contact force between vehicle and surface of planet > 0,

$\Rightarrow$ vehicle will stay on surface on planet

....

....

....[3]

For Examiner's Use

(f) A space probe is launched from the North pole of the planet. During the launch, the energy E given to the space probe of mass m is

$$E = \frac{3GMm}{4R}$$

where G is the gravitational constant and M and R are the mass and radius of the planet respectively. Work done in overcoming resistive forces can be neglected.

(i) State and explain whether the space probe will be able to escape from the gravitational field of the planet.

Gravitational force acting at surface on vehicle,

$F_g = mg = 3.0 \times 10^4 \times 0.120 = 3600\ N$

Since $F_g > F_c \Rightarrow$ contact force between vehicle and surface of planet > 0,

$\Rightarrow$ vehicle will stay on surface on planet

....[2]

(ii) The space probe enters a circular orbit of radius r around the planet. Derive expressions, in terms of G, M, R , m and r for

1. the change in gravitational potential energy of the space probe as it travels from the planet's surface to its orbit,

Change in gravitational p.e. = $-\frac{GMm}{r} - (-\frac{GMm}{R}) = GMm\left(\frac{1}{R} - \frac{1}{r}\right)$

change in gravitational potential energy = ... J [2]

2. the kinetic energy of the space probe when it is in its orbit.

Gravitational force provides/acts as the centripetal force for the circular motion

$G\frac{Mm}{r^2} = m\frac{v^2}{r}$

$\Rightarrow$ ke = $\frac{1}{2}mv^2 = G\frac{Mm}{2r}$

kinetic energy = ... J [2]

(iii) Use your answers in **(f)(ii)** and the total energy supplied to the space probe as given in **(f),** to determine the height of the orbit above the planet's surface in terms of *R*.

Energy supplied = increase in k.e. + increase in g.p.e

$\frac{3GMm}{R} = \frac{GMm}{2r} + \frac{GMm}{R} - \frac{GMm}{r}$ [1]

$\frac{1}{4R} = \frac{1}{2r}$

$\Rightarrow$ r = 2 *R* [1]

Hence, height above the surface = *R* [1]

height = ... m [3]

For Examiner's Use

6 **(a)** **(i)** State the *First Law of Thermodynamics*.

In a closed system, the increase in internal energy is equal to the heat supplied to the system and the work done on the system.

..................[1]

(ii) The densities of water and steam at 100 °C and 1.01×10^5 Pa are 1000 kg m^{-3} and 0.590 kg m^{-3} respectively. Calculate the change in volume which occurs when 1.00 kg of water changes to steam at 100 °C and atmospheric pressure of 1.01×10^5 Pa.

Change in volume
$= V_f - V_i$
$= m/\rho_f - m/\rho_i$
$= 1.00 / 0.590 - 1.00 / 1000$

$= 1.69$ m^3

change in volume = ... m^3 [2]

(iii) Calculate the work done against the atmosphere when water changes to steam.

$W = -p\Delta V$
$= - 1.01 \times 10^5 (1.6939)$
$= - 1.71 \times 10^5$ J

work done = ... J [2]

(iv) The specific latent heat of vaporisation of water at 100 °C is 2.26×10^6 J kg^{-1}. Calculate the increase in internal energy of the molecules when 1.00 kg of water changes to steam.

$Q = ml_v$
$= 1.00 (2.26 \times 10^6)$
$= 2.26 \times 10^6$ J

$\Delta U = Q + W$
$= 2.26 \times 10^6 - 1.71 \times 10^5$
$= 2.09 \times 10^6$ J

increase in internal energy = ... J [2]

(v) State the increase in potential energy of the molecules. Explain your answer.

Since there is not change in temperature, but only a change in state/phase, there is no change in kinetic energy. Therefore the increase in internal energy is equal to the increase in potential energy which is 2.09×10^6 J.

..................[2]

For Examiner's Use

(b) Fig. 6.1 shows the below shows a p-V diagram for a fixed mass of gas.

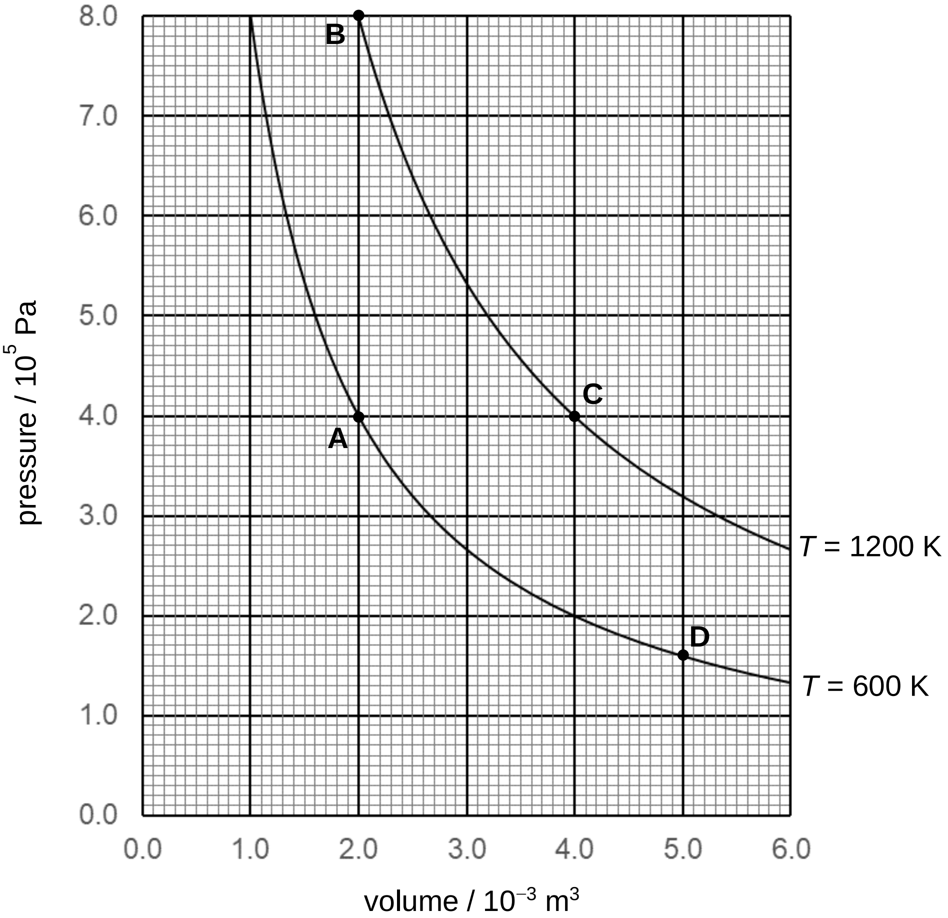


Fig. 6.1

(i) Write down the ideal gas equation.

pV = nRT or pV = NkT

....[1]

(ii) Show that the data of the graph are consistent with the gas behaving as an ideal gas over the range of temperature from 600 K to 1200 K.

p_A/p_B
= 4.0/8.0
= 0.50
T_A/T_B
= 600/1200
= 0.50
Hence p is directly proportional to T.

V_A/V_C
= 2.0/4.0
= 0.50
T_A/T_B
= 600/1200
= 0.50
Hence V is directly proportional to T.

Therefore pV is directly proportional to T and the ideal gas equation is obeyed.

[3]

For Examiner's Use

(iii) Calculate the number of moles of the gas.

At point A, $pV = nRT$
$(4.0 \times 10^5)(2.0 \times 10^{-3}) = n\,(8.31)(600)$
$n = 0.160$ moles

number of moles = ... [1]

(iv) The gas has a heat capacity of 3.33 J K^{-1} at constant volume and 4.66 J K^{-1} at constant pressure. Calculate the amount of heat supplied when the gas undergoes a process:

1. from A to B along line AB,

At constant volume, $Q = 3.33\,(600) = 1998 = 2000$ J

heat supplied = ... J [1]

2. from A to C along line AC.

At constant pressure, $Q = 4.66\,(600) = 2796 = 2800$ J

heat supplied = ... J [1]

(v) If the internal energy at A is given to be 2000 J, determine the internal energy at C.

From A to C, $Q = 2800$ J
$W = -p\Delta V$
$= -(4.0 \times 10^5)(4.0 - 2.0) \times 10^{-3}$
$= -800$ J

By First Law of Thermodynamics, $\Delta U = Q + W$
$U_C - U_A = 2800 + (-800) = 2000$ J
$U_C = 2000 + 2000 = 4000$ J

internal energy = ... J [3]

(vi) Explain why the internal energy of the gas at D is also 2000 J.

For ideal gases, their internal energy depends on temperature only ($U = 3/2\ nRT$). Points A and D are on the same isotherm, which means that they have the same temperature. Hence the internal energy at D is the same as that at A which is 2000 J [1]

Section C

Answer the question from this section.
It is recommended that you spend about 30 minutes on this section.

7 A student is investigating the bending of a loaded wooden strip. Fig. 7.1 shows a rectangular strip of width b and thickness t overhanging the edge of a bench. A length L of the strip is unsupported.

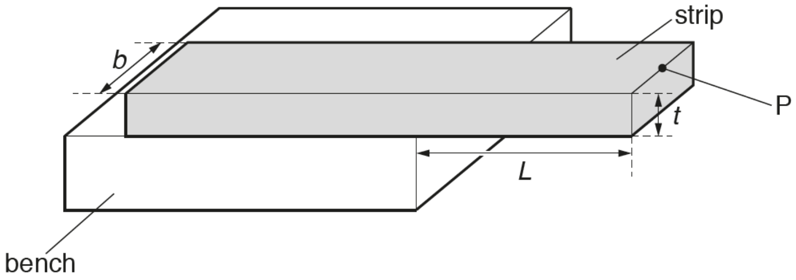


Fig. 7.1

A load of mass M is positioned at point P. This causes the unsupported part of the strip to bend with a deflection s, as shown in Fig. 7.2

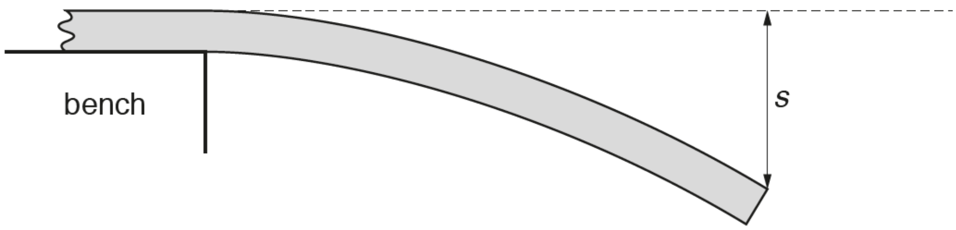


Fig. 7.2 (not to scale)

It is suggested that the relationship between s and L is

$$E = \frac{4MgL^3}{bst^3}$$

where g is the acceleration of free fall and E is the Young modulus of the wood.

Design a laboratory experiment to test the relationship between s and L.
Explain how your results could be used to determine a value for E.

In your account you should pay particular attention to:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

[12]

For Examiner's Use

Defining the problem	Total: 1
L is the independent variable and s is the dependent variable **or** vary L and measure s	
keep mass of load or M constant OR use same wood (keep b and t constant)	1
Methods of data collection	**Total: 4**
labelled diagram of workable experiment including: • method of fixing strip at one end, e.g. with a G-clamp or (heavy) mass placed on top of strip over bench, NOT blue-tack • load shown touching at point P • load and G-clamp or (heavy) mass labelled	1
method of attaching load to strip, e.g. use glue/tape/blue-tack/attach with a hook and string	1
use a rule to measure L and s	1
Repeat readings to obtain at least 6 sets of L and s	1
Method of analysis	**Total: 3**
plot a graph of s against L^3 ONLY (but allow lg s against lg L, or log)	1
relationship valid if a straight line through (0,0) (for lg s against lg L gradient of straight line = 3)	1
$E=\frac{4Mg}{bt^3\times \text{gradient}}$ (must explicitly see this expression to award the mark) (for lg s against lg L, $E=\frac{4Mg}{bt^3}\div 10^{y\text{-intercept}}$)	1

Additional details		**Max. 3**
D1	clamp rule vertically to measure s with elaboration e.g. s = reading of vertical rule with loaded strip – reading of vertical rule with no load or place marker when there is no load, and measure s from the marker when strip is loaded	
D2	method to ensure clamped rule to measure s is vertical, e.g. correctly positioned set square indicated at right angles to the horizontal surface or plumb line shown in appropriate position OR method to ensure strip is perpendicular to the bench, e.g. repeat measurements of L on each side of strip to check that L is constant or set square correctly indicated on diagram	
D3	use a balance to measure M (if M is not a standard mass) OR use a micrometer/calipers to determine t	
D4	repeat s measurement for each L (unloading and loading strip) and average s OR repeat readings for b and/or t at different points along/across the strip and average	
D5	wait until block is stationary/in equilibrium or measure s after a fixed time	
Safety Procedures		

For Examiner's Use

D1	use cushion/foam/sandbox in case mass/load falls **or** wear goggles in case strip snaps or recoils **or** wear safety boots in case mass drop on feet NOT wear gloves to protect from splinters	**1**

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

SOLUTION

PHYSICS

9749/01

Paper 1 Multiple Choice

2 October 2018

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **12** printed pages.

[Turn over

1	2	3	4	5	6	7	8	9	10
D	B	C	D	B	C	A	B	B	A
11	12	13	14	15	16	17	18	19	20
A	B	D	B	C	D	A	A	B	B
21	22	23	24	25	26	27	28	29	30
B	C	D	A	B	A	C	A	B	D

1 A student uses a digital ammeter to measure a current. The reading of the ammeter is found to fluctuate between 1.98 A and 2.02 A.

The manufacturer of the ammeter states that any reading has a systematic uncertainty of ±1 %. Which of the following values of current should be quoted by the student?

A (2.00 ± 0.01) A
B (2.00 ± 0.02) A
C (2.00 ± 0.03) A
D (2.00 ± 0.04) A

Answer: **D**
The lowest possible value of the current would be 0.99% of 1.98 A = 1.96 A
The lowest possible value of the current would be 1.01% of 2.02 A = 2.04 A
The current would be in the range 1.96 A to 2.04 A, which is (2.00 ± 0.04) A

2 The following four possible sources of error in a series of measurements are listed as follows.

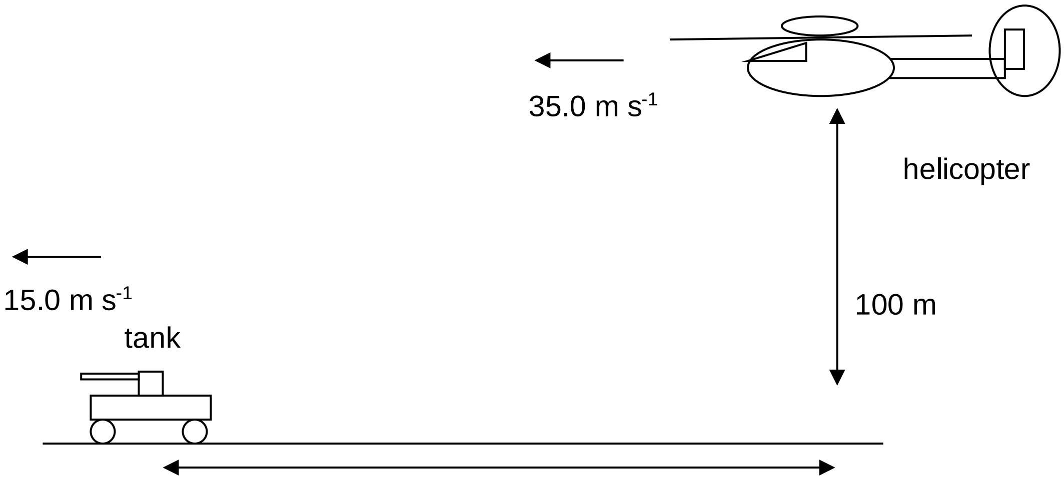
1) An analogue meter whose scale is read from different angles.
2) A meter whose measurements are always 5% too high.
3) A meter with a needle that is not frictionless, so the needle sometimes do not turn properly.
4) A meter with a zero error.

Which of the above sources of errors are random and which are systematic?

	random error	systematic error
A	1 and 2	3 and 4
B	1 and 3	2 and 4
C	2 and 4	1 and 3
D	3 and 4	1 and 2

Answer: **B**

3 A helicopter flies at 100 m above a tank with a constant horizontal speed 35.0 m s^{-1} while the tank travels with a constant speed 15.0 m s^{-1} and is 550 m away from the helicopter.



At t = 0 s, the helicopter and the tank are at the above position, with the tank located 550 m horizontally away from the helicopter. How many seconds later, after this initial position at t = 0 s, should the helicopter release a bomb so that it will eventually hit the tank?

A 2.57 s **B** 4.52 s **C** 23.0 s **D** 27.5 s

Ans: **C**

Consider time taken to fall 100 m vertically,

$$s = ut + \frac{1}{2}at^2 \quad \rightarrow \quad t = 4.515\ s$$

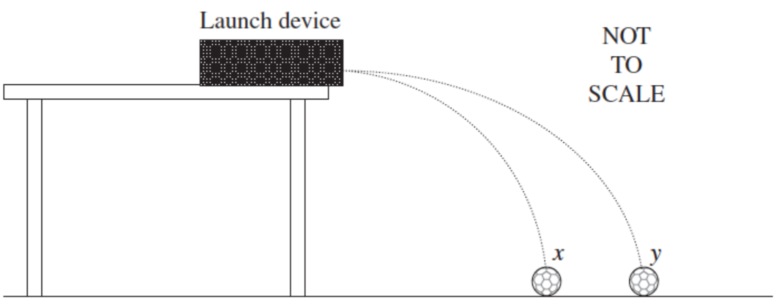
Consider relative speed of 20 m s^{-1}, for 4.515 s the separation must be

$$s = ut + \frac{1}{2}at^2 \quad \rightarrow \quad s = 90\ m$$

Consider time needed to reach this separation at relative speed of 20 m s^{-1},

$$t = \frac{550 - 90}{20} \quad \rightarrow \quad t = 23.0\ s$$

4 A device launches two identical balls x and y horizontally from the same height at the same time. The balls eventually land on the ground. The landing positions of the balls are as indicated in the below diagram.



Which of the following statements is correct?

A x hits the ground before y as it is closer to the launch site.

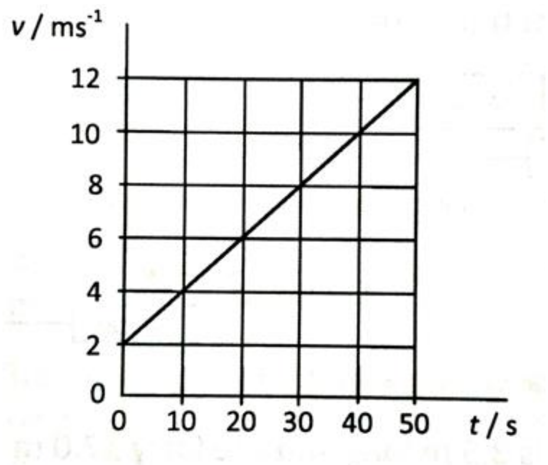
B y hits the ground before x as it has a higher launch velocity.

C x and y hit the ground simultaneously with the same velocity.

D x and y hit the ground simultaneously with different velocities.

Ans: **D** same displacement from ground: hit the ground simultaneously
different horizontal initial velocity: hit with different velocities

5 A train travelling at 2.0 m s^{-1} passes through a station. The graph below shows the variation with time t of the speed v of the train after leaving the station.



What is the speed of the train when it is 150 m from the station?

A 6.0 m s^{-1} **B** 8.0 m s^{-1} **C** 10 m s^{-1} **D** 12 m s^{-1}

Ans: **B**

$v^2 = u^2 + 2as \quad \rightarrow \quad v = \sqrt{u^2 + 2as}$

From given graph, a can be determined,

$a = \dfrac{12.0 - 2.0}{50} \quad \rightarrow \quad a = 0.20\ m\ s^{-2}$

Substituting a = 0.20 m s^{-2} & s = 150 m,

$v = 8.0\ m\ s^{-1}$

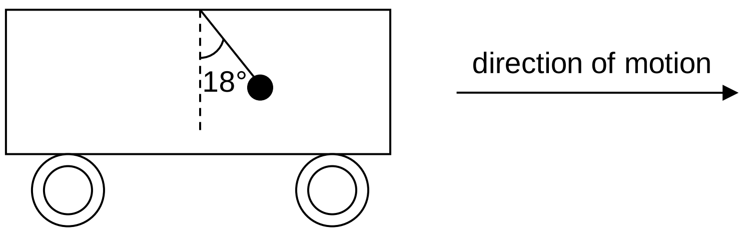
OR Since area under graph = displacement,

$\left(\dfrac{2.0 + v}{2}\right)(t) = s$

Since 8.0 m s^{-2} & 30 s gives s = 150 m,

$v = 8.0\ m\ s^{-1}$

6 A pendulum bob is suspended in a bus of mass 3000 kg that is undergoing constant deceleration. The pendulum makes an angle of 18° with the vertical. What is the deceleration of the bus?



A 0.32 m s^{-2} **B** 3.0 m s^{-2} **C** 3.2 m s^{-2} **D** 9.3 m s^{-2}

Ans: **C**
Consider pendulum bob,
$\sum F_x = ma \quad \rightarrow \quad T\sin 18° = ma$
$\sum F_y = ma \quad \rightarrow \quad T\cos 18° - mg = 0$

Taking ratio of both equations,
$\tan 18° = a/g \quad \rightarrow \quad a = 3.2\ m\ s^{-2}$

7 A movable noticeboard of mass 4.0 kg is placed on a smooth horizontal floor. A horizontal stream of water with speed 10 m s^{-1} strikes the noticeboard at a rate of 1.0 kg s^{-1} for a duration of 60 s. Assuming that the water does not rebound upon hitting the noticeboard and the mass of the noticeboard remains constant, what is the acceleration of the noticeboard?

A 2.5 m s^{-2} **B** 5.0 m s^{-2} **C** 10 m s^{-2} **D** 40 m s^{-2}

Ans: **A**
Consider change in momentum of water,
$$\sum F_{water} = \frac{60(10-0)}{60} \quad \rightarrow \quad F_{by\ board\ on\ water} = 10\ N$$

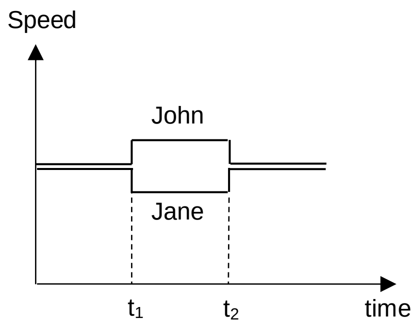
By Newton's third law of motion,
$F_{by\ board\ on\ water} = F_{by\ water\ on\ board}$

Consider change in momentum of board,
$\sum F_{board} = m_{board}\, a_{board} \quad \rightarrow \quad 10 = 4.0\ a_{board}$

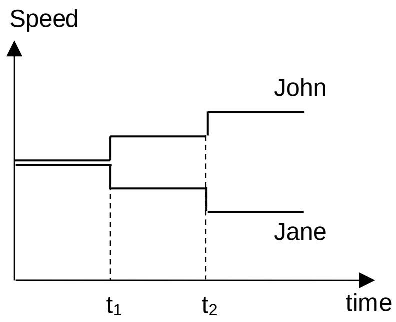
8 John and Jane are skating on smooth ice such that they are moving with equal speeds in the same straight line. John skates backwards facing Jane in front of her. At time t_1 John throws a ball to Jane and at time t_2 receives it back.

Assuming that the time of flight of the ball and air resistance are both negligible, which of the following gives the correct speed-time graph for the two skaters?

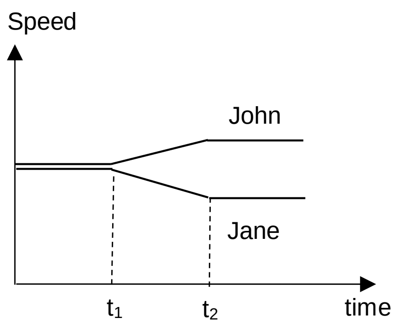
A



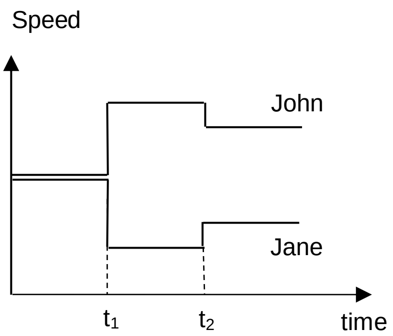
B



C

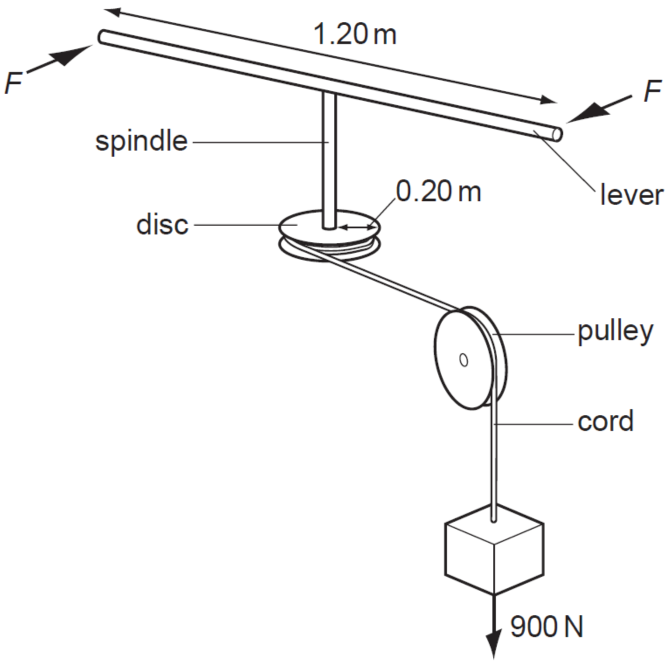


D



Ans: **B** At t_1, John gains momentum, since he moves forward while tossing ball backwards, while Jane loses momentum of the same magnitude, since she receives backward-moving ball while moving forward. At t_2, John gains momentum again while Jane loses momentum of the same magnitude again.

9 A spindle is attached at one end to the centre of a lever 1.20 m long and at its other end to the centre of a disc of radius 0.20 m. A cord is wrapped round the disc, passes over a pulley and is attached to a 900 N weight.

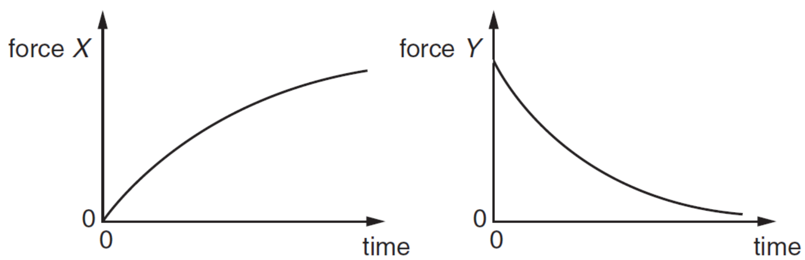


What is the minimum force *F*, applied to each end of the lever, that could lift the weight?

A 75 N **B** 150 N **C** 300 N **D** 950 N

Answer: **B**
The tension in the vertical part of the cord is 900 N
The tension is the horixontal part of the cord is also 900 N, assuming the pulley is frictionless.
The pull of the string on the disc is 900 N, causing a torque of (900N X 0.20m)
To be able to lift the weight the forces F must provide the same torque in the opposite direction. The two forces form a couple.
Torque of couple = F X 1.20 m
F X 1.20 = 900 X 0.20
F = 150 N

10 A ball falls from rest through air and eventually reaches a constant velocity. For this fall, forces *X* and *Y* vary with time as shown. Which of the following could be forces *X* and *Y*?



	force X	force Y
A	air resistance	resultant force
B	air resistance	weight
C	upthrust	resultant force
D	upthrust	weight

Answer: **A**

The magnitude of upthrust and weight do not change with time. The graphs of these quantities with time would be horizontal lines.
Air resistance varies with speed. As the ball falls its speed increases and so does air resistance.
At the beginning, when v = 0, air resistance is zero.
Weight would be much larger than upthrust. Resultant force = weight – upthrust.
As the ball falls, resultant force = weight – upthrust – air resistance

11 A thin horizontal plate of area 0.036 m^2 lies beneath the surface of a liquid of density 930 kg m^{-3}. The force on one side of the plate due to the pressure of the liquid is 290 N. What is the depth of the plate beneath the surface of the liquid?

A 0.88 m **B** 1.1 m **C** 1.8 m **D** 8.7 m

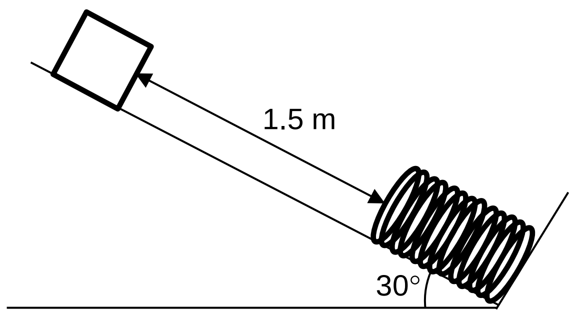
Answer: **A**

Pressure = ρ g h

$$\frac{290}{0.036} = (930)(9.81)\,h$$

h = 0.88 m

12 A block of mass 250 g is placed on a rough, inclined plane which makes an angle 30° with the horizontal. The spring at the end of the inclined plane has spring constant 5.0 N cm^{-1}. The distance between the mass and spring is 1.5 m as shown.



The block is then released from rest and it slides down the inclined plane before hitting the spring. Given that the frictional force acting on the mass is $\frac{1}{5}$ of its weight, what is the maximum compression of the spring?

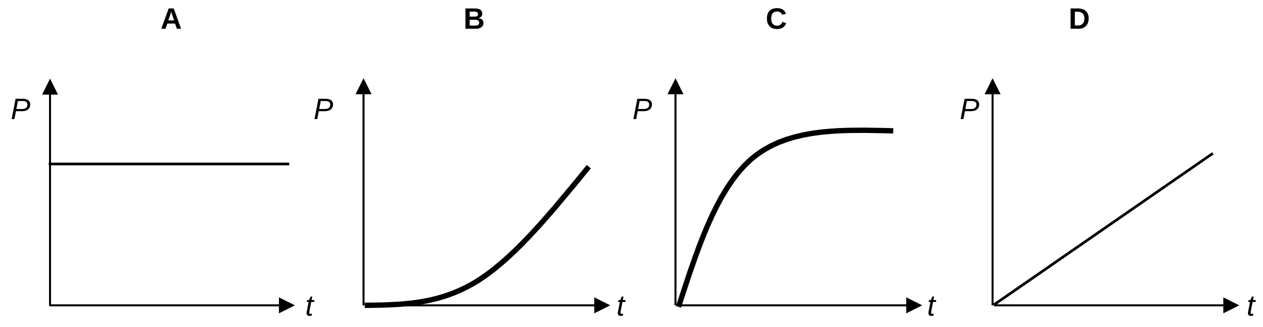
A 6.5 cm **B** 6.8 cm **C** 10 cm **D** 83 cm

Answer: **B**

Let compression of spring be x,

$$E_i + W = E_f$$
$$GPE_i + W = EPE_f$$
$$mg\,(d+x)\sin\theta - \left(\frac{1}{5}mg\right)(d+x) = \frac{1}{2}kx^2$$
$$\frac{1}{5}mg\,(d+x)(5\sin\theta - 1) = \frac{1}{2}kx^2$$
$$\frac{1}{5}(250\times10^{-3})(9.81)(1.5+x)(5\sin30° - 1) = \frac{1}{2}(5.0\times10^2)x^2$$
$$x = 0.068 \text{ m}$$
$$= 6.8 \text{ cm}$$

13 A constant force is applied to a body which is initially stationary. Assuming that the effects of friction are negligible, which of the following graphs best represents the variation of the power supplied P with time t?



Answer: **D**

Applying Newton's Second Law of motion, since force is constant, acceleration of the body is constant (as mass is constant).

$F = ma$

$a = \dfrac{F}{m}$

Using $v = u + at$

$= at \quad (\because u = 0)$

$= \left(\dfrac{F}{m}\right)t$

Using $P = Fv$

$= F\left(\dfrac{F}{m}\right)t$

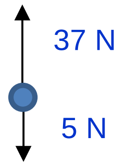
$= \dfrac{F^2}{m}t$

Therefore P is directly proportional to t. i.e. a straight line graph passing through the origin.

14 A light inextensible string can bear up to 3.7 kg of mass. A stone of mass 500 g is tied to one end of the string and revolved in a vertical circular path of radius 4.00 m. Taking g = 10 m s^{-2}, what is the maximum angular velocity of the stone?

A 3.0 rad s^{-1} **B** 4.0 rad s^{-1} **C** 5.0 rad s^{-1} **D** 6.0 rad s^{-1}

Ans: **B**
Maximum speed occurs when the stone is at the bottom of the vertical circular path. Tension in the string is also maximum at this position.

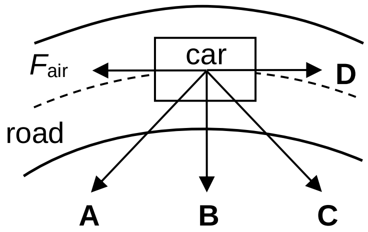


$37 - 5 = 0.5\,(4.00)\,\omega^2$

ω = 4.0 rad s^{-1}

15 A car travels at constant speed on a horizontal circular road as shown. F_{air} is the air resistance acting on the car.

Which of the following best represents the horizontal force exerted by the road on the car?



Ans: **C**
Since the car is travelling at a constant speed, there must be no tangential acceleration. Therefore the frictional force exerted by the road on the car must must have a component that is directed to the right.

In order for the car to move in a circular path, the frictional force exerted by the road on the car must have another component that is directed owards the centre of the circle.

Hence the resultant frictional force exerted by the road on the car acts in the direction shown in C.

16 A racing car moving round a circular track of radius 300 m travels at a constant speed of 95 m s^{-1}. Given that the mass of the car is 700 kg, what is the angle at which the track should be banked, so that frictional force is not required for the car to make the turn?

A 18 ° **B** 36 ° **C** 57 ° **D** 72 °

Ans: **D**

$$N\sin\theta = \frac{mv^2}{r}$$

$$N\cos\theta = mg$$

$$\Rightarrow \tan\theta = \frac{v^2}{rg}$$

$$\tan\theta = \frac{95^2}{(300)(9.81)}$$

$$\theta = 72^o$$

17 The surface area of Earth is A and its density is ρ. What of the following is a correct expression for the gravitational field strength at the surface of Earth?

A $\dfrac{2}{3}G\rho\sqrt{A\pi}$ **B** $\dfrac{2}{3}(6A)^{\frac{1}{3}}G\pi^{\frac{2}{3}}\rho$ **C** $\dfrac{2}{3}G\pi\rho$ **D** $4G\pi\rho$

Answer: **A**

$$g = \frac{GM}{R^2} = \frac{G}{R^2}\rho\left(\frac{4}{3}\pi R^3\right) = \frac{4}{3}G\pi\rho R \quad \ldots \quad (1)$$

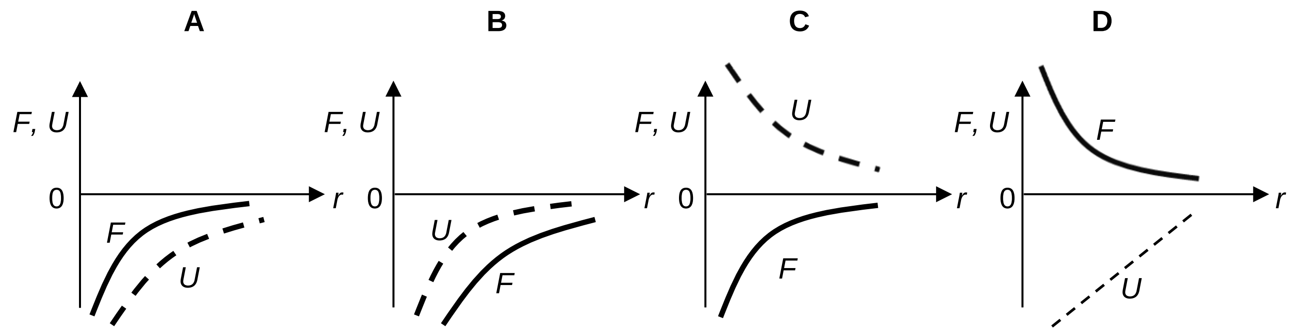
$$A = 4\pi R^2$$

$$R = \sqrt{\frac{A}{4\pi}} \quad \ldots \; (2)$$

Substituting (2) into (1),

$$g = \frac{4}{3}G\pi\rho\sqrt{\frac{A}{4\pi}} = \frac{2}{3}G\rho\sqrt{A\pi}$$

18 Which of the following correctly shows the variation of gravitational force F acting on a mass, and the variation of its gravitational potential energy U, with its distance r from another mass?



Answer: **A**

$$F = -\frac{GMm}{r^2}$$

$$U = -\frac{GMm}{r}$$

19 In a binary star system, two stars of mass M and $2M$ are at a distance d apart. The stars orbit each other (i.e. they orbit about their common centre of mass), with the same angular speed. Where is the common centre of mass of this binary star system located?

A $\left(\sqrt{2}-1\right)d$ from M

B $\dfrac{2}{3}d$ from M

C $\left(2-\sqrt{2}\right)d$ from $2M$

D $\dfrac{2}{3}d$ from $2M$

Answer: **B**

Let the distance from M be x.

$$2M(d-x) = Mx$$

$$2(d-x) = x$$

$$x = \frac{2}{3}d$$

20 A spring is suspended from a fixed point. A mass attached to the spring is set into vertical undamped simple harmonic motion. When the mass is at its lowest position, which one of the following has its minimum value?

A the potential energy of the system.

B the kinetic energy of the mass.

C the acceleration of the mass.

D the tension in the spring.

Answer: **B**
The speed at the extreme position is zero.

21 A mass is attached to the end of a vertical spring. It is given a downward displacement of 3.0 cm from its equilibrium position and then released. The mass is found to oscillate with a period of 0.50 s. What is the maximum speed of the oscillating mass?

A 0.21 m s^{-1} **B** 0.38 m s^{-1} **C** 0.53 m s^{-1} **D** 0.88 m s^{-1}

Answer: **B**
$v_{max} = \omega A = (2\pi/T) A = (2\pi/0.50) \times 0.03 = 0.38$ m s^{-1}

22 Which of the following is *false* for a system in resonance?

A The driving frequency coincides with the natural frequency of the system.

B The amplitude of oscillation of the system is maximum.

C When damping is increased, the peak of the frequency response graph shifts to the right.

D When damping is increased, the amplitude of oscillation of the system decreases.

Answer: **C**
The peak should shift to the left with increased damping.

23 Gas leaks out slowly of a cylinder of constant volume. The temperature of the gas in the cylinder does not change. Which of the following is constant for the gas molecules in the cylinder?

A The number of molecules striking a unit area of the cylinder surface per unit time.

B The number of collisions between molecules per unit time.

C The number of molecules per unit volume.

D The average speed of the molecules.

Answer : **D**
Since the temperature of gas does not change, the average speed of molecules remains unchanged.

24 Two containers of volume 4.0 m^3 and 6.0 m^3 contain ideal gases at pressures of 100 Pa and 50 Pa respectively. They have the same temperature. A tube of negligible volume then joins the containers so that the molecules can move from one container to the other with no change in temperature. The final pressure in the containers is

A 70 Pa **B** 75 Pa **C** 80 Pa **D** 150 Pa

Answer: **A**
$n_1 + n_2 = n_f$
$P_1 V_1 + P_1 V_1 = P_f V_f$
$(100)(4.0) + (50)(6.0) = P_f(10.0)$
$P_f = 70$ Pa

25 To determine the specific latent heat of vaporisation of water, a student uses a heater to boil water. When the water is boiling, the mass of water vapour produced per minute is measured at two different powers of the heater.

The reason the student repeats the experiment using a different power of the heater is to

A reduce random errors in the measurements of the mass of water vapour produced per minute.

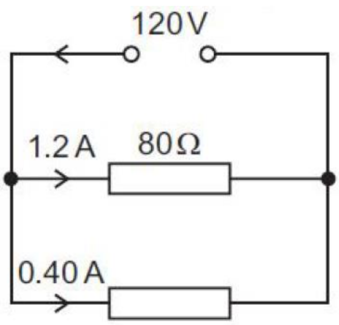
B allow the rate of heat loss from the apparatus to be eliminated from the calculations.

C determine an average value of the specific latent heat of vaporisation.

D check for reproducibility of the measurements.

Answer: **B**
As the water boils at the same temperature, the heat loss to the surrounding will be included and thus eliminated with 2 sets of data.

26 The electromotive force of a power supply is 120 V. It delivers a current of 1.2 A to a resistor of resistance 80 Ω and a current of 0.40 A to another resistor, as shown.



What is the internal resistance of the power supply?

A 15 Ω **B** 20 Ω **C** 60 Ω **D** 75 Ω

Ans : **A**
Terminal p.d. = 1.2 x 80 = 96 V ---(1)
Terminal p.d. = 120 – (1.2+0.40) r ---(2)
Equating (1) and (2), r = 15 Ω

<u>Alternative method:</u>

Let r be the internal resistance of supply and X the resistance of the lower resistor.

p.d. across 80 Ω resistor = p.d. across the lower resistor,

$$X = \frac{1.2 \times 80}{0.40} = 240\ \Omega$$

total current = 1.2 + 0.40 = 1.6 A = supply voltage/total resistance

$$1.6 = \frac{120}{r + \left(\frac{80 \times 240}{80 + 240}\right)}$$

$$r = 15\ \Omega$$

27 There is a current in a resistor for an unknown period of time.

Which two quantities can be used to calculate the energy dissipated by the resistor?

A The current in the resistor and the potential difference across the resistor.

B The resistance of the resistor and the current in the resistor.

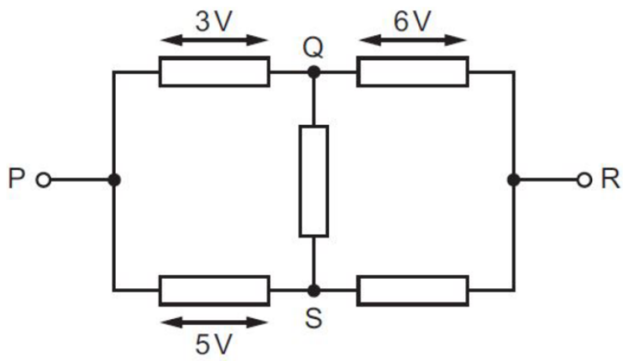
C The total charge passing through the resistor and the potential difference across the resistor.

D The total charge passing through the resistor and the resistance of the resistor.

Ans : **C**

Energy = QV

28 There is a current from P to R in the resistor network shown.



The potential difference (p.d.) between P and Q is 3 V.

The p.d. between Q and R is 6 V.

The p.d. between P and S is 5 V.

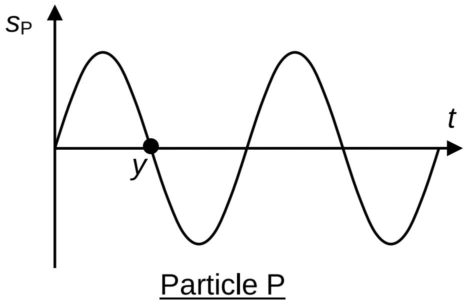
Which of the following is correct?

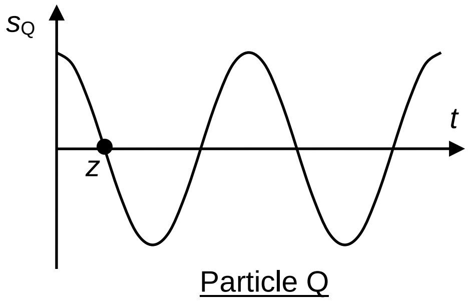
	p.d. between Q and S	p.d. between S and R
A	2 V	4 V
B	2 V	10 V
C	3 V	4 V
D	3 V	10 V

Ans : **A**

Let $V_R = 0$ V.
$V_Q = 6$ V
$V_P - V_Q = 3 \text{ V} \Rightarrow V_P = 9$ V
$V_P - V_S = 5 \text{ V} \Rightarrow V_S = 4$ V
Hence, $V_{QS} = 6 - 4 = 2$ V and $V_{SR} = 4 - 0 = 4$ V

29 The diagrams below show the displacement-time graphs of two particles P and Q separated by a fixed distance x along the path of a wave.





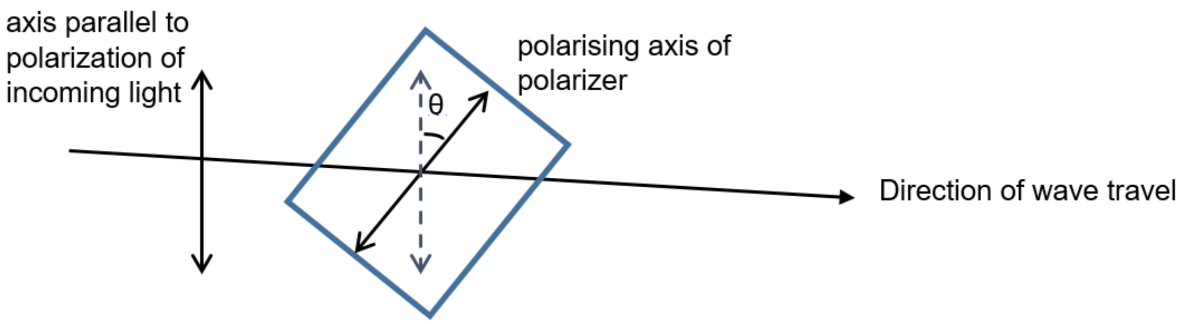
Which of the following correctly gives the wavelength and speed of the wave?

	wavelength	speed
A	$4x$	$4x / y$
B	$4x$	x / z
C	$2y$	$y / 2z$
D	$4z$	$2z / y$

Answer : **B**
From the 2 graph, $\Delta\emptyset = \frac{\pi}{2}$
And $\Delta\emptyset = \frac{x}{\lambda} \times 2\pi$
So , $\lambda = 4x$
Speed = $\lambda f = (4x)\left(\frac{1}{4z}\right) = \frac{x}{z}$

30 An incoming beam of plane-polarised light of intensity I falls normally onto a thin sheet of polarizer. The polarising axis of the polarizer is at an angle θ to the axis of polarization of the incoming beam of light.

If the intensity of the beam after passing through the polarizer is $\frac{1}{4}I$, what is the angle θ?



A 22.5° **B** 30° **C** 45° **D** 60°

Answer : D
$I = I_o \cos^2\theta$
Since $I = I_o/4$, $\frac{1}{4} = \cos^2\theta$
$\theta = 60^o$

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME: **SOLUTION**

CLASS:

TUTOR'S NAME:

PHYSICS

9749/02

Paper 2 Structured Questions

2 October 2018

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **10** printed pages.

[Turn over

For Examiner's Use

1 One end of a wire is connected to a fixed point. A load is attached to the other end so that the wire hangs vertically.

The diameter *d* of the wire and the load *F* are measured as

$$d = 0.40 \pm 0.02 \text{ mm}$$
$$F = 25.0 \pm 0.5 \text{ N}$$

(a) For the measurement of the diameter of the wire, state

(i) the name of a suitable measuring instrument,

Micrometer screw gauge .... [1]

(ii) how random errors may be reduced when using the instrument named in **(i)**.

Average a number of readings (across different diameters around the same circumference or at different points along the wire).

.... [1]

Examiner's Comments:
Because this question is situation-specific (measuring the diameter of a wire) the answer to this question must also be specific to the situation, or else you imply that you are taking a number of readings across the same diameter at the same part of the wire.

(b) The stress σ in the wire is calculated by using the expression

$$\sigma = \frac{4F}{\pi d^2}$$

(i) Determine the percentage uncertainty in σ.

$$\frac{\Delta\sigma}{\sigma} = \frac{\Delta F}{F} + 2\frac{\Delta d}{d}$$
$$= \frac{0.5}{25.0} + 2\frac{0.02}{0.40}$$
$$= 12\%$$

percentage uncertainty = ... % [1]

(ii) Hence determine the value of σ with its associated uncertainty.

$$\sigma = \frac{4F}{\pi d^2} = 1.989 \times 10^8$$
$$\Delta\sigma = \frac{\Delta\sigma}{\sigma}\,\sigma$$
$$= 0.012 \times 1.989 \times 10^8$$
$$= 0.2 \times 10^8$$
$$\sigma = (1.9 \pm 0.2) \times 10^8 \text{ N m}^{-2}$$

For Examiner's Use

σ = (.............................. ± ....) N m^{-2} [2]

Examiner's Comments:
Students seem to forget that

- Percentage uncertainties are to be expressed to 1 or 2 sf only.
- Absolute uncertainties must be expressed to 1 sf only.
- Quantities when expressed with their uncertainties must have the same precision as their uncertainties.

2 **(a)** A steady stream of air hits a vertical wall horizontally and is brought to rest immediately.

(i) Using Newton's laws of motion, explain why the air exerts a force on the vertical wall.

On hitting the wall, the momentum of the air changes. By Newton's second law, the rate of change of momentum of the air is the force exerted by the wall on air [1]. By Newton's third law, the air also exerts a force on the wall.

.... [3]

Examiner's Comments:
There is no need to regurgitate the laws as this is an explanation question and not a definition question; phrase the laws in this specific scenario instead of just stating the generic phrasing.
N2L is used to explain the resultant force that acts on the air (which is F by wall on air in this scenario) while N3L is used to explain the force that acts on the wall by air.

(ii) Explain why the vertical wall does not experience a change in momentum when it is hit by the stream of air.

The wall experiences no net force as the earth also exerts a force of the same magnitude on it in the opposite direction. [1]

Examiner's Comments:
The wall remaining stationary is an indication that the resultant force acting on it must be zero. Since we know air pushed the wall in one direction, there must be another force pushing the wall in the opposite direction such that the wall experiences zero resultant force.
Do not confuse this with N3L. For example, N3L is applicable in the case where wind pushes wall leftward, hence wall pushes wind rightwards. N3L is not applicable for wind pushing wall leftwards and earth pushing wall rightwards (i.e. when both forces act on the same body).

(b) A steady stream of air with speed 10.0 m s^{-1} hits block A of mass 0.50 kg (block A is not stationary initially). It is given that the density of air is 1.25 kg m^{-3} and the effective cross-sectional area of block A is 0.50 m^2. Assuming that the stream of air is immediately brought to rest after hitting block A,

(i) calculate the change in momentum of the air in one second,

$$\Delta p = 10.0 \times 0.50 \times 1.25 \times (10.0 - 0)$$
$$\Delta p = 62.5\ kg\ m\ s^{-1}$$

change in momentum = ... kg m s^{-1} [2]

Examiner's Comments:
Change in momentum of air can be determined using the product of air mass and air's change in velocity. The air mass that hits the block every second can be determined by the product of its length, cross-sectional area and density. The length of air mass that hits the block every second is 10 m because air is moving at 10 m s^{-1}.

(ii) determine the force exerted by the air on the block.

$$F_{by\ air\ on\ boy} = F_{by\ boy\ on\ air} = \sum F_{air} = \frac{\Delta p_{air}}{\Delta t} = 62.5\ N$$

force = ... N [1]

(iii) After being hit by the stream of air, block A slides on the ground and collides at a speed of 3.0 m s^{-1} with a stationary block B of mass 0.80 kg. Given that block A rebounds at a speed of 1.0 m s^{-1} after the collision,

1. determine the speed of block B after the collision.

$$m_f v_{f,f} + m_b v_{b,f} = m_f v_{f,i} + m_b v_{b,i}$$
$$0.80 v_{f,f} + 0.50 \times -1.0 = 0 + 0.50 \times 3.0$$
$$v_{f,f} = 2.5\ m\ s^{-1}$$

speed = ... m s^{-1} [2]

Examiner's Comments:
Block A rebounds in the opposite direction. If its initial velocity is positive then its final velocity must be negative and vice versa.

2. State and explain whether the collision between blocks A and B is elastic.

relative speed of approach = 3.0 m s^{-1}
relative speed of separation = 3.5 m s^{-1}

The difference in the relative speeds of approach and separation of the blocks shows that the collision is not elastic. [2]

Examiner's Comments:
The differentiating factor between elastic and non-elastic collisions is that KE is conserved for the former (before and after collision). If KE is conserved for elastic collisions, the relative speeds of approach and separation are the same. Conversely, if KE is not conserved for a collision, the collision must be non-elastic (can either be inelastic or super-elastic).

For Examiner's Use

3 A pulley system is used to lift a mass *m* of 100 kg which is initially at rest, as shown in Fig. 3.1.

Fig. 3.1

A constant force *F* of 2000 N is exerted on the light cable, pulling the cable down by a distance of 1.2 m. Determine

(a) the work done by force *F*,

$$W = Fs\cos\theta$$
$$= Fs$$
$$= 2000(1.2)$$
$$= 2400 \text{ J}$$

Examiner's Comments:

The direction of the force (downwards) and displacement is the same hence $\theta = 0°$ (not 180°) and cos θ = 1. The symbol for work done is *W*, if *F* is written instead, one mark will be deducted as it is already defined in the question as force.

work done = ... J [2]

(b) the gain in gravitational potential energy of the mass *m*,

$$\text{gain in GPE} = mgh$$
$$= mg\left(\frac{s}{2}\right)$$
$$= 100(9.81)\left(\frac{1.2}{2}\right)$$
$$= 590 \text{ J}$$

gain in gravitational potential energy = ... J [2]

Examiner's Comments:

The majority of candidates do not know that the mass will rise by **half** the distance the cable is pulled down.

(c) the speed of the mass *m* after the cable has been pulled down by 1.2 m.

$$E_i + W = E_f$$

$$W = KE_f + GPE_f$$

$$= \frac{1}{2}mv^2 + mgh$$

$$v = \sqrt{\frac{2(W - mgh)}{m}}$$

$$= \sqrt{\frac{2(2400 - 590)}{100}}$$

$$= 6.0 \text{ m s}^{-1}$$

Examiner's Comments:
As there is positive work done on the system, **both** GPE and KE increase. It is wrong to equate loss in GPE to gain in KE.

speed = ... m s^{-1} [2]

4 **(a)** Explain why a body moving with uniform speed in a circle must experience a force towards the centre of the circle. [2]

As the object moves in a circle, the direction of its velocity changes continuously, hence the object experiences an acceleration.
By Newton's second law, this means that the object experiences a net force.

Since the body moves with constant speed, the net force exerted on the object cannot have any component in the direction of the velocity of the object (i.e. tangential to its circular path). Therefore this force must be acting towards the centre of the circular path (i.e. perpendicular to the direction of velocity of the object).

Examiner's Comments:
Students must remember to address two points in their answer: why a force is required for a body to move in a circle, and why the force exerted on the body must be towards the centre of a circle in order for the body to move with uniform speed.
Some students wrongly stated that the net force on the body must be zero in order for it to move with uniform speed. If the net force is zero, the body cannot possibly move in a circle!

(b) A massless spring with force constant *k* = 78.4 N m^{-1} is fixed to the left side of a level track. A block of mass *m* = 0.50 kg is pressed against the spring and compresses it by a distance *d* as shown in Fig. 4.1. The block is then released from rest and travels toward a circular loop-the-loop of radius *R* = 1.5 m.

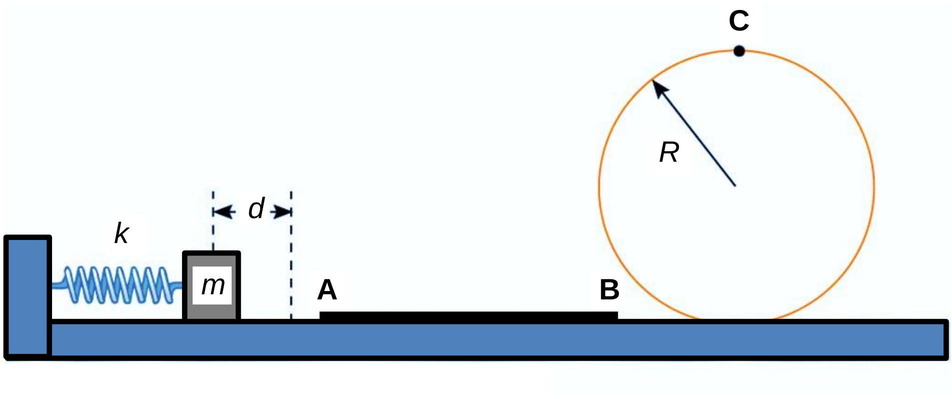


Fig. 4.1

The entire track and the loop-the-loop are frictionless except for the section of track between points **A** and **B**.

Given that the friction between the block and the track along **AB** is 1.47 N and the length of **AB** is 2.5 m, determine the minimum compression *d* of the spring that enables the block to just make it through the loop-the-loop at point **C**.

For the block to just make it through the loop-the-loop at point C, the normal contact force exerted by the loop on the block at C is zero. The weight of the block provides the required centripetal force for the block.

$$mg = \frac{mv_C^{\;2}}{R}$$

$$9.81 = \frac{v_C^{\;2}}{1.5}$$

$$v_C = 3.84 \text{ m s}^{-1}$$

Apply conservation of energy as the block moves from its initial position (when spring is compressed) to its final position at C:

Loss in EPE = Gain in GPE + Gain in KE + Work done by block against friction

$$\frac{1}{2}kd^2 = mg(2R) + \frac{1}{2}mv_C^{\;2} + f.l$$

$$\frac{1}{2}(78.4)d^2 = 0.50(9.81)(3.0) + \frac{1}{2}(0.50)(3.84)^2 + 1.47(2.5)$$

$$d = 0.750 \text{ m}$$

d = ... m [3]

Examiner's Comments:
A large number of students incorrectly took the KE of the block at point C to be zero.

(c) An elastic cord has a natural length of 13.0 cm. One end of the cord is attached to a fixed point **D**. A small mass of weight 5.0 N is hung from the free end of the cord. The cord extends to a length of 14.8 cm, as shown in Fig. 4.2.

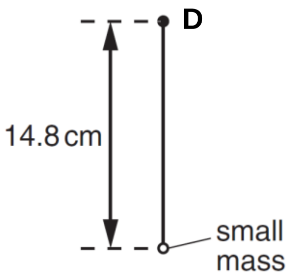


Fig. 4.2

The cord and mass are now made to rotate at *constant* angular speed ω in a vertical plane about point **D**. When the cord is vertical and above **D**, its length is its natural length of 13.0 cm, as shown in Fig. 4.3.

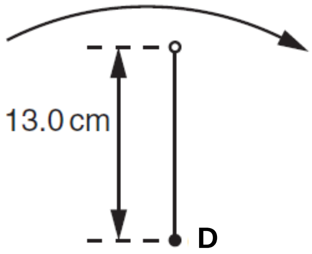


Fig. 4.3

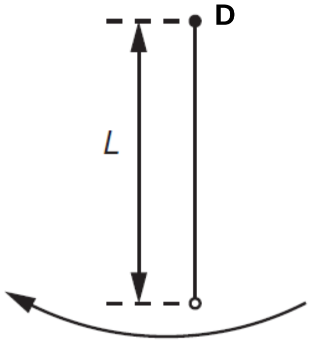


Fig. 4.4

The cord and mass rotate so that the cord is vertically below **D**, as shown in Fig. 4.4. Calculate the length L of the cord in Fig. 4.4, assuming that it obeys Hooke's law.

$$5.0 = k(0.148 - 0.130)$$

$$k = \frac{5}{0.018}$$

When the mass is at the top of the circle in Fig. 4.3, the tension in the cord is zero, so the weight of the mass provides the required centripetal force.

$$mg = mr\omega^2$$

$$\omega^2 = \frac{9.81}{0.130}$$

Let T be the tension in the cable when the mass is at the bottom of the circle in Fig. 4.4.

$$T - mg = mr_1\omega^2$$

$$kx - mg = m(0.130 + x)\omega^2$$

$$\left(\frac{5}{0.018}\right)x - 5.0 = \frac{5.0}{9.81}(0.130 + x)\left(\frac{9.81}{0.130}\right)$$

$$x = 0.0418 \text{ m}$$

$$L = 0.130 + 0.0418 = 0.172 \text{ m}$$

L = ... m [3]

Examiner's Comments:
Many students did not convert the length from cm to m. Hence the value of their calculated spring constant and angular velocity is not correct when expressed in SI units (i.e. N m^{-1} and rad s^{-1} respectively). Students must look at the unit expected of them in the final answer and express the value of L in the correct unit.

For Examiner's Use

5 **(a)** A block M_1 of mass 3.0 kg is connected to a spring with spring constant k. M_1 rests on a smooth surface. Another block M_2 of mass 2.0 kg is placed on top of M_1, as shown in Fig. 5.1.

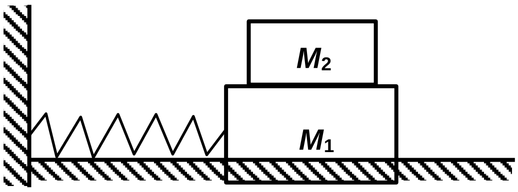


Fig 5.1

M_1 is then given a horizontal displacement and released. The above system oscillates with simple harmonic motion and its acceleration is given by the expression

$$a = -\frac{k}{M_1 + M_2}x$$

where x is the displacement of the system from its equilibrium position.

(i) Given that the spring constant of the spring is 50 N m^{-1}, calculate the frequency of oscillation of the system.

$\omega^2 = 50 / 5.0$
$\omega = 2\pi f$
f = 0.50 Hz

frequency = ... Hz [2]

(ii) The maximum potential energy of the system is 8.0 J. Determine the speed of the system when its displacement is equal to half the amplitude of its oscillation.

Max KE = max PE = 8.0 J
$1/2mv_o^2 = 8.0$ J

$v_o = 1.8$ m s^{-1}
at $x = ½\, x_o$, $v = (0.87v_o) = 1.6$ m s^{-1}

speed = ... m s^{-1} [2]

(b) **(i)** One possible consequence of the oscillations is that block M_2 may slide along M_1 if the amplitude of the oscillating system exceeds a certain value. Explain why this can happen.

Restoring force acting on M2 is provided by the static friction and there is a limiting value. If the amplitude is increased, the acceleration need to move with M1 will increase required greater net force.

.... [2]

Examiner's Comments:

This part prove to be challenging for most students as rarely can the students explain clearly why the block M2 may slide.

(ii) The positions of the two blocks are now swapped, such that block M_2 is now connected to the spring instead. This system of blocks M_1 and M_2 is then set into oscillation by giving it an initial horizontal displacement. State and explain whether the frequency and amplitude of this oscillating system will remain the same as those in **(a)**.

Frequency: There is no change as the total mass of the system remains the same.

Amplitude: It depends only on the amount displaced and independent of the mass of the system. It will only remains the same if the amount displaced is the same.

[2]

Examiner's Comments:

Students need to know that the amplitude of the oscillation depends ONLY on the body displaced initially when starting the oscillation. The amplitude of the oscillation in generally is not affect by the frequency of the oscillation.

There are still a significant number of students who did not realise that the frequency depends on the total mass of the body even though it is reflected in the expression given.

(c) The spring-mass system consisting of only the mass M_1 is now connected to a vibrator, as shown in Fig. 5.2. The frequency of the vibrator is slowly increased.

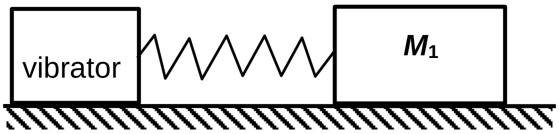


Fig 5.2

The amplitude of M_1 is observed to increase to a maximum before it decreases again.

Determine the frequency of the vibrator at the instant when maximum amplitude is observed. Explain your working clearly.

When amplitude is maximum,
Natural frequency of spring mass system f = driving frequency.
$f^2 \propto M$
$f = \sqrt{5.0 / 3.0} \times 0.50 = 0.65$ Hz

frequency = ... Hz [2]

Examiner's Comments:

There are many students who are not aware that that the mass is undergoing forced oscillation. For resonance to take place, the natural frequency of the system is equal to the driving frequency of the driver. There are quite a number of students who did not mentioned this showing a lack of explanation.

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**
CLASS	
TUTOR'S NAME	

PHYSICS

9749/03

Paper 3 Structured Questions

4 October 2018

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Section A and Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
Section B	
6	
Total	

This document consists of **19** printed pages.

[Turn over

For Examiner's Use

Section A

1 A performer juggles 3 balls A, B and C in a repeated pattern as shown in Fig. 1.1. The performer starts with balls A & C in his left hand and ball B in his right hand, and begins juggling by tossing ball A into the air while still holding balls B and C. As ball A reaches its peak, the performer begins to toss ball B into the air. As ball B reaches its peak, the performer catches ball A with his right hand and begins to toss ball C with his left hand, and the cycle continues.

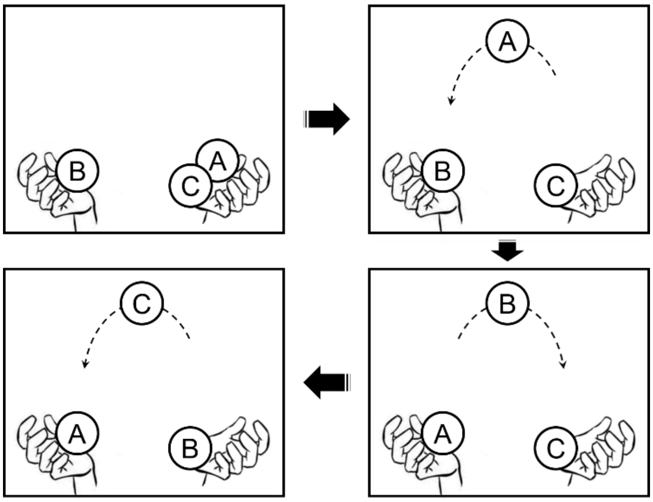


Fig. 1.1

(a) Show that the vertical component of the speed of projection of the ball has to be 4.43 m s^{-1} if the performer wants to throw a ball to a maximum height of 1.0 m from the point of release.

Consider vertical component of motion from point of release to peak of motion,

$$v_y^2 = u_y^2 + 2a_y s_y$$
$$0 = u_y^2 + 2(-9.81)(1.0)$$
$$u_y = 4.43 \ m\,s^{-1}$$

[1]

Examiner's Comments:

Some candidates wrongly substituted $u_y = 0$ instead of $v_y = 0$ and arrived at $v_y = 4.43 \ m\,s^{-1}$ which shows the vertical component of the speed of landing.

(b) Show that ball C stays in the performer's hand for 0.90 s while ball A is in the air.

Consider vertical component of motion from point of release to point of landing,

$$v_y = u_y + a_y t$$
$$-4.43 = 4.43 + (-9.81)t$$
$$t = 0.90 \ s$$

[1]

Examiner's Comments:

Ball C stays in the hand for the entire duration of Ball A in air in which it is projected and landed with a speed of $4.43 \ m\,s^{-1}$.

(c) Hence determine the angle of projection of the ball if the performer keeps his hands 30 cm apart.

Consider horizontal component of motion from point of release to landing,

$$s_x = u_x t + \frac{1}{2} a_x t^2$$

$$0.30 = u_x (0.90) + \frac{1}{2}(0)(0.90)^2$$

Since $\tan\theta = \frac{u_y}{u_x}$,

$$0.30 = \frac{4.43}{\tan\theta}(0.90) + \frac{1}{2}(0)(0.90)^2$$

$$\theta = 85.7°$$

angle of projection = ... ° [2]

Examiner's Comments:

The angle derived from an isosceles triangle with a 30 cm base is different from the angle of projection as the trajectory of the balls are not straight.

(d) With reference to the juggling sequence described above, sketch, on Fig. 1.2, the velocity-time graphs for the vertical component v_y of the velocity of **balls A and B**.
On your graphs, **label** appropriate values of v_y and time t.
Your graphs should begin at t = 0 s when **ball A first leaves** the perfomer's hand, and end when **ball B first returns** to the performer's hand.

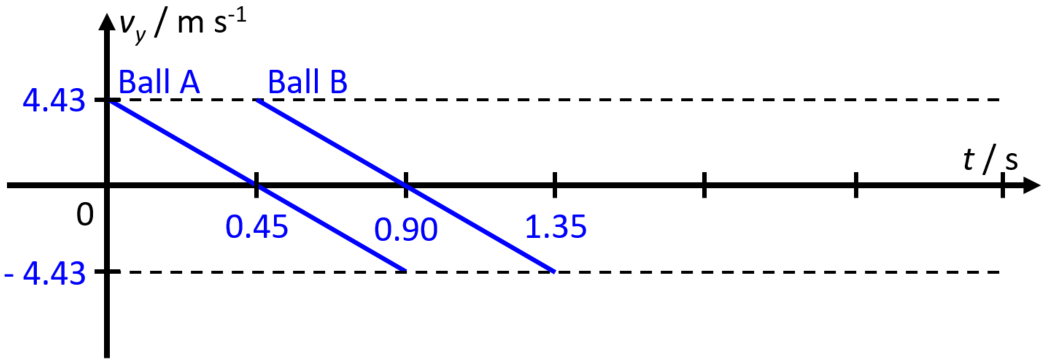


Fig. 1.2

[3]

Examiner's Comments:

Most candidates lost marks due to missing labels. The graphs are straight lines as the acceleration experienced by the balls are constant at 9.81 m s^{-2} which was the required assumption for the calculations in the earlier parts of this question.

For Examiner's Use

2 **(a)** A cylinder of weight 0.60 N is hung from the end A of a non-uniform bar AB, as shown in Fig. 2.1.

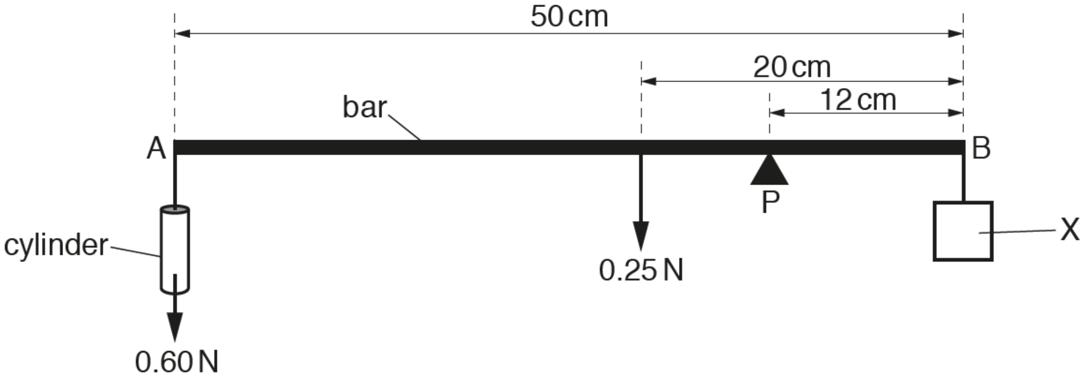


Fig. 2.1

The bar has length 50 cm and has weight 0.25 N. The centre of gravity of the bar is 20 cm from B. The bar is pivoted at P. The pivot is 12 cm from B.

An object X is hung from end B. The weight of X is adjusted until the bar is horizontal and in equilibrium.

(i) Explain what is meant by *centre of gravity*.

It is the position/point where the gravitational force/weight acts.

[1]

Examiner's Comments:

A number of students stated incorrectly that it was the point where mass acts.

(ii) State the two conditions necessary for a body to be in *equilibrium*.

1. The resultant force acting on the body must be zero.

2. The resultant moment exerted on the body about any point must be zero.

[2]

Examiner's Comments:

These are simple conditions which should be memorised correctly. Students who attempted to paraphrase did not convey the full meaning of the condition and thus lost the marks.

(iii) Calculate the weight of X.

$0.60\ (0.38) + 0.25\ (0.08)_X = W\ (0.12)$

$X = 2.1$ N

weight = ... N [2]

(b) The cylinder is now immersed in water, as illustrated in Fig.2.2.

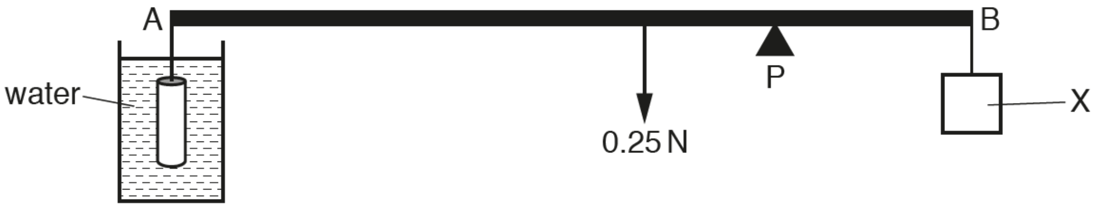


Fig. 2.2

An upthrust acts on the cylinder and the bar is not in equilibrium.

(i) Explain the origin of the upthrust.

Upthrust is the force due to the pressure difference between the top and the bottom of the cylinder.

[1]

Examiner's Comments:

"the origin of upthrust" means how upthrust arises.

(ii) Explain why the weight of X must be reduced in order to obtain equilibrium for AB.

Upthrust will cause an additional clockwise moment at position A .

The weight of X must be reduced in order to reduce the overall clockwise moment so that total clockwise moments equal to total clockwise.

[2]

OR

Upthrust will cause a decrease in the downward force pulling at point A.

This would reduce the existing anticlockwise moment at position A .

The weight of X must be reduced in order to reduce the overall clockwise

Examiner's Comments:

Correct answers would show an understanding that the addition of upthrust changes the moments and so another existing moment is required to be changed so as to restore the balance.

3 Fig. 3.1 shows a simple heat engine. When gas inside the metal cylinder is heated by the heat reservoir, a load on the platform is raised and thereby gains gravitational potential energy. In this way, thermal energy is converted into mechanical energy.

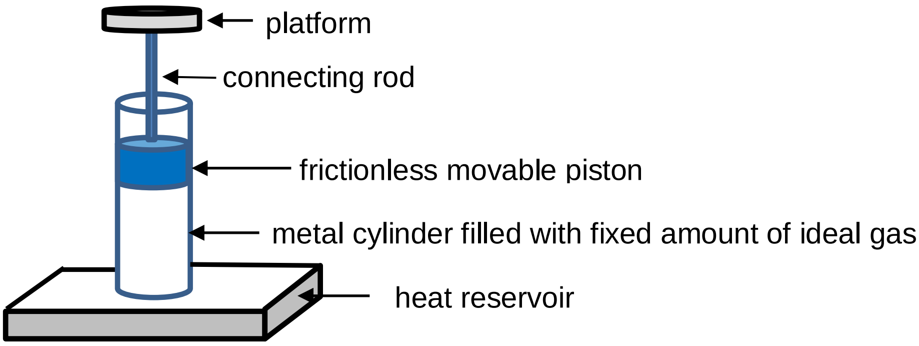


Fig. 3.1

In one cycle, the heat engine goes through the states $A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$ as shown in Fig. 3.2.

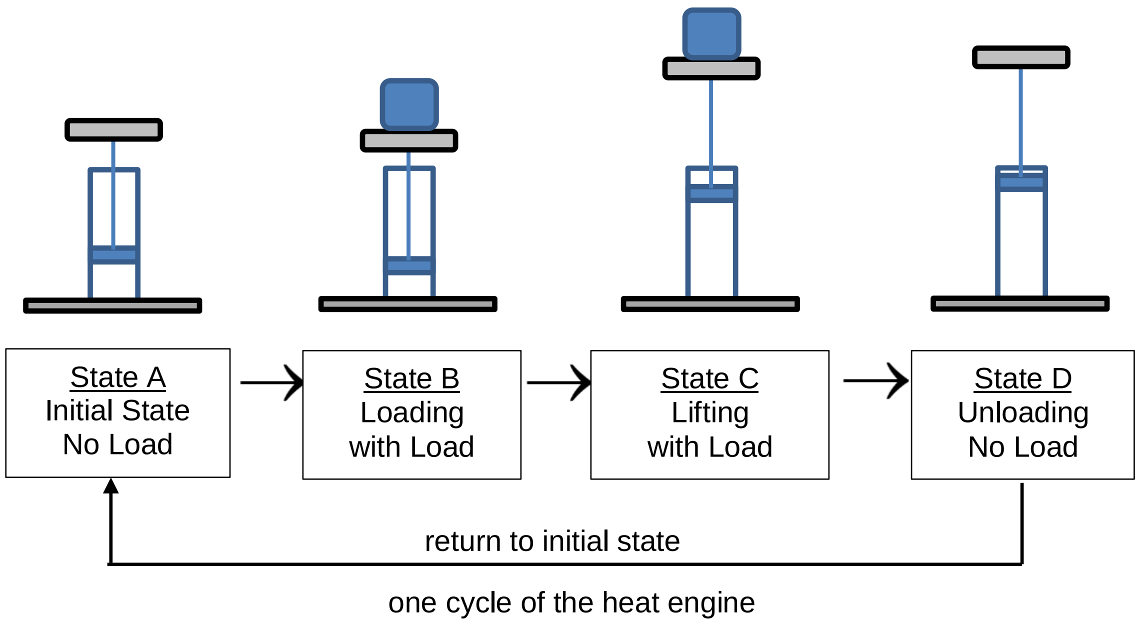


Fig. 3.2

(a) Fig. 3.3 shows the pressure, volume and temperature of the ideal gas inside the metal cylinder for states A, B, C and D.

	Ideal Gas		
State	**Pressure / kPa**	**Volume / m^3**	**Temperature / K**
A	100	1.000	292
B	110	0.909	292
C	112	1.150	376
D	100	**1.209**	353

Fig. 3.3

(i) Complete Fig. 3.3 by filling in the volume for state D. [1]

Examiner's Comments:
The values for this column will be 3 dp to be consistent. Please do not use round off values.

(ii) With reference to Fig. 3.2, explain why the pressure for states A and D are the same.

The pressure in the gas is given by the sum of the atmospheric pressure and the pressure due to the combined weight of the piston, connecting rod and platform. Since these components are the same for both states A and D, the pressure for State D is therefore the same as that for State A.

.... [1]

Examiner's Comments:
The clue given is that you are to make reference to Fig 3.2. Thus, please make good use of it.

(b) Fig. 3.4 illustrates the cycle of changes of pressure, volume and temperature undergone by the fixed mass of ideal gas inside the metal cylinder from state A to state B to state C.

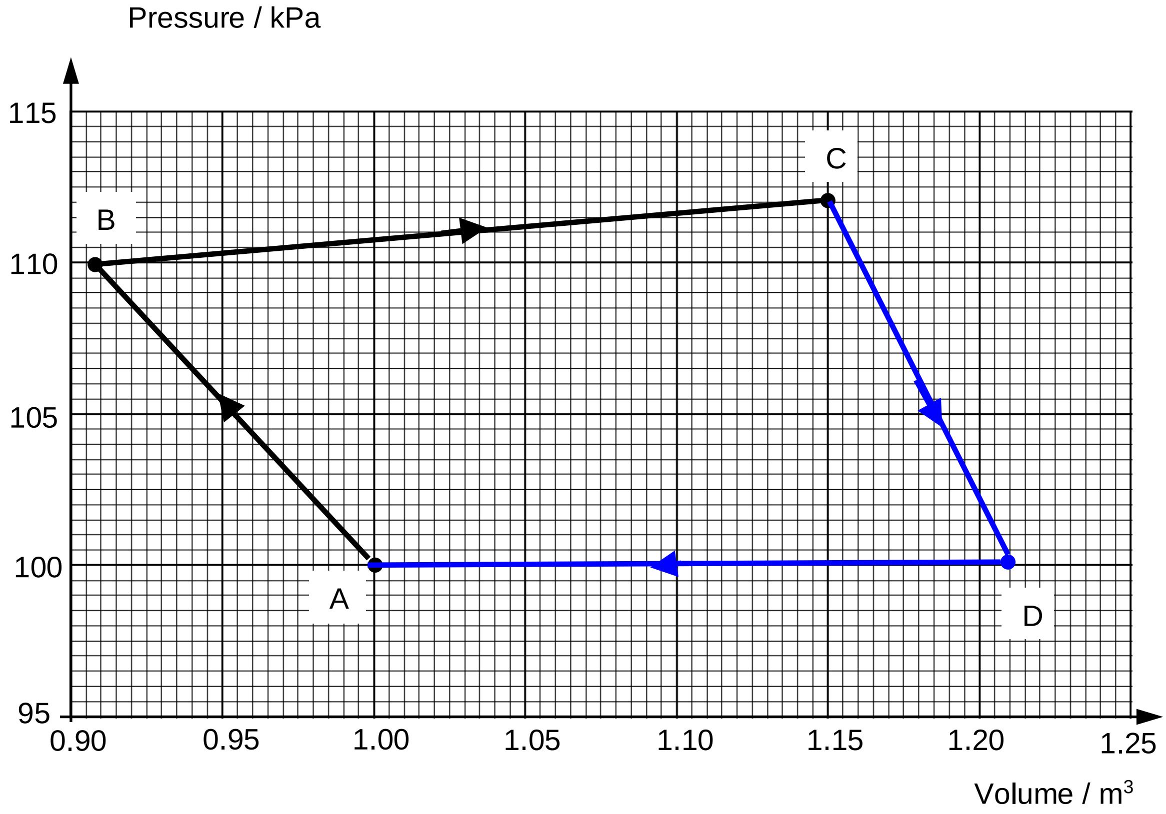


Fig. 3.4

(i) **1.** On Fig. 3.4, mark and label state D. [1]

Examiner's Comments:
Please read the scale correctly. You make to mark the point precisely and label it.

For Examiner's Use

2. On Fig. 3.4, draw the process lines joining state C to state D to state A, with arrows to indicate the direction. [1]

(ii) Using Fig. 3.4, estimate the work done by the ideal gas in one cycle.

Work done is area enclosed by the graph

W = 1/2(0.091)(10 800)+1/2 (0.15)(10800+12000)+1/2(12000)(0.11) [1]

= 491.4 + 1710 + 660

= 2870 J [1] (Correct answer)

work done = ... J [2]

Examiner's Comments:

Please learn how to determine area under the graph. Some miss out the prefix of the units kPa. As the graph is area of the loop which is clockwise, the work done on gas is negative. But the question ask for the work done by the gas, hence, the work done is positive.

(c) **(i)** State the *first law of thermodynamics*.

In a closed system, the increase in internal energy is equal to the heat supplied to the system and the work done on the system.

[1]

Examiner's Comments:

The **increase** in internal energy is important, likewise for the heat supplied **to the system** and work done **on system** and it has to be a closed system.

(ii) **1.** State what is meant by the *internal energy* of a system.

The sum of the random distribution of microscopic kinetic energy and microscopic potential energy of all the atoms or molecules is called internal energy.

[1]

Examiner's Comments:

Please recall all the definition correctly.

2. Explain why the internal energy of an *ideal gas* is proportional to the temperature of the gas.

In an ideal gas, the potential energy of its atoms is negligible because there is no interatomic forces. Therefore, the internal energy is solely equal to the random distribution of kinetic energies associated with the atoms of the ideal gas and increases as temperature of gas increases.

[1]

Examiner's Comments:

There are 2 parts, the potential energy is negligible and that kinetic energy is dependent on temperature, then internal energy is dependent on kinetic energy and thus dependent on temperature.

(iii) Calculate the change in internal energy of the ideal gas in the metal cylinder when it goes from state B to state C in **(b)**.

For ideal gas, the internal energy equals its kinetic energy.
Internal energy at B,

Since $PV = nRT$, $\Delta U = \frac{3}{2} nR\Delta T$ [1]

nR = PV/T = (100 000)(1.000) /292 = 342.5

The change in internal energy from B to C,
$\Delta U =$ 3/2 (342.5)(376-292)
= 43 200 J [1] (find change in U)

change in internal energy = ... J [2]

Examiner's Comments:
Note that change in internal energy is dependent on the change in temperature, or the change in the product of pressure and volume. This is not the product of change in pressure and change in volume.
An ideal gas need not be just 1 mole.

(iv) Hence determine the amount of thermal energy *Q* absorbed by the gas from the heat reservoir as it goes from state B to state C.

Based on the First Law of Thermodynamics
$Q = \Delta U - W$
= 43200 + 1/2(1.15- 0.908) (110 000 + 112 000) [1] (correct subsitution)
= 43 200 + 26 860 = 70 100 J [1] (correct answer)

Examiner's Comments:
The work done on the system is negative as the gas is expanding..

Q = ... J [2]

4 The I-V characteristic of an electrical component X is investigated using the circuit shown in Fig. 4.1.

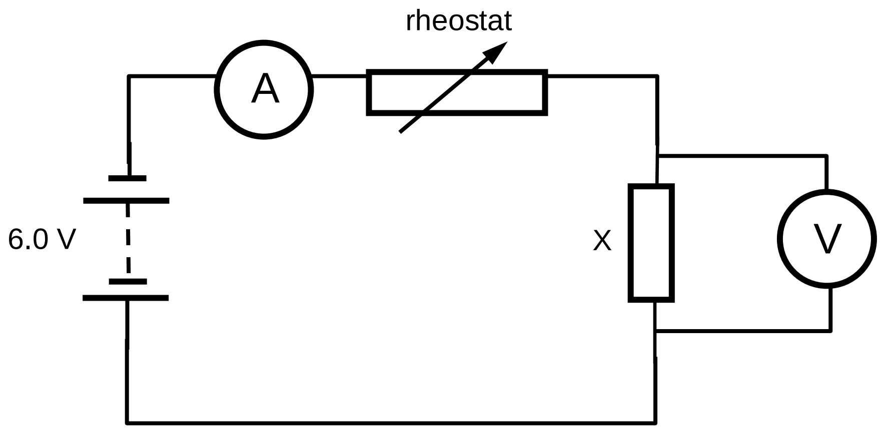


Fig 4.1

The I-V graph obtained from the results is shown in Fig 4.2.

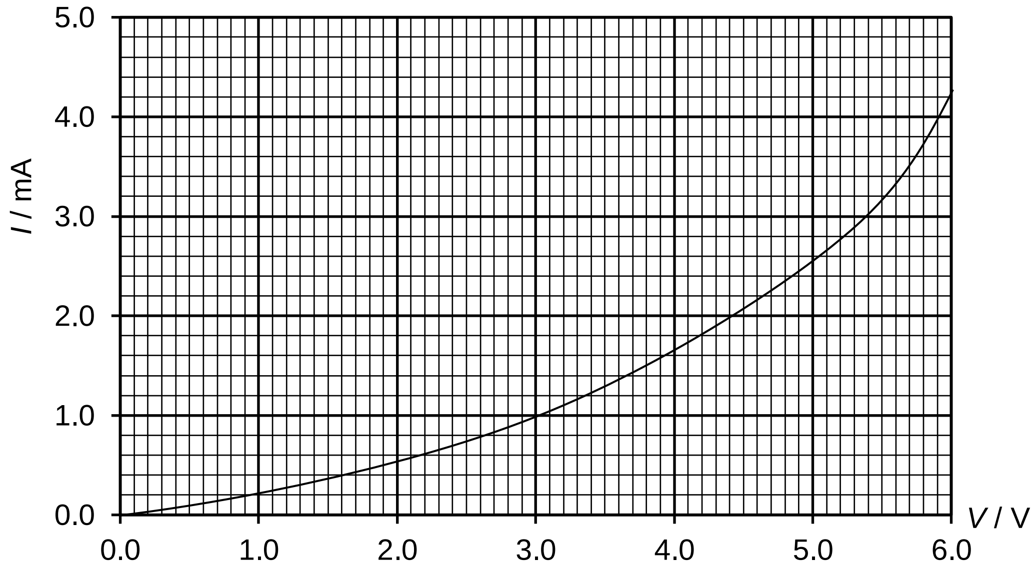


Fig. 4.2

(a) Determine the minimum and maximum resistance of component X over the range 0 – 6.0 V.

Min R = 6.0 / 4.3mA = 1400 Ω

Max R = 6000 – 10000 Ω.

minimum resistance = ... Ω

maximum resistance = ... Ω [3]

For Examiner's Use

Examiner's Comments:

A significant number of students have difficulty determine the maximum resiance fro m the graph. The suggested method is to draw a tangent at the point where p.d. is 0 V and determine 1/gradient of the tangent.

(b) State and explain whether the voltmeter reading is equal to the terminal p.d. of the cell.

.. The voltmeter reading only measure p.d. across X but there is also the rheostat in series with it. Hence the terminal p.d. is the total p.d. across the rheostat and X. ....

.. ..

.... [2]

Examiner's Comments:

Most of the students are aware that the terminal p.d. is total sum of the p.d. across component X and rheostat.

(c) The rheostat used in Fig. 4.1 has a resistance that ranges from 0 – 10 kΩ.

(i) Explain how the rheostat should be adjusted in order to measure a p.d. of 6.0 V across the component X.

When is it set to 0 Ω, the p.d. across the component will be numerically equal to the e.m.f. of the cell..

(ii) State an assumption made in your answer to **(c)(i)**.

The internal resistance of the cell is small compare to the resistance of the component when p.d. is 6.0 V.

Examiner's Comments:

A large number of students did not do a comparison between the internal resistance and another resistor. There is no cell with no internal resistance as the internal resistance can only be considered negligible if compared with a much larger resistance.

(iii) Suggest whether it is possible to obtain a value for the p.d. across the component X that is close to 0 V.

When p.d. across component X is close to 0 V, the resistance is about 6000 Ω. But the maximum resistance of the rheostat is only 10 000 Ω which is not significantly much larger, hence by potential divider, the potential will not be close to 0 V.

Examiner's Comments:

For this part, most student did not make a comparison when checking whether 0 V can be measured.

For Examiner's Use

(d) Three identical pieces of component X are arranged as shown in Fig 4.3.

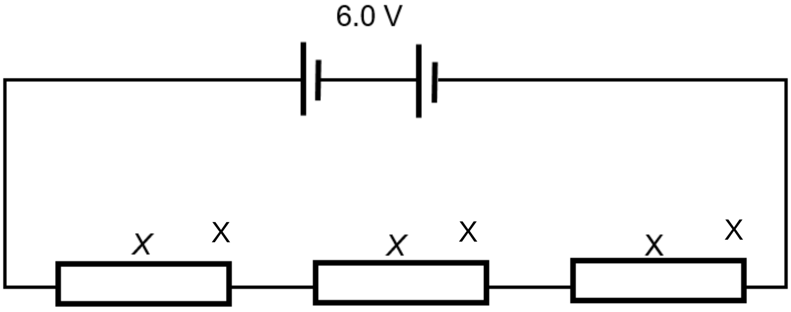


Fig. 4.3

(i) Determine the total resistance of the circuit.

When V = 2.0 V, R = 2.0/ (0.55 mA) = 3640 Ω

Hence total R = 3(3640) = 10 900 Ω

total resistance = ... Ω [2]

Examiner's Comments:

There is a large number of student who did not read the current through component X from the graph accurately . The current through component X is clearly more than 0.50 mA.

(ii) Explain why your answer in **(d)(i)** is not equal to the minimum resistance of component X.

The current through each resistor when the p.d. is 2.0 V is not 3 times smaller than when the p.d. across a single component X is 6.0 V. In fact, it is current is more than 3 times larger , hence the minimum resistance is smaller .

(iii) The circuit is then re-arranged as shown in Fig. 4.4. The total current in the circuit is 1.65 mA. Using Fig 4.2, deduce the new total resistance of the circuit in Fig. 4.4.

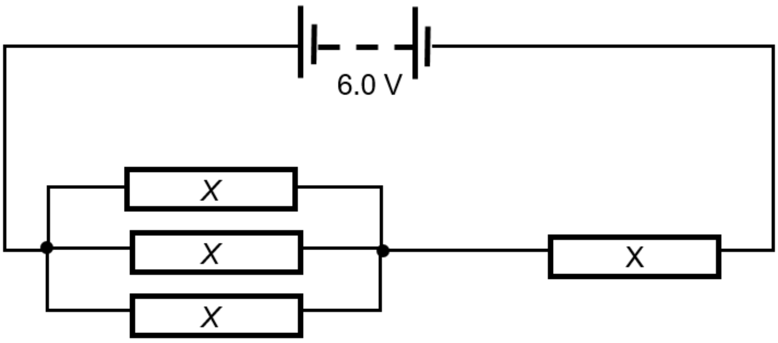


Fig. 4.4

When V = 2.0 V, Rx = 2.0/ 0.55 m = 3640 Ω

When V = 4.0 V, Rx = 2420 Ω

Hence total R = (3640/3) + 2420 = 3630 Ω

new total resistance = ... Ω [1]

5 The article below is based on an article on the Internet.

Read the article and then answer the questions that follow.

Photovoltaic (PV) Efficiency: The Temperature Effect

A photovoltaic (PV) cell absorbs light energy and converts this into electrical energy. A PV panel consists of a large number of photovoltaic cells. A PV system consists of a PV panel and the rest of the circuit to which it is connected.

Temperature generally affects current in an electrical circuit by changing the speed at which the electrons travel. In metals, this is due to an increase in resistance of the circuit that results from an increase in temperature. The opposite effect is seen in semiconductor materials where an increased temperature results in a decrease in resistance due to a change in the number density of charge carriers.

It is important that the equipment associated with a PV panel is appropriate for the context in which it will be used. The current and voltage output of a PV cell is affected by changing weather conditions. A PV system at a higher temperature will have a lower maximum voltage, lower efficiency and lower power output than the same system at a lower temperature.

Engineers must carefully choose the PV system for different temperature environments to ensure that the output voltage is not too high, which could damage the equipment. It is also important to consider the average operating voltage and current of a PV system for safety concerns, equipment capabilities and choices, and to minimize the amount of wire required for construction.

Since PV panels are more efficient at lower temperatures, engineers design systems with active and passive cooling. An example of active cooling is to pump water behind the panels to remove the heat. An example of passive cooling is to let the system be cooled by convection currents in the air.

While it is important to know the temperature of a solar PV panel to predict its power output, it is also important to know the PV panel materials because the efficiencies of different materials have varied levels of dependence on temperature. Therefore a PV system must be engineered not only according to the maximum, minimum and average environmental temperatures at each location, but also with an understanding of the materials used.

The temperature dependence of a material is described with a temperature coefficient. For monocrystalline PV panels, if the temperature decreases by 1 °C, the voltage increases by 0.48 V, so the temperature coefficient is 0.48 V $^{o}C^{-1}$. The general equation for estimating the open circuit voltage V of a material at the temperature T of the panel is

$$V = \mu \ (T_R - T) + V_R$$

where μ is the temperature coefficient, T_R is a reference temperature and V_R is the open circuit voltage at the reference temperature. The temperatures are in degrees Celsius.

The variation with voltage of current at two different temperatures for one cell of the panel is shown in Fig. 5.1.

For Examiner's Use

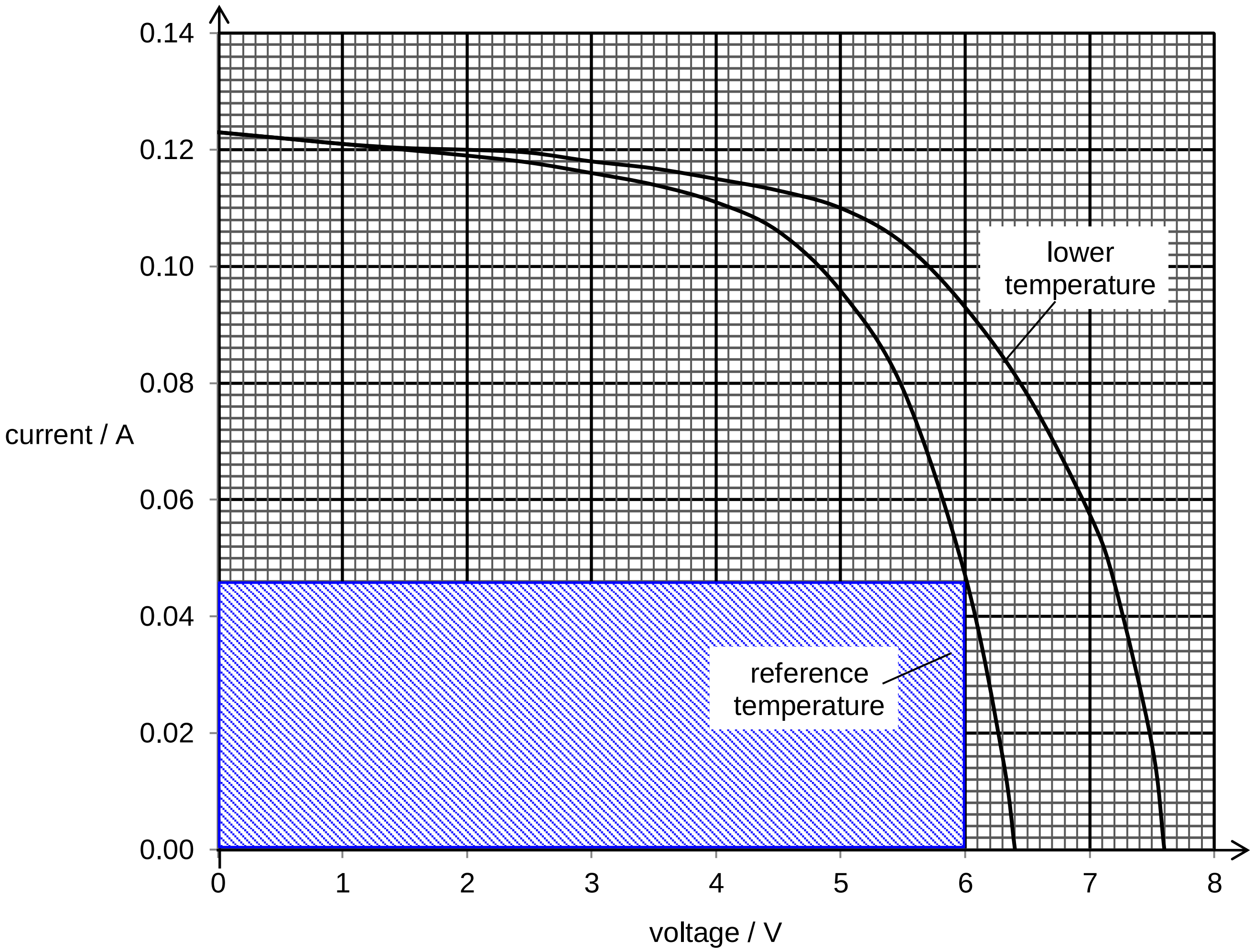


Fig. 5.1

(a) State and explain why the resistance of metals increases with temperature.

When temperature increases, the amplitude of vibration of the metal ions increases and the free electrons collide more frequently with these ions. Therefore the drift velocity of the electrons decreases, resulting in the current decreasing (recall: $I = nAve$). Hence the resistance of the metal increases.

[2]

Examiner's comments:
Students must make clear that the reduction in the drift velocity of the electrons is due to increased collisions between the electrons and the metal ions which now vibrate with larger amplitude, and that it is the reduction in drift speed that results in a lower current.A large number of students wrongly stated that electrons travel faster.

(b) The panel produces a much larger voltage or current than an individual cell. State how the cells are connected in a panel so that

(i) the voltage is increased,

In series

[1]

(ii) the current is increased.

In parallel

[1]

(c) **(i)** Suggest what is meant by *passive cooling*.

Passive cooling is an approach to cooling that focuses on the removal of heat from a system, with low or zero energy consumption, using natural means, without mechanical / electronic devices, and without additional energy input.

.... [1]

(ii) Suggest why engineers do not design systems with active cooling alone.

This is to reduce energy consumption, which would put a strain on our natural resources.
OR
This is to reduce the cost of cooling.
OR
This is to allow the system to still be cooled should the active cooling system malfunctions.

1]

(d) Give one suggestion on how passive air cooling may be enhanced for a PV panel.

Create a solar cooling chimney where the solar energy absorbed heats up air at the bottom of the chimney, which then rises to the top. This creates the suction to allow ambient cool air to enter from the bottom of the solar cooling chimney and flow over the heated PV panel surface, thereby reducing its temperature.
OR
Attach fins made from thin aluminum sheets to the PV panel. These fins help to absorb the heat generated with the PV panel and cools it under natural convection.

[2]

Examiner's comments:
To enhance passive air cooling means to use natural means to enhance it, so there should not be any fans or other mechanical devices proposed.

(e) **(i)** Use Fig. 5.1 to state the open circuit voltage (e.m.f.) of the PV cell at both the reference temperature and the lower temperature.

V_R = 6.40 V V

V = 7.60 V .... V [2]

Examiner's comments:
The open circuit voltage is found by reading from Fig. 7.1 the value of the voltage when the current is zero. It should be read to half the smallest square, i.e. to two decimal places.

(ii) Use Fig. 5.1 to describe qualitatively the variation with temperature of the current in the cell.

Current < 0.120 A:
As temperature decreases, current in the cell increases.

Current ≥ 0.120 A:
Current in the cell is independent of temperature.

.... [2]

Examiner's comments:

This part is poorly answered. Most students failed to recognise that the graph in Fig. 7.1 shows two different trends in terms of the variation of current with temperature.

Although current decreases when temperature increases for current < 0.120 A, it is **incorrect** to state that temperature and current are inversely proportional. To show inverse proportionality, one must prove that *T*.*I* = constant for at least two instances (ideally should prove that the product is a constant for 3 instances), which is not possible in this question because the temperature is unknown and there is only one variation in temperature.

It is also wrong to say that when current increases, then the temperature decreases. The cause is the change in temperature, and the effect is the change in current.

A number of students described how current changes with voltage, which meant they had totally misinterpreted the question. To determine how current changes with temperature, the voltage should be kept constant as a control variable.

Some students mentioned changes in rate of change of current, instead of just how current changes with temperature. There is insufficient information given to make any conclusion regarding the rate of change of current with time, or with temperature.

(iii) Fig. 5.2 shows the variation with temperature *T* of the open circuit voltage *V*.

For Examiner's Use

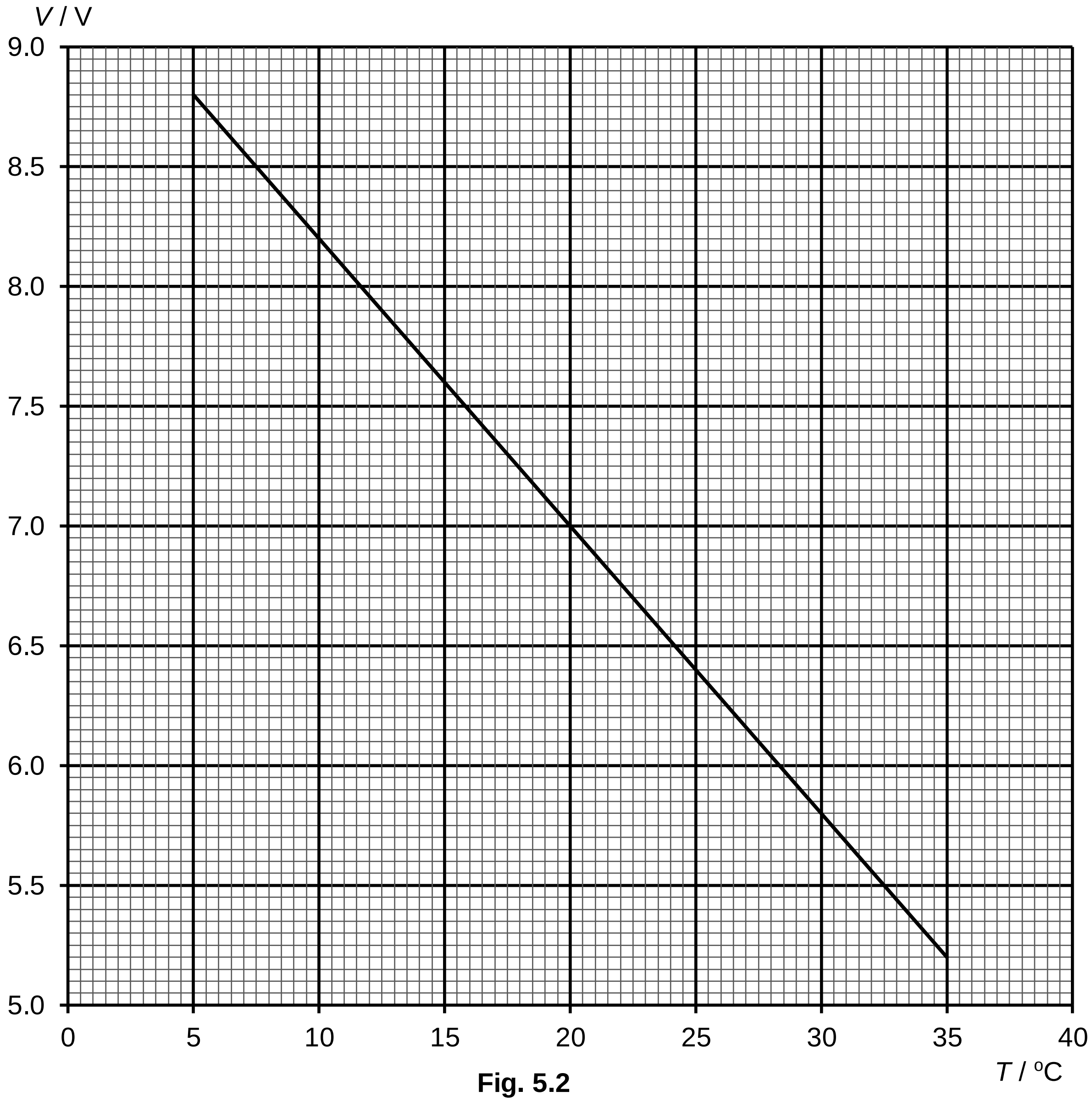


Fig. 5.2

Use Fig. 5.2 to determine the constants μ and T_R.

$V = \mu\ (T_R - T) + V_R$

$V = -\mu T + (\mu T_R + V_R)$

$\Rightarrow$ Gradient $= -\mu$

y-intercept $= \mu T_R + V_R$

Using coordinates (7.5,8.50) and (32.5,5.50):

$$\text{Gradient} = \frac{8.50 - 5.50}{7.5 - 32.5}$$

$$= \frac{3.00}{-25.0}$$

$$= -0.120$$

$\Rightarrow \mu = 0.120\ \text{V}\ ^{o}\text{C}^{-1}$

$y = mx + c$

$8.50 = -0.120(7.5) + c$

$c = 8.50 + 0.90$

$c = 9.40$

$\Rightarrow 0.120T_R + 6.40 = 9.40$

$T_R = 25.0\ ^oC$

μ = ... V $^oC^{-1}$

T_R = ... ^oC [2]

(iv) Use your answers to **(e)(i)** and **(e)(iii)** to determine the lower temperature used to obtain the data for Fig. 5.1.

From Fig. 5.2, when V = 7.60 V, T = 15.0 ^oC

lower temperature = ... ^oC [1]

(v) The PV cell is producing 6.0 V at the reference temperature. On Fig. 5.1, **shade clearly** the area which represents the output power of the cell. [1]

Rectangular area with bottom left corner at (0.00, 0.000) and upper right corner at (6.00, 0.046)

Examiner's comments:

Many students wrongly took the area under the graph from V = 0.0 V to 6.0 V to be equal to the output power. If power were to be equal to area under this I-V graph, it would mean that $P = \int I\ dV$, which would then incorrectly mean that $I = \frac{dP}{dV}$!

Since $P = IV$ (and not $P = \int I\ dV$), the output power is simply the product of I and V at the point on the graph where V = 6.0 V. Hence the area should be a rectangle with its diagonals at (0.00, 0.000) and (6.00, 0.046). For clarity, it would be good for students to draw a border around the rectangle, so that it is clear where the boundary of the shaded area lies.

(vi) Use Fig. 5.1 to estimate the maximum power output of the PV cell at the reference temperature.

Max $I.V$ occurs when V = 4.80 V and I = 0.101 A
Hence max P = 4.80(0.101) = 0.48 W
[accept max P from 0.47 W to 0.48 W]

maximum power output = ... W [2]

Examiner's comments:

Again the maximum power is determined by taking the product $I.V$ at a particular point on the graph in Fig. 7.1, not the area under the graph. This point is found by trial and error, taking one point to find the product IV, and then finding the product IV at the neighbouring points, before deciding which product is maximum.

For Examiner's Use

(f) **(i)** A PV cell may have multiple layers of different semi-conducting materials. As the number of layers increases, the efficiency of conversion of light energy to electrical energy increases.

Suggest a reason why the efficiency increases.

Different semi-conducting materials absorb different parts of the solar spectrum. By having multiple layers of these different materials, more parts of the solar spectrum can be captured. Hence the conversion efficiency increases.

.... [1]

(ii) Suggest how the angle between the PV panel and the incident sunlight affects the power output of the PV panel.

As the angle between the PV panel and the incident sunlight increases, the power output of the PV panel increases. ...

The PV panel will absorb solar radiation most effectively when the sun's rays are perpendicular to the panel's surface. Hence maximum power output of the PV panel is obtained when the angle between the PV panel and the incident sunlight is 90^{o}. ... [1]

For Examiner's Use

Section B

6 **(a)** State what is meant by a *gravitational field*.

It is a **region** of space where a **mass** experiences a gravitational **force**.

[1]

Examiner's Comments:

Some students wrote area instead of region or left out region completely. Some used point/unit mass instead of mass.

(b) Distinguish between the mass of a body and its weight.

Mass - property of body which resists change in motion, constant (independent of gravitational field strength) or scalar quantity

Weight - effect of gravitational field on a mass/body or force due to (pull of) gravity/gravitational force acting on the body, variable (dependent on gravitational field strength) or vector quantity

[2]

Examiner's Comments:

Majority of students defined unacceptably the mass as the amount of substance in a body. Some students incorrectly stated mass as the property to resist motion or to resist inertia. Some mentioned that weight is the gravitational force acting by the body instead of on. Quite a few wrote force exerted by earth or force acting downwards which is very specific to our planet and therefore not accepted. Comparison between mass and weight must be done for the marks to be awarded.

(c) Two bodies A and B, of mass 1.0×10^{30} kg and 4.0×10^{30} kg respectively, are placed at an initial distance 1.5×10^{8} km apart in space and are far away from other massive bodies, as shown in Fig. 6.1.

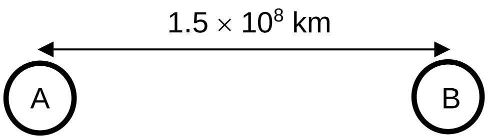


Fig. 6.1

(i) Sketch the graph of gravitational field strength g against distance x from A, and the corresponding graph of gravitational potential ϕ against distance x from A, for the region of space between bodies A and B only, on Fig. 6.2 and Fig. 6.3 respectively.

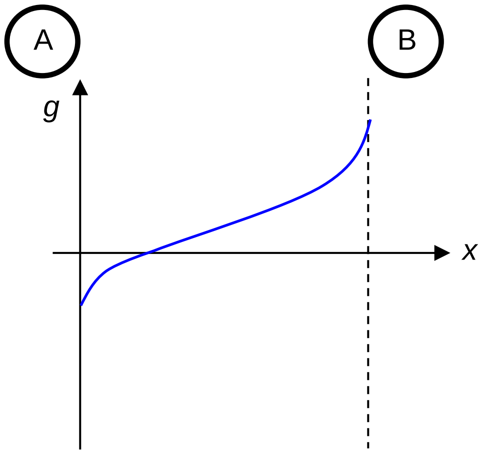


Fig. 6.2

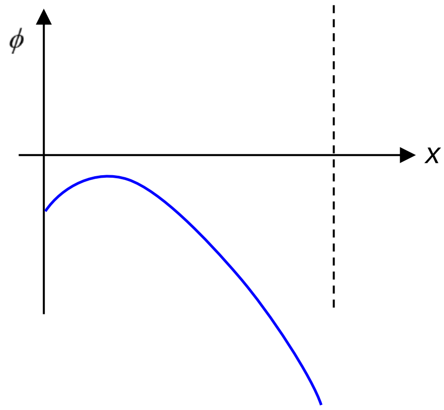


Fig. 6.3

1. correct shape of g-x graph (must cut the horizontal axis) [1]
2. correct shape of ϕ-x graph (must all lie either above of below horizontal axis) [1]
3. maximum point of ϕ-x graph corresponds to g = 0 and closer to the vertical axis [1]
4. magnitude of g(A) < magnitude of g(B) and g(A) and g(B) are of opposite signs and magnitude of ϕ(A) < magnitude of ϕ(B) and both are of the same sign. Graphs must be drawn between A and B. [1]

[4]

Examiner's Comments:
Some students continued drawing beyond the dotted vertical line despite being asked to draw for the region of space between the bodies. The line is there for a reason. Many did not start and end the graphs on the vertical lines. The vertical axis and line are not vertical asymptotes. The values of g and ϕ are finite on the surfaces.

(ii) Bodies A and B are now released at the same time from their initial positions as shown in Fig. 6.1.

1. Determine the speeds of bodies A and B when the distance between them is half their initial distance apart.
Let the initial distance between the two be d,
By law of conservation of energy,

For Examiner's Use

$$E_i = E_f$$
$$GPE_i = KE_f + GPE_f$$
$$KE_f = GPE_i - GPE_f$$
$$= -\frac{Gm_A m_B}{d} - \left[-\frac{Gm_A m_B}{\left(\frac{d}{2}\right)} \right]$$
$$= \frac{Gm_A m_B}{d}$$
$$= \frac{(6.67\times10^{-11})(1.0\times10^{30})(4.0\times10^{30})}{1.5\times10^{11}}$$
$$= 1.78\times10^{39} \text{ J}$$

By principle of conservation of linear momentum,

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$
$$v_B = -\frac{m_A v_A}{m_B}$$
$$= -\left(\frac{1.0\times10^{30}}{4.0\times10^{30}}\right) v_A$$
$$= -\frac{v_A}{4} \quad \ldots \quad (1)$$
$$KE_f = \frac{1}{2} m_A v_A{}^2 + \frac{1}{2} m_B v_B{}^2$$
$$= \frac{1}{2} m_A v_A{}^2 + \frac{1}{2} m_B \left(-\frac{v_A}{4}\right)^2$$
$$= \frac{1}{32}(16m_A + m_B) v_A{}^2$$
$$v_A = \sqrt{\frac{32KE_f}{16m_A + m_B}}$$
$$= \sqrt{\frac{32(1.78\times10^{39})}{16(1.0\times10^{30}) + 4.0\times10^{30}}}$$
$$= 5.3\times10^4 \text{ m s}^{-1}$$
$$v_B = -\frac{v_A}{4}$$
$$= -\frac{5.33\times10^4}{4}$$
$$= -1.3\times10^4 \text{ m s}^{-1}$$

speed of body B = 1.3×10^4 m s^{-1}

speed of body A = ... m s^{-1}

speed of body B = ... m s^{-1} [4]

Examiner's Comments:

Students who tackled the problem as a motion in a circle question are not given any mark. Extremely few students realised that the GPE belongs to the system consisting bodies A and B and equate the loss in GPE to the gain in

KE of both bodies. Very few applied the principle of conservation of linear momentum and none got the question right.

2. Calculate the ratio of the initial acceleration of A to that of B.

By N3L, the force exerted by A on B is equal in magnitude but opposite in direction to the force exerted by B on A,

$$F_{\text{A on B}} = -F_{\text{B on A}}$$

$$\left(4.0\times10^{30}\right)a_{B} = -\left(1.0\times10^{30}\right)a_{A}$$

$$\frac{a_A}{a_B} = -4$$

ratio = ... [2]

Examiner's Comments:

Some students calculated force when the distance between A and B is halved and are not given any credit as question specifically asks for initial accelerations. Students who treated the bodies as undergoing circular motion are not awarded any mark.

(iii) Both A and B are now fixed in position and a third mass m is placed at a distance r from A as shown in Fig. 6.4.

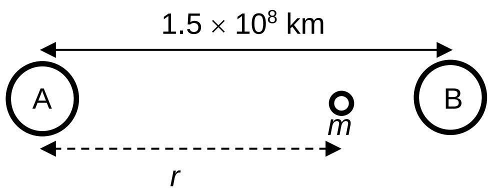


Fig. 6.4

1. Determine the range of possible values which r can take, such that m will accelerate towards A when it is released from rest at this distance r from A.

At neutral point, net force acting on m is zero.

$$F_A = F_B$$

$$\frac{GMm}{r^2} = \frac{G(4M)m}{(d-r)^2}$$

$$\left(\frac{d-r}{r}\right)^2 = 4$$

$$\frac{d-r}{r} = 2$$

$$3r = d$$

$$r = \frac{d}{3}$$

$$= \frac{1.5\times10^{11}}{3}$$

$$= 5.0\times10^{10}\ \text{m}$$

In order for m to accelerate towards A, the mass has to be nearer to A than B such that the net force is towards A. Hence $r < 5.0\times10^{10}$ m.

range: .... [2]

For Examiner's Use

Examiner's Comments:
Calculations done with r in km are accepted. Many did not square root first which will simplify the calculation significantly. Students who did not substitute the values of masses and distances are penalised. Some students did not write the correct range of r using $\leq$ instead of $<$. Quite a number did not write r to the correct s.f. with the correct unit. A few do not know how to leave numbers in standard form.

2. Using $r = 6.0 \times 10^{10}$ m and $m = 2.5 \times 10^{28}$ kg, calculate the gravitational potential energy of m in Fig. 6.4.

$$GPE = -\frac{Gm_A m}{r} + \left(-\frac{Gm_B m}{d-r}\right)$$

$$= -Gm\left(\frac{m_A}{r} + \frac{m_B}{d-r}\right)$$

$$= -\left(6.67 \times 10^{-11}\right)\left(2.5 \times 10^{28}\right)\left(\frac{1.0 \times 10^{30}}{6.0 \times 10^{10}} + \frac{4.0 \times 10^{30}}{1.5 \times 10^{11} - 6.0 \times 10^{10}}\right)$$

$$= -1.0 \times 10^{38} \text{ J}$$

gravitational potential energy = ... J [2]

Examiner's Comments:
Many students did not consider both masses when calculating the GPE. Some did not convert the distance from km to m. A significant number of students subtract the two terms instead of adding. A handful of students did not substitute the values of masses and distances and are penalised for that. No mark will be awarded at all for incorrect substitution of the value of G.

3. Using the same values of r and m as in **(c)(iii)2.**, determine the speed of mass m when it is midway between A and B, after being released from rest at its initial position in Fig. 6.4.

By law of conservation of energy,

$$E_i = E_f$$

$$GPE_i = KE_f + GPE_f$$

$$KE_f = GPE_i - GPE_f$$

$$= GPE_i - \left[-\frac{Gm_A m}{\left(\frac{d}{2}\right)} - \frac{Gm_B m}{\left(\frac{d}{2}\right)}\right]$$

$$= GPE_i + \frac{2Gm}{d}\left(m_A + m_B\right)$$

$$\frac{1}{2}\left(2.5 \times 10^{28}\right)v^2 = -1.0 \times 10^{38} + \frac{2\left(6.67 \times 10^{-11}\right)\left(2.5 \times 10^{28}\right)}{1.5 \times 10^{11}}\left[\left(1.0 + 4.0\right)10^{30}\right]$$

$$v = 2.7 \times 10^{4} \text{ m s}^{-1}$$

speed = ... m s^{-1} [2]

Examiner's Comments:
Many students did not consider both masses A and B when computing the final GPE. Some were not able to apply the law of conservation of energy and are not given any credit.

For Examiner's Use

(iv) State an assumption made in the calculations in **(c)(ii)** and **(c)(iii)**.

Bodies are point masses.

[1]

Examiner's Comments:

Some students stated that there is no air resistance/resistive force which is not accepted as the bodies are placed in space and there will not be air resistance because there is no air in space. Some mentioned that there is no loss in energy or all the loss of GPE is converted to KE which is merely a statement of the law of conservation of energy.

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMNATION
Higher 2

PHYSICS 9749/01

Paper 1 Multiple Choice

28 September 2017

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the one you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{\left(x_o{}^2 - x^2\right)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

1 The resistance R of a conductor is defined as the ratio of potential difference across it to current through it. Which of the following is an acceptable unit of R?

A V A **B** kg A^{-2} m^2 s **C** kg m^2 s^{-3} **D** kg C^{-2} m^2 s^{-1}

Ans: D

$[R] = [V / I] = [(W / Q) / I] = [W / I^2 t] = \text{kg m}^2 \text{s}^{-2} \text{A}^{-2} \text{s}^{-1} = \text{kg A}^{-2} \text{m}^2 \text{s}^{-3}$
$= \text{kg } (\text{A}^{-2} \text{s}^{-2}) \text{m}^2 \text{s}^{-1} = \text{kg C}^{-2} \text{m}^2 \text{s}^{-1}$

2 On a map, the distance of towns P and Q from town T are measured to a precision of ±0.5 cm as 38.5 cm and 43.5 cm respectively. If the scale of the map is 1:20 000, which of the following best expresses how much further town Q is from town T on the ground compared to town P?

A 1.00 km ± 20%

B 1.0 km ± 20%

C 0.100 km ± 4%

D 0.1 km ± 4%

Ans: B

On map: Difference d = 43.5 – 38.5 = 5.0 cm
$\Delta d = \pm(0.5 + 0.5) = 1$ cm

On ground: Difference $D = 5.0/100 \times 2\times10^4 = 1000$ m = 1.00 km
$\Delta D = \pm(0.5 + 0.5) \times 2\times10^4 = 0.2$ km → D is precise to 1dp of km
$\Delta D/D = 0.2 / 1.0 = 20\%$

3 PQRS is a parallelogram made up of four vectors PQ, QR, RS and SP.

At time $t = 0$, the velocities of cars X and Y are represented by the vectors PQ and –SP respectively. At $t = 10$ s, both cars are moving with the same velocity.

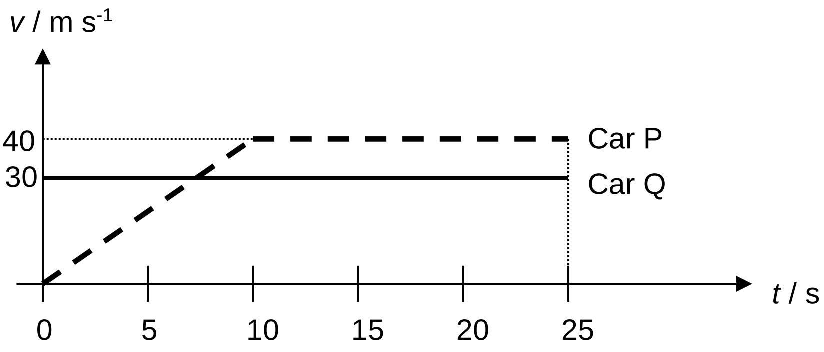
Between $t = 0$ and $t = 10$ s, car X undergoes a change in velocity represented by the vector QR. What is the change in velocity of car Y during the same time period and its final velocity?

	change in velocity	final velocity
A	RS	–QS
B	RS	QS
C	–RS	PR
D	–RS	–PR

Ans: C

Final velocity of X = PQ + QR = PR   = Final velocity of Y
Change in velocity of Y = PR – (– SP) = –RS

4 The figure below shows the velocity-time graph of two cars moving along the same road. If both cars were at the same point at t = 0 s, at what time will they meet again?



A 7.5 s **B** 15 s **C** 20 s **D** 25 s

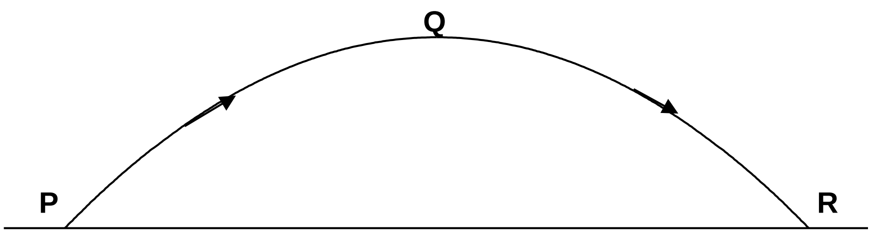
Ans : C
Distance by Q = Distance by P
30t = ½(10x40) + 40(t−10)
t = 20 s

5 A projectile is projected at an angle θ above the ground. When it reaches its maximum height of 10 m, it has a speed of 20 m s^{-1}. The value of θ is

A 26° **B** 35° **C** 45° **D** 67°

Ans: B
$v_y^2 = u_y^2 + 2as$
$0 = u_y^2 + 2(-9.81)(10)$
$u_y = 14$
$\tan^{-1} = uy / u_x = 35^o$
solving, θ = 35°

6 In the absence of air resistance, a stone thrown from **P** follows a parabolic path, reaching the highest point at **Q**, and finally landing at **R**.



Which of the following statements is true?

A The velocity of the stone at **Q** is zero because it has reached maximum height.
B The time taken to reach **Q** from **P** is greater than the time taken to reach **R** from **Q**.
C The acceleration of the stone between **P** and **Q** is positive and the acceleration between **Q** and **R** is negative.

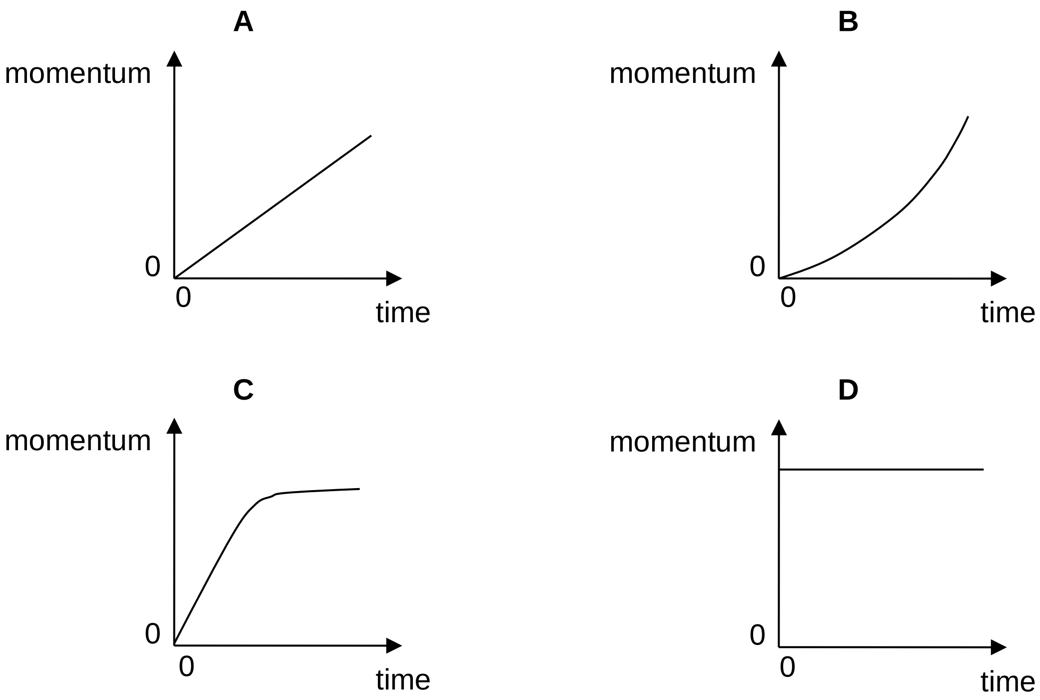
D The speed of the stone is the same at **P** and **R**.

Ans: D

By symmetry, u_x at P = u_x at R and u_y at P = $-u_y$ at R

Although the velocities at P and R have different directions, they have the same magnitude.

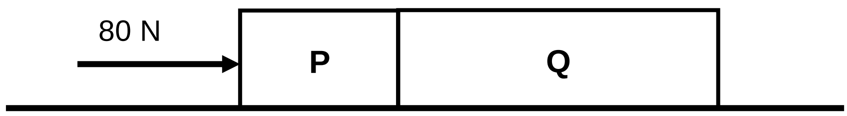
7 Which graph best shows the variation with time of the momentum of a body accelerated by a constant force?



Ans: A

Constant force implies the momentum changes at a constant rate.

8 Box P and Q of masses 1.0 kg and 4.0 kg respectively are being pushed along a rough, horizontal surface by a constant force of 80 N. The two boxes slide across the rough surface with a constant velocity of 2.0 m s^{-1} to the right. The frictional force acting on box P is 25 N. The force exerted by box Q on box P is



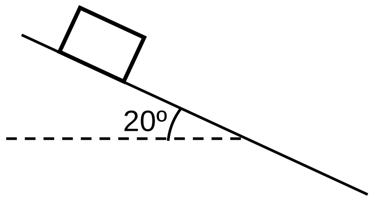
A 52 N **B** 55 N **C** 64 N **D** 80 N

Ans: B

Since boxes are moving at constant speed, the contact force acting on box P = 80 – 25 = 55 N

Hence by Newton's Third Law, N by Q on P = 55 N

9 A block of mass 1.2 kg slides down a smooth slope from rest as shown below. What is the momentum of the block along the slope after 4.0 s?



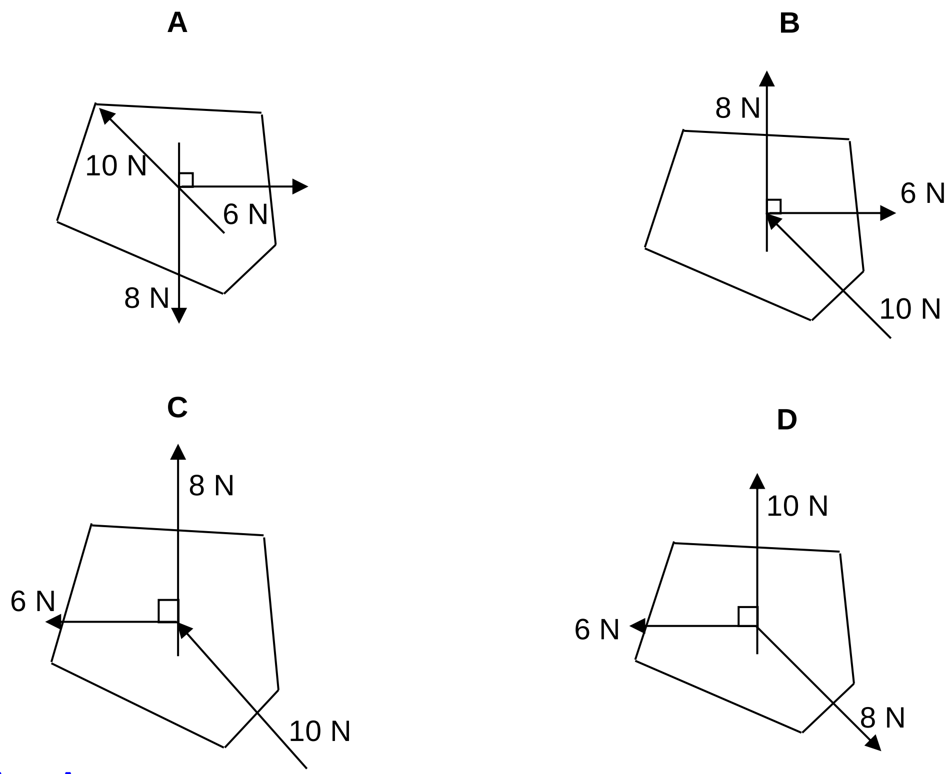
A 13 kg m s^{-1} **B** 16 kg m s^{-1} **C** 37 kg m s^{-1} **D** 44 kg m s^{-1}

Ans: B

v = u + at = (9.81 sin20)(4)

p = mv = 16

10 Three coplanar forces, 10 N, 8 N and 6 N act on a flat object. Which one of the following shows the flat object in equilibrium under the action of the forces?



Ans: A

Forces must form a triangle when re-arranged in a vector diagram.

11 A submarine descends vertically at a constant velocity. The three forces acting on the submarine are viscous drag, upthrust and weight. Which relationship between the magnitudes of the forces is correct?

A weight < drag
B weight = drag
C weight < upthrust
D weight > upthrust

Ans: D

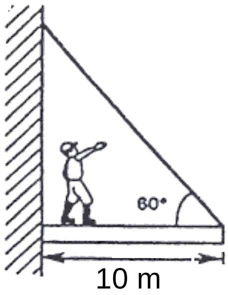
Weight => downward

Upthrust = > upward

Drag (opposes motion) = > upward

Weight = Upthrust + Drag (constant velocity)

12 A uniform horizontal beam of length 10 m and weight 200 N is attached to a wall as shown below.
The far end of the beam is supported by a cable which makes an angle of 60° with respect to the beam. A 500 N boy stands 2.0 m from the wall. The tension in the cable is 230 N.

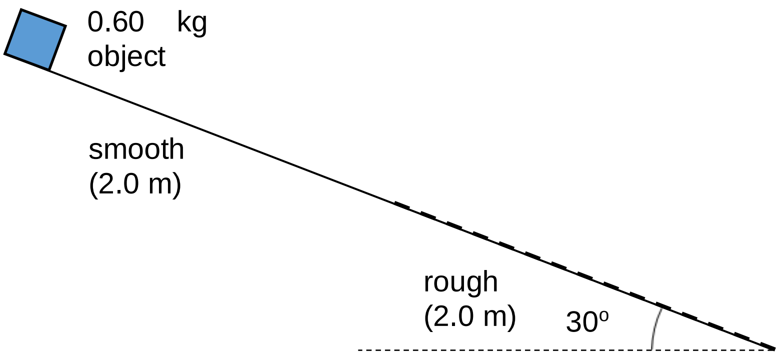


The force exerted by the wall on the beam is

A 150 N **B** 470 N **C** 510 N **D** 620 N

Ans: C
$F_x = 230 \cos 60^o = 115$
$F_y = 230 \sin 60^o - 200 - 500 = -501$
$F = \sqrt{((-501)^2 + 115^2)} = 514$ N

13 An plane inclined at 30° to the horizontal consists of a 2.00 m smooth portion at the top and a 2.00 m rough portion at the bottom.



A 0.600 kg object is released from rest at the top of the plane. Assuming that it experiences a constant frictional force of 7.50 N from the rough portion, what is the total distance travelled by the object before it comes to a stop?

A 2.44 m **B** 2.65 m **C** 2.78 m **D** 3.29 m

Ans: D
Let distance in rough portion be x.
Change in GPE = WD by friction (KE no net change)
$-(0.600)(9.81)(2.00 + x) \sin 30^o = -7.50x$
$x = 1.29$ m

14 A car is moving horizontally at a constant velocity of 12 m s^{-1}. The driving force provided by the engine of the car is 500 N.

Which of the following statements is correct?

A The net force on the car is 500 N.

B The power provided by the engine is 42 W.

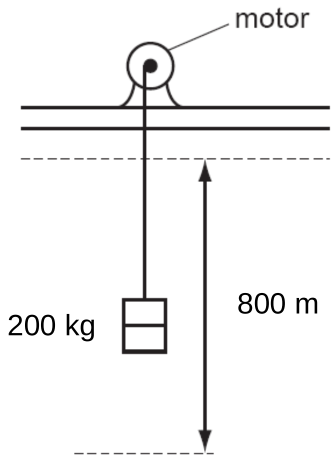
C The work done by the engine to maintain constant velocity is 42 J.

D The rate of energy lost by the car is 6.0 kW.

Ans: D

For a car to move at constant velocity, the net force on it must be 0 N. Since the engine of the car exerts a forward force on the car, there exists a resistive force that opposes this forward force and causes the net force to be 0 N. This resistive force does negative work on the car. By Conservation of Energy, this energy must come from the engine itself so we can calculate the rate of energy lost by calculating the power of the engine, which is 6.0 kW.

15 An electric motor is required to raise a 200 kg mass at constant speed through a vertical height of 800 m in 4.0 minutes.



The efficiency of the motor is 75%. What is the electrical power supplied to the motor?

A 4.9 kW **B** 8.7 kW **C** 26 kW **D** 520 kW

Ans: B

$$\text{Useful power} = \frac{\text{Useful work done}}{\text{time taken}}$$
$$= \frac{\text{Change in gravitational potential energy}}{\text{time taken}}$$
$$= \frac{mgh}{t}$$

$$\text{Electrical power supplied to motor} = \frac{100}{75} \times \text{Useful power}$$
$$= \frac{100}{75} \times \frac{mgh}{t}$$
$$= \frac{100}{75} \times \frac{200 \times 9.81 \times 800}{4.0 \times 60}$$
$$= 8.7 \text{ kW}$$

16 Two identical particles P and Q are set to travel in circular paths of the same radius. P moves in a vertical circle while Q moves in a horizontal circle. Both move with the same uniform speed.

Which one of the following statements concerning the *net force* acting on P and Q is true?

A The magnitudes of the net forces on P and Q are not constant throughout the motion and are not equal to each other.

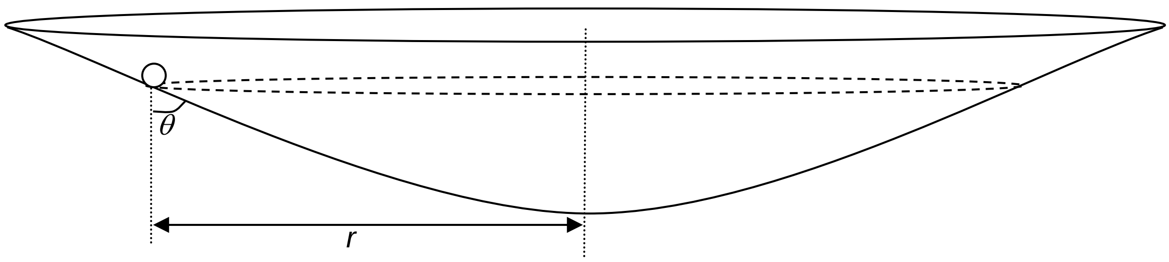
B The magnitudes of the net forces on P and Q are not constant throughout the motion but are always equal to each other.

C The magnitudes of the net forces on P and Q remain constant throughout the motion but are not equal to each other.

D The magnitudes of the net forces on P and Q remain constant throughout the motion and are always equal to each other.

Ans: D
The speed of both motions is the same. Hence, magnitude of net force is the same although the direction keeps changing.

17 A sphere of mass *m* moves along a smooth horizontal circular path of radius *r* in a bowl with a constant linear speed *v*. The side view of the bowl is as shown below.



Which of the following gives the expression for angle θ?

A $\tan^{-1}\left(\dfrac{rg}{v^2}\right)$ **B** $\tan^{-1}\left(\dfrac{v^2}{rg}\right)$ **C** $\sin^{-1}\left(\dfrac{mv^2}{r}\right)$ **D** $\sin^{-1}(mg)$

Ans: A

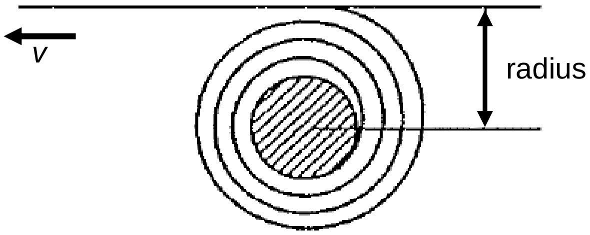
$N\sin\theta = mg$

$N\cos\theta = \dfrac{mv^2}{r}$

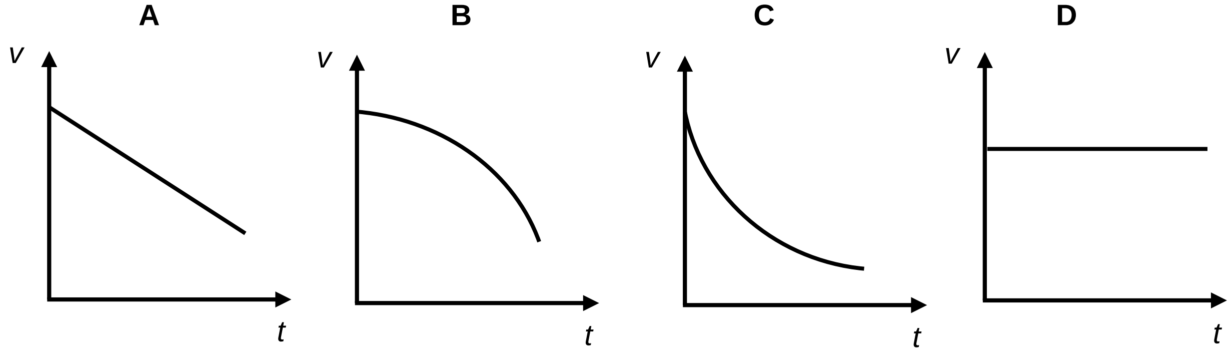
Therefore, $\tan\theta = \dfrac{rg}{v^2}$.

$\theta = \tan^{-1}\dfrac{rg}{v^2}$

18 A straight length of tape unwinds from a roll rotating about a fixed axis with constant angular velocity. The radius of the roll decreases at a steady rate.



Which of the following graphs correctly shows how the variation of speed v at which the tape moves away from the roll with time t?



Ans: A

Using v = rω, since angular velocity ω remains constant, hence speed v varies proportionally with r, which decreases at a constant rate

19 Which of the following statements about gravitational field is correct?

A The gravitational potential increases with the strength of the field.

B The field is directed towards increasing potential.

C Where the strength of the field is maximum, gravitational potential must be zero.

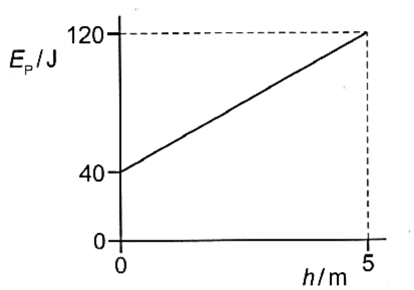
D Where gravitational potential is maximum, the strength of the field must be zero.

Ans: D

$$g = -\frac{d\phi}{dt}$$

Field strength is proportional to potential gradient and in the direction of negative gradient.

20 The graph below shows how the gravitational potential energy E_p of an object near Mars' surface varies with height h.



Assuming that Mars' gravitational field is uniform, the gravitational force that Mars exert on the object is

A 8.0 N **B** 16 N **C** 24 N **D** 32 N

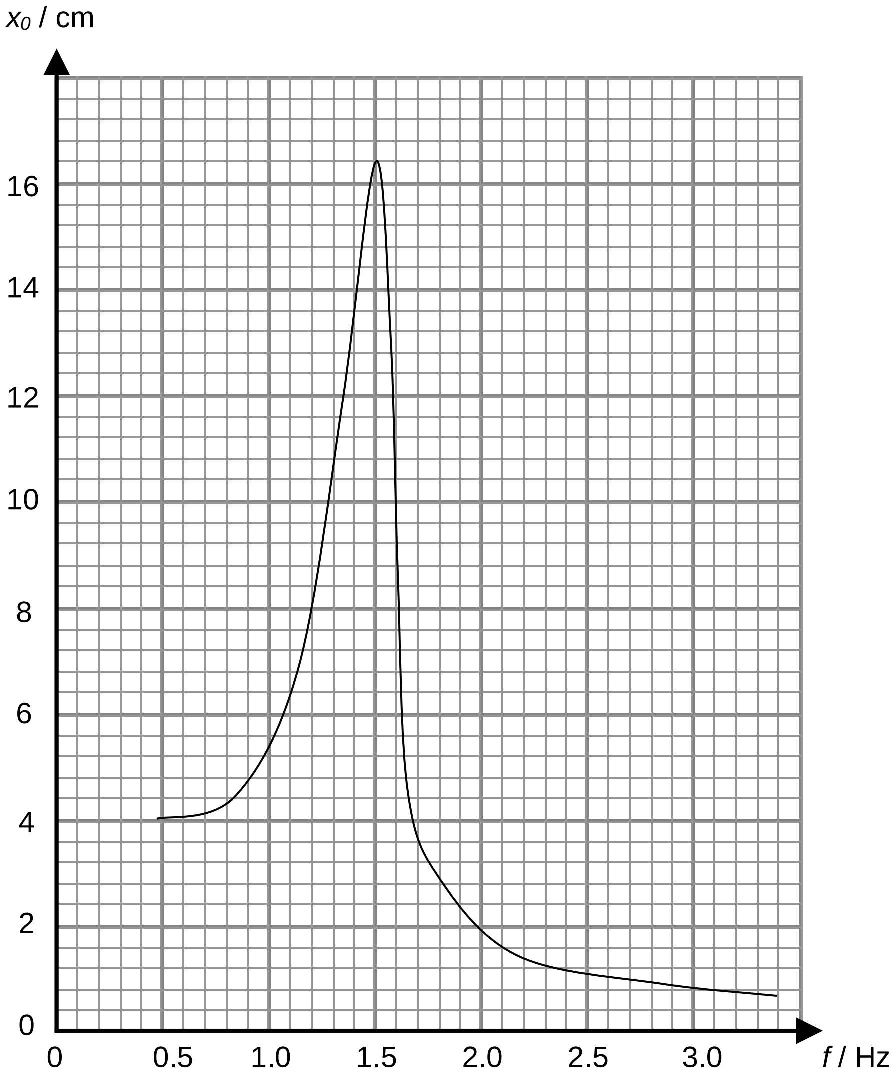
Ans: B

Force = Gradient of Potential Energy vs Distance graph

$$= \frac{120-40}{5-0}$$

$= 16$ N

21 The diagram below shows the variation with driving frequency f of the amplitude x_0 of a machine undergoing forced oscillation.



At resonance, which of the following correctly shows the maximum linear velocity and whether the machine experiences any damping?

	velocity / m s^{-1}	damping
A	1.55	No
B	1.55	Yes
C	14.6	No

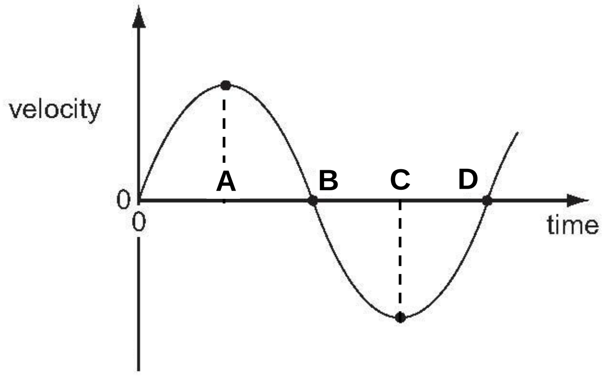
D	14.6	Yes

Ans: B

Resonant freq, f = 1.5 Hz, x_0 = 16.4 cm.

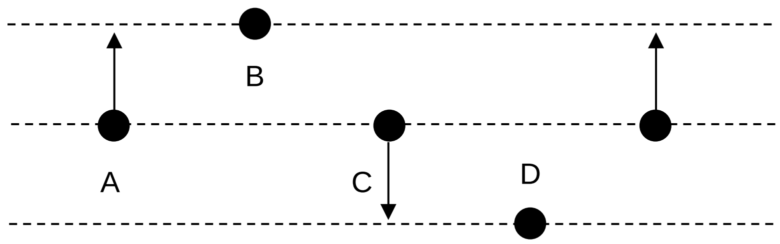
Hence $v_{max} = \omega x_o = x_0\,(2\pi f)$ = 1.55 m s^{-1}

22 The figure below shows the variation with time of the velocity for a mass oscillating vertically on the end of a spring. Taking the upward direction to be positive, which of the points shows the time at which the mass experiences maximum upward acceleration?



Ans: D

Displacement of the mass at each instant is shown below. At time D, it has maximum displacement and hence maximum acceleration in the opposite direction to displacement.



23 A particle performs simple harmonic motion with a maximum acceleration of 5.0 m s^{-2} and a maximum speed of 3.0 m s^{-1}. What is the frequency of the particle's oscillation?

A 0.095 Hz

B 0.27 Hz

C 0.60 Hz

D 1.7 Hz

Ans: B

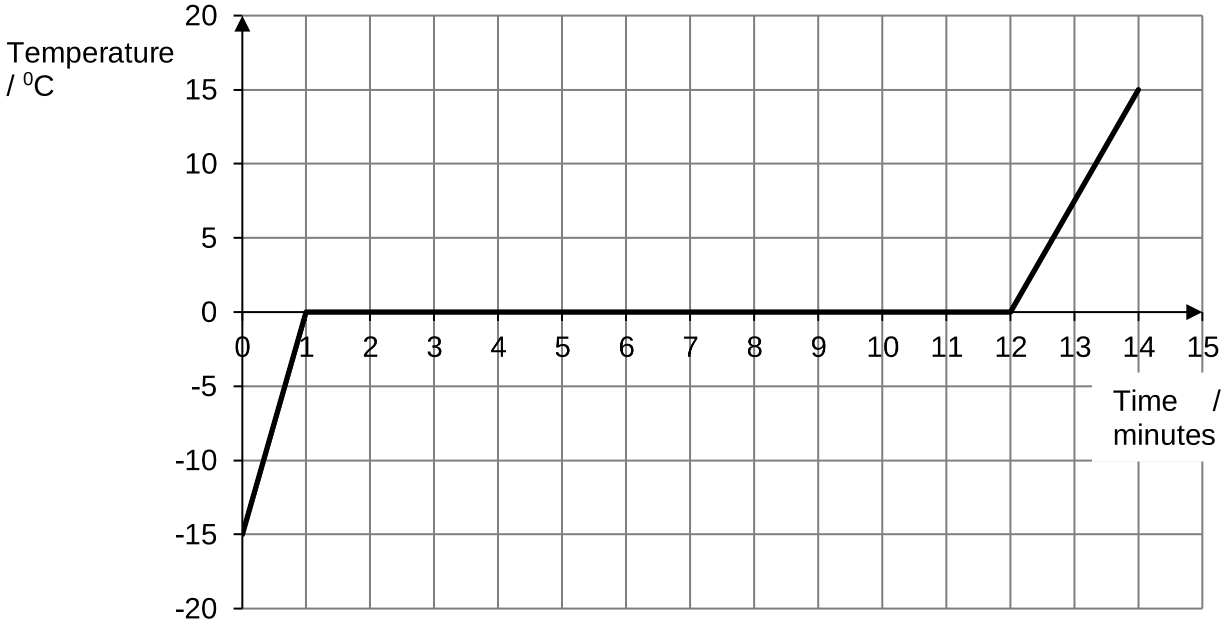
Using $a_{max} = \omega^2 x_{max}$ and

$v_{max} = \omega\, x_{max}$,

then $\omega = \dfrac{a_{max}}{v_{max}} = \dfrac{5.0}{3.0}$

f = $\omega/2\pi = 0.27$

24 A block of ice is heated at a constant rate by a 0.25 kW heater. The graph below shows how the temperature of the ice and subsequently water changes with time.



Given that the specific latent heat of fusion of water is 3.3×10^5 J kg^{-1} and there is no heat loss to surroundings, what is the mass of the block of ice?

A 0.023 kg **B** 0.045 kg **C** 0.50 kg **D** 8.3 kg

Ans: C

Time taken to melt the ice = 11 minutes

$$Pt = ml$$

$$0.25 \times 10^3 \times 11 \times 60 = m \times 3.3 \times 10^5$$

$$m = 0.50 \text{ kg}$$

25 A cylinder contains a mixture of helium and argon gas in thermal equilibrium. The gases are assumed to be ideal.

Which of the following statements is correct about the mixture?

A The average kinetic energy of the particles of both gases are the same.

B The particles of both gases have the same root mean square speed.

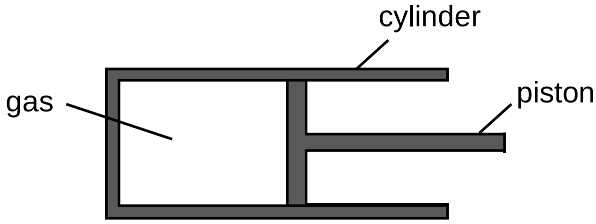
C All the particles move at the same speed.

D Both gases must have the same number of moles because they are in thermal equilibrium.

Ans: A

The average kinetic energy is proportional to the temperature. Since the gases are at the same temperature, both have the same average kinetic energy. Since the mass of the particles are different, they will have different root mean square speeds.

26 An ideal gas is contained in a cylinder fitted with a piston, as shown.



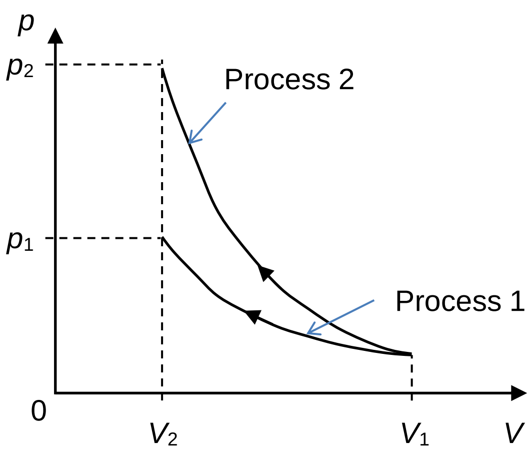
Process 1 is an isothermal process whereby the piston is moved inwards slowly so that the volume of the gas is reduced slowly to half its initial volume. The work done on the gas is W_1 and the final temperature of the gas is θ_1.
Process 2 is an adiabatic process whereby the piston is moved inwards suddenly so that the volume of the gas is reduced to half its initial volume. The work done on the gas is W_2 and the final temperature of the gas is θ_2.
Which of the following correctly describes work done on the gas and the final temperature of the gas in Processes 1 and 2?

	work done on gas	final temperature of gas
A	W_1 is the same as W_2	θ_1 is the same as θ_2
B	W_1 is the same as W_2	θ_1 is less than θ_2
C	W_1 is less than W_2	θ_1 is less than θ_2
D	W_1 is less than W_2	θ_1 is greater than θ_2

Ans: C
In Process 1, as the piston is moved inwards slowly, there will be no change in temperature of the gas in the cylinder. Hence, this is a constant temperature process, $\Delta T = 0$, $\Delta U = 0$.
Applying the First Law of Thermodynamics, $\Delta U = 0$, $Q = -W$. As it is a compression, work is done on gas, i.e. W is positive. However, as the process takes place slowly, the gain in energy due to the work done on the gas is lost to the surrounding.

In Process 2, as the piston is moved inwards suddenly, there is insufficient time for heat energy to leave nor be supplied to the gas in the cylinder. Hence, $Q = 0$.
Applying the First Law of Thermodynamics, $\Delta U = Q + W$, $\Delta U = W$. As it is a compression, work is done on gas, i.e. W is positive. Hence, $\Delta U = W$ is positive, implying increase in internal energy and increase in temperature of gas.

By drawing a p-V graph, it can be deduced that the work done on the gas in Process 1 is lower than that in Process 2.



27 A point source emits sound with a power of 60.0 W. A small microphone of area 0.75 cm^2 detects the sound at a distance of 5.0 m from the source. What is the power detected by the microphone?

A 1.4×10^{-5} W

B 7.2×10^{-5} W

C 1.4×10^{-3} W

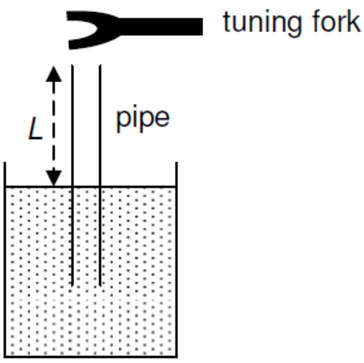
D 1.9×10^{-1} W

Ans: A

$$I = \frac{P}{4\pi r^2}$$
$$= \frac{60.0}{4\pi 5.0^2}$$
$$P_{detected} = I \times \text{Area}$$
$$= 1.4 \times 10^{-5} W$$

28 A small open pipe is initially submerged in water with its top end just above the surface of the water. A tuning fork vibrating at frequency 600 Hz is placed over the top of the pipe. The pipe is slowly raised such that a series of loud sounds is heard. The second loud sound is heard when the length of pipe above water is L.

The experiment is repeated with another tuning fork of unknown frequency f and in this instance, the second loud sound is heard when the length of pipe above water is $3L$. Given that the speed of sound in air is 300 m s^{-1}, what is the value of f?



A 110 Hz **B** 200 Hz **C** 360 Hz **D** 400 Hz

Ans: B

v = 300

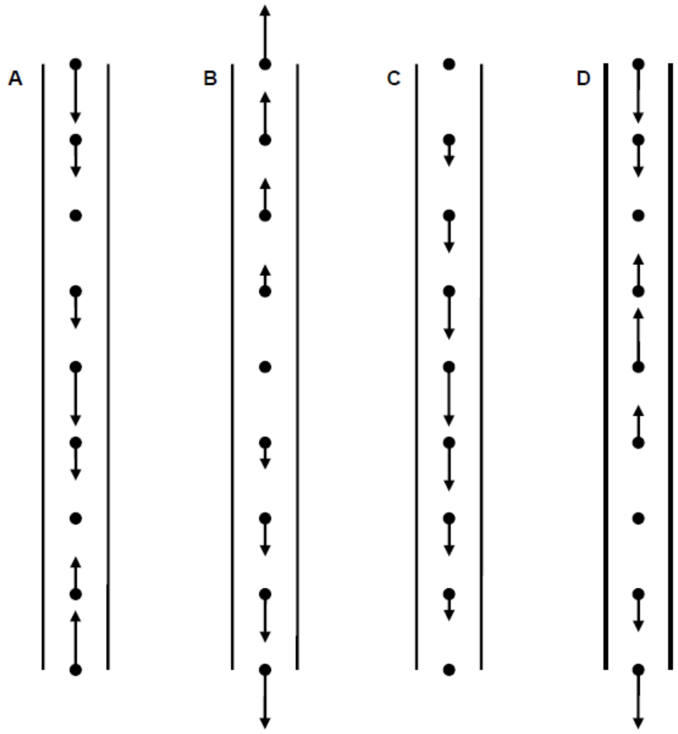
f = 600 Hz, λ = 0.5 m

L = 0.75λ = 0.375 m

3L = 1.125 m, λ = 1.5 m

f = 200 Hz

29 A stationary longitudinal wave has been set up in a pipe of length L. For a stationary wave of wavelength L, which diagram shows the displacement of the air molecules from the equilibrium at a particular instant?



Ans: D

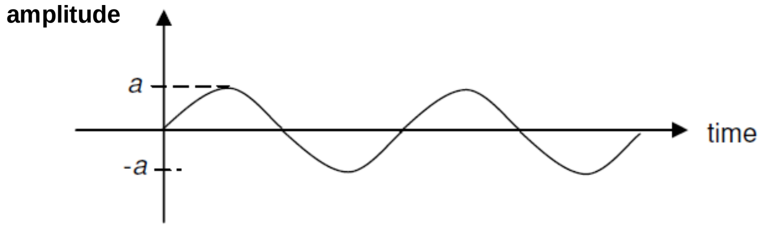
Given that λ = pipe length L and that the open ends must be antinodes,
the only option with A N A N A is option D.

30 S_1 and S_2 are two water wave generators of equal frequency. The water waves meet at point P away from the generators.

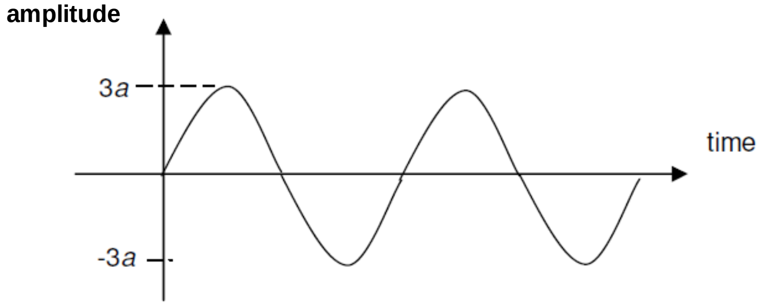
When only S_1 is switched on, amplitude of the wave at P is 2a. When only S_2 is switched on, amplitude of the wave at P is a. When both S_1 and S_2 are switched on, the two waves arrive in anti-phase.

Which of the following shows the amplitude of the resultant wave at P when both generators are switched on?

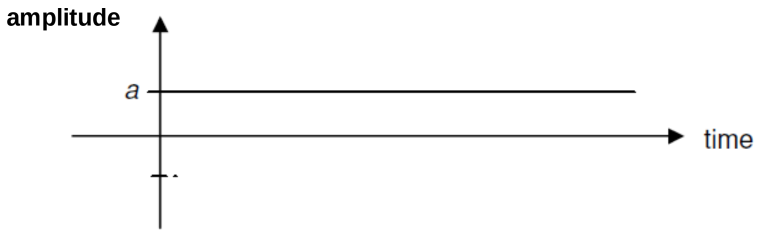
A



B



C



D

Ans: C
Antiphase means when S1 is max, S2 is min.
Hence resultant amplitude is 2a + (−a) = a

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMNATION
Higher 2

CANDIDATE NAME	SOLUTION
CLASS	
TUTOR'S NAME	

PHYSICS

9749/02

Paper 2 Structured Questions

28 September 2017

1 hour

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/8
2	/9
3	/7
4	/16
Deductions	
Total	/40

This document consists of **12** printed pages and **1** blank page.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/^{o}C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\,\omega\sqrt{\left(x_o^{\,2} - x^2\right)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

2017 H2 PHYSICS JC1 END-OF-YEAR EXAMNATION

Paper 1 Answer Key

1	2	3	4	5	6	7	8	9	10
D	B	C	C	B	D	A	B	B	A
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
D	C	D	D	B	D	A	A	D	B
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
B	D	B	C	A	C	A	B	D	C

Paper 2 Suggested Solution

Answer ALL questions.

1 Four men A, B, C and D are pushing an object of mass 125 kg which is initially moving at 2.50 m s^{-1} in the direction 35° above the negative x-axis as shown in Fig. 1.1.

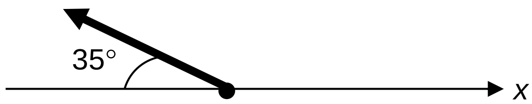


Fig. 1.1

Under the influence of the forces, the object then moves at 5.30 m s^{-1} in the direction 45° above the positive x-axis.

(a) Determine the change in velocity of the object.

$$\Delta v_x = v_x - u_x = 5.30\cos 45° - (-2.50\cos 35°) = 5.80 \text{ m s}^{-1}$$

$$\tan\theta = \frac{\Delta v_y}{\Delta v_x} = \frac{2.31}{5.80}$$
$$\theta = 21.8°$$

$$\Delta v = \sqrt{(\Delta v_x)^2 + (\Delta v_y)^2} = \sqrt{5.80^2 + 2.31^2} = 6.24 \text{ m s}^{-1}$$

$$\Delta v_y = v_y - u_y = 5.30\sin 45° - 2.50\sin 35° = 2.31 \text{ m s}^{-1}$$

magnitude of change in velocity = ...6.24...... m s^{-1}

direction of change in velocity = ...21.8° above positive x-axis... [3]

(b) Given that the forces are exerted over 3.7 s, calculate the net force acting on the object.

$$F_{net} = ma = \frac{m\Delta v}{t} = \frac{125(6.24)}{3.7} = 211 \text{ N}$$

net force = ...211...... N [2]

(c) The forces exerted by A, B and C are as shown in Fig. 1.2.

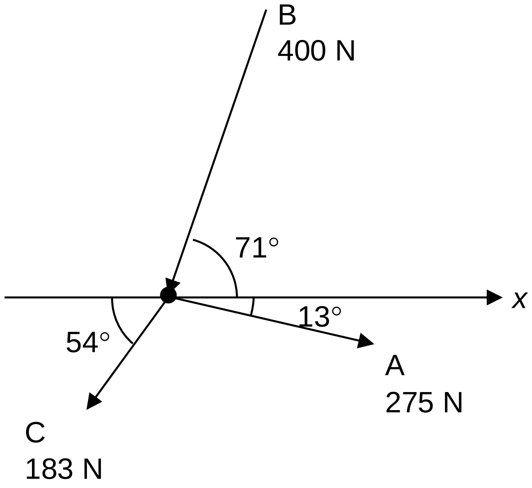


Fig. 1.2

Hence, determine the force exerted by D.

Taking right as positive,

$$F_x = F_{net} \cos\theta$$
$$= 211\cos 21.8°$$
$$= 196 \text{ N}$$

Taking up as positive,

$$F_y = F_{net} \sin\theta$$
$$= 211\sin 21.8°$$
$$= 78.2 \text{ N}$$

Considering horizontal forces,

$$A_x + B_x + C_x + D_x = F_x$$
$$275\cos 13° - 400\cos 71° - 183\cos 54° + D_x = 196$$
$$D_x = 166 \text{ N}$$

Considering vertical forces,

$$A_y + B_y + C_y + D_y = F_y$$
$$-275\sin 13° - 400\sin 71° - 183\sin 54° + D_y = 78.2$$
$$D_y = 666 \text{ N}$$

$$D = \sqrt{D_x^{\ 2} + D_y^{\ 2}}$$
$$= \sqrt{166^2 + 666^2}$$
$$= 687 \text{ N}$$

$$\tan\alpha = \frac{D_y}{D_x}$$
$$\alpha = \tan^{-1}\left(\frac{666}{166}\right)$$
$$= 76.0°$$

magnitude of force = ...687.......................... N

direction of force = ...76.0° above positive *x*-axis.... [3]

2 Fig. 2.1 shows a safety test conducted to study the extent of damage caused during a car crash onto a hard stationary block that is fixed to the ground. The combined mass of the car and dummy is 1000 kg.

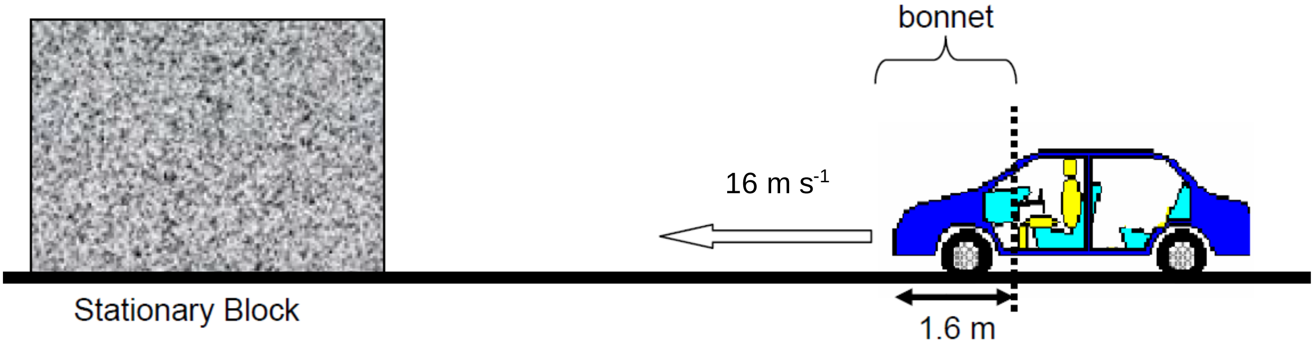


Fig. 2.1

(a) **(i)** If the car is traveling at a constant speed of 16 m s^{-1}, calculate the impulse required to act on the car to cause it to come to a complete stop.

Impulse Δp

$= m\Delta v$

$=1000\ (0-16)$

$= 1.6 \times 10^4$

impulse = ... kg m s^{-1} [1]

(ii) During every crash, the bonnet is designed to crumple the entire distance of 1.6 m so that the dummy can escape unscathed. The crash constant, *k*, of the bonnet is defined as the average force per unit distance crumpled.

If the car comes to a complete stop in 0.19 s, determine its crash constant, *k*.

Crash constant k

$= F / d$

$= \Delta p / (\Delta t \times d)$

$= 1.6 \times 10^4 / (0.19 \times 1.6)$

$= 5.26 \times 10^4$

k = ... N m^{-1} [2]

(iii) Explain whether the principle of conservation of momentum is applicable in this collision.

Taking the car and the wall as a system, the principle cannot be applied as there is a net external force by the ground on the wall.

Taking the car, wall and Earth as a system, the principle can be applied as there is no net external force by the ground on the wall. [1]

(b) Two identical cars A and B of mass 1000 kg are traveling with speeds of 10 m s^{-1} and 20 m s^{-1} respectively as shown in Fig. 2.2.

Fig. 2.2

(i) If both cars coalesce together after collision, calculate the final velocity of the cars.

Taking rightwards as positive,

by conservation of linear momentum,

m (10) + m (-20) = 2m v

v = - 5.0 m s^{-1}

velocity = ... m s^{-1} [1]

(ii) Hence, calculate the corresponding loss in the total kinetic energy of both cars.

Total initial KE = ½ m ($u_1^2 + u_2^2$)

= ½ (1000) ($10^2 + 20^2$)

= 2.50 x 10^5

Total final KE = ½ m ($u_1^2 + u_2^2$)

= ½ (1000) ($5^2 + 5^2$)

= 2.50 x 10^4

Loss in KE = 2.250 x 10^5 J

loss in total kinetic energy = ... J [2]

(iii) Explain which car experiences a larger force during the collision.

Using Newton's Third law, the force exerted by A on B is the same in magnitude as that by N on A. Hence, despite the difference in initial speeds, neither car experiences a larger force at the intant of collision.

.... [2]

3 A Hot Wheels toy set consists of a toy car and a track forming a vertical circular loop of radius r. The toy car is launched from the bottom of the loop with a minimum speed v_{min} such that it just barely remains in contact with the track at the top.

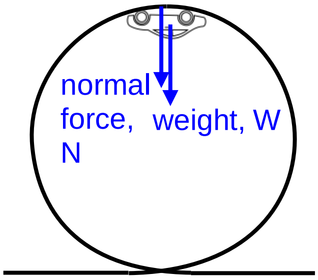


Fig. 3.1

(a) **(i)** On Fig. 3.1 above, draw a labelled arrow for each force exerted on the toy car at the top of the loop. [1]

(ii) Show that $v_{min} = \sqrt{5rg}$.

At minimum speed, N = 0 [1]

At top of loop, $mg = m\frac{{v_{top}}^2}{r}$, ${v_{top}}^2 = rg$ [1]

$$\frac{1}{2}m{v_{top}}^2 + mgh = \frac{1}{2}m{v_{bottom}}^2$$

By conservation of energy, $\frac{1}{2}mrg + mg(2r) = \frac{1}{2}m{v_{bottom}}^2$ [1]

$${v_{bottom}}^2 = 5rg,\ v_{bottom} = \sqrt{5rg}$$

[3]

(b) In 2012, a scaled-up version of the toy was built to set a new world record as shown in Fig. 3.2. In this stunt, two race cars entered the bottom of the loop with a speed of 23.1 m s^{-1} and completed the loop successfully.

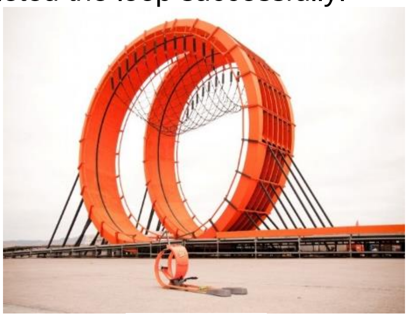


Fig. 3.2

(i) The actual radius of the loop used in the stunt was 10.0 m. Calculate the centripetal acceleration experienced by the cars at the bottom of the loop.

$$a = \frac{v^2}{r} = \frac{23.1^2}{10.0}$$

$$= 53.4 \text{ m s}^{-2}$$

centripetal acceleration = ... m s^{-2} [1]

(ii) Hence, determine the force exerted by the car on the driver who has a mass of 75.0 kg at the bottom of the loop.

Centripetal force, $F_c = ma_c$

$$N - mg = ma_c$$

$$N = m(g + a_c)$$

$$= (75.0)(9.81 + 53.4)$$

$$= 4740 \text{ N}$$

force = ... N [2]

For Examiner's Use

BLANK PAGE

For Examiner's Use

4 Fig 4.1 gives the schedule of Train P as it makes its stops on its route from Annecy to Faulkner and back.

Towns	**Arrive (hh:mm)**	**Depart (hh:mm)**	**Distance from Annecy (km)**
Annecy	–	07:10	–
Bloom	08:10	08:20	80
Carhill	09:50	10:00	200
Denison	12:20	12:30	340
Eagen	14:30	14:40	480
Faulkner	15:30	16:00	540
Eagen	16:50	17:00	480
Denison	18:40	18:50	340
Carhill	20:20	20:30	200
Bloom	22:00	22:10	80
Annecy	23:10	–	–

Fig 4.1

Fig 4.2 is a chart that allows the station master to track the position of Train P at any time during its operation.

(a) Fill in Fig 4.1 with the distances of Bloom and Carhill from Annecy. [2]

(b) Complete the line chart on Fig 4.2 for Train P's return journey. [3]

(c) Using Fig 4.2, determine the legs in Train P's entire route with the highest speed and lowest speed.

Highest speed: from Denison to Carhill

Lowest speed: from Carhill to Denison [2]

(d) Explain what the answers to **(c)** suggest about the elevation of the towns in the legs stated.

Denison is at a higher elevation than Carhill.

Speed going up is significantly lower than speed coming down.

.... [2]

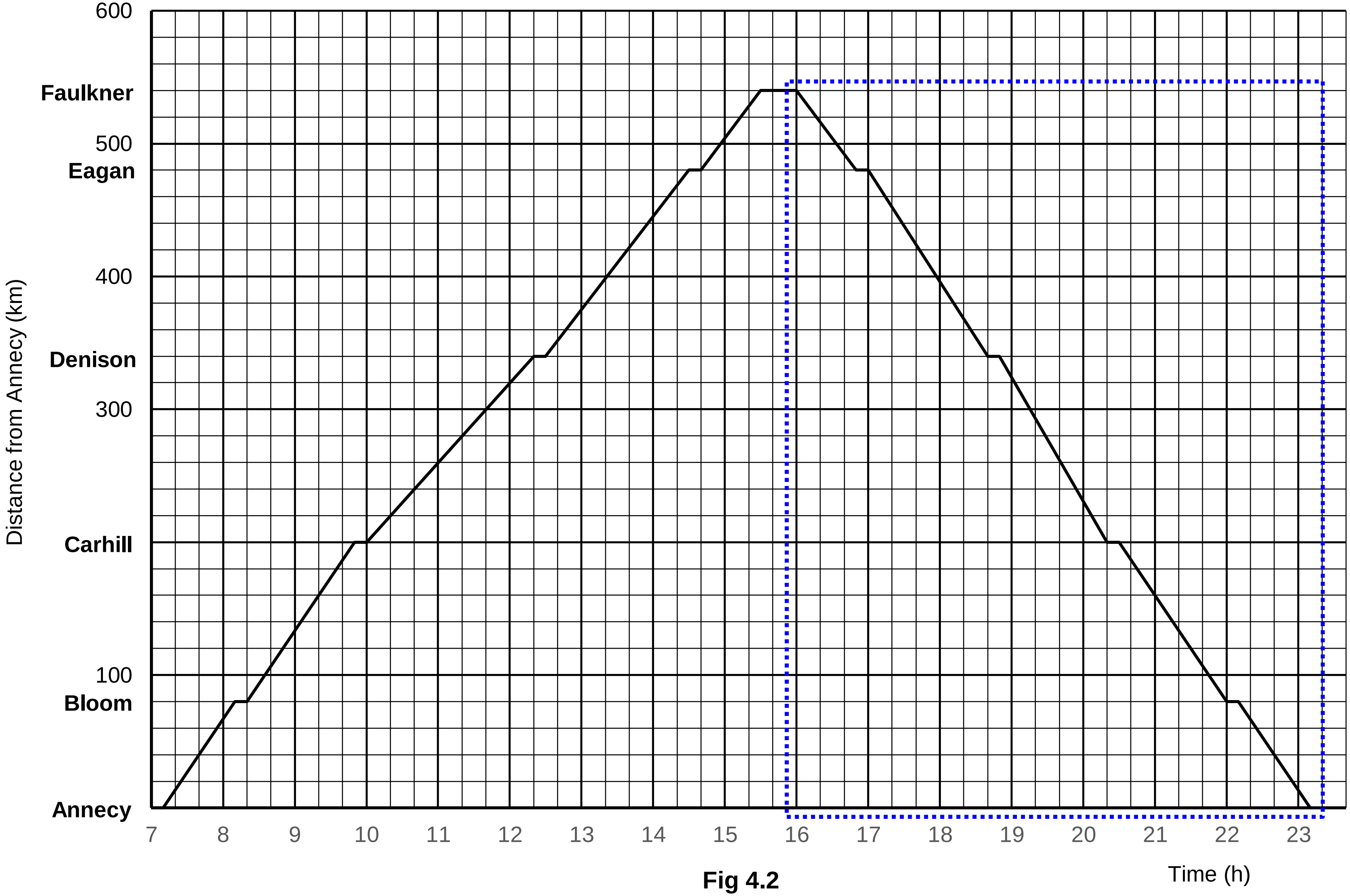

600
Faulkner
500
Eagan
400
Denison
300
Carhill
100
Bloom
Annecy
Distance from Annecy (km)
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Time (h)

Fig 4.2

(e) Calculate the average speed of Train P when travelling between Eagen and Faulkner.

$\langle v \rangle = 60 / (50/60) = 72$ km h^{-1}

average speed = ... km h^{-1} [2]

(f) The value in **(e)** for both directions of travel is lower than the average speed for the rest of the route. Suggest a reason for this.

There is a tunnel in the route. Or The route is winding.

....

....

.... [1]

(g) Train P, like many others, uses coal for fuel. Fig 4.3 shows how fuel efficiency for coal-fuelled trains has increased from 1980 to 2010. The average energy density of coal is 40 GJ per m^3.

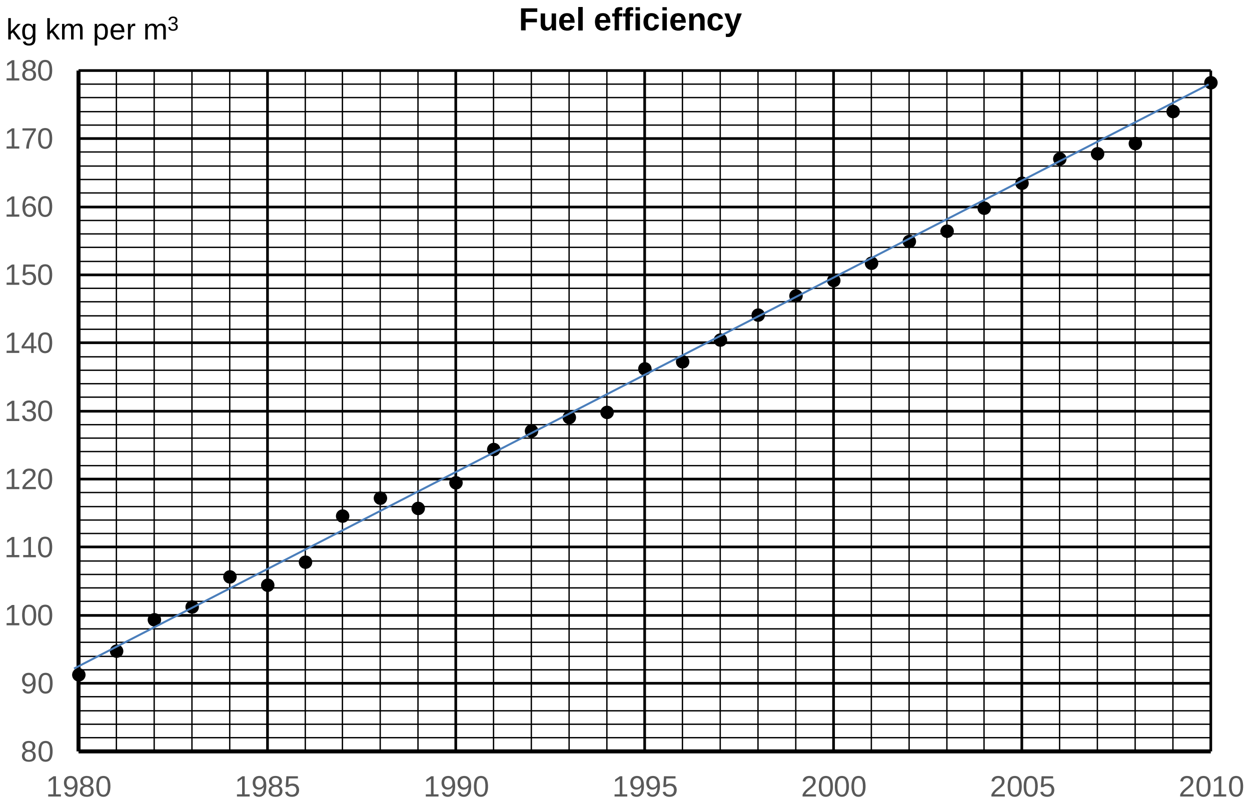


Fig 4.3

For Examiner's Use

(i) Using the trend indicated in Fig 4.3, estimate the value of fuel efficiency in the year 2030 in kg km per m^3.

Gradient = (178 – 92) / 30 = 2.87

Rate of increase in efficiency = 2.87 kg km m^{-3} $year^{-1}$

In 2030: efficiency = 178 + 20 × 2.87 = 235 kg km m^{-3}

fuel efficiency = ... kg km per m^3 [3]

(ii) Using your answer in **(g)(i)**, estimate for the year 2030 the average amount of coal consumed per adult male in m^3 when he travels from Annecy to Faulkner. Present your reasoning clearly.

Mass of adult male = 80 kg
Distance between A and F = 540 km
Fuel required = 80 × 540 / 235 = 184 m^3 (error) 1.84×10^{-4} m^3 (actual)

amount of coal = ... m^3 [1]

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMNATION
Higher 2

CANDIDATE NAME **Solution**

CLASS

TUTOR'S NAME

PHYSICS

9749/03

Paper 3 Structured Questions

4 October 2017

2 hours 10 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Sections A and C.
Answer **1 out of 2** questions in Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/8
2	/10
3	/8
4	/7
5	/9
6	/6
7	/20
8	/20
9	/12
Deductions	
Total	/80

This document consists of **21** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\ 2} - x^2\right)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\ln 2 / t_{1/2}$

For Examiner's Use

Section A

Answer ALL the questions in this section.

1 Trap-jaw ants are a species of ants with jaws that can open to 180° and snap shut in a few microseconds. In an experiment, researchers plotted the variation with time of the velocity of the ants' jaws in Fig. 1.1. Each line represents one of the ant's jaws.

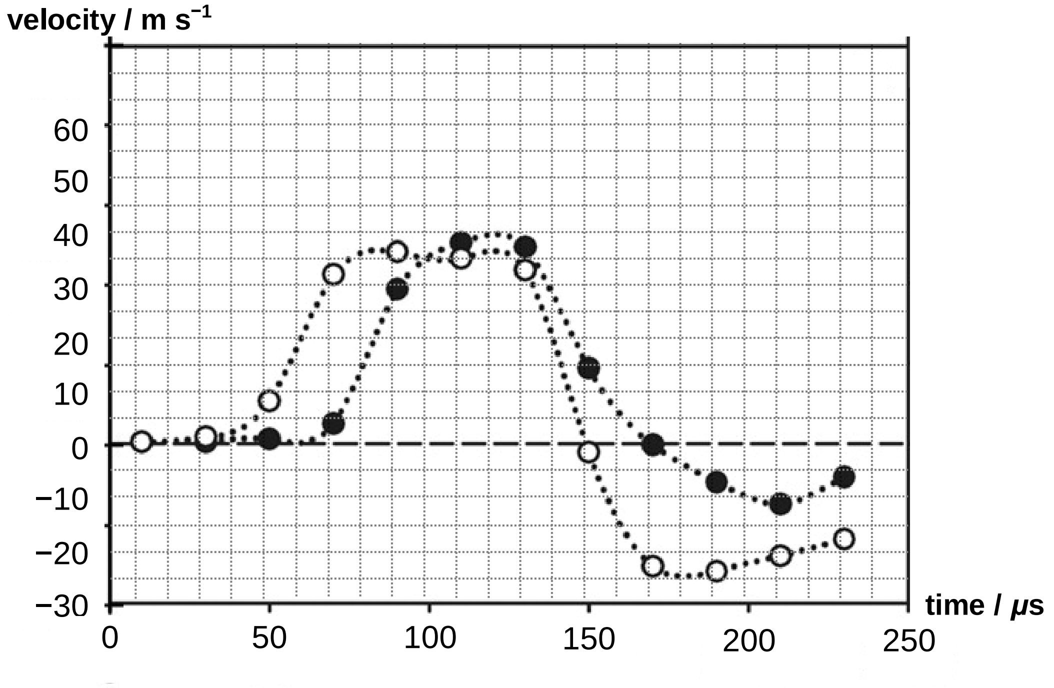


Fig. 1.1

(a) From the values in Fig. 1.1, estimate the maximum acceleration of the ant's jaws.

Maximum acceleration occurs between 130 and 150 μs

$$a = \frac{32.5-(-2.5)}{(150-130)\times10^{-6}} = 1.75\times10^{6}\ \text{m s}^{-1}$$

maximum acceleration = ... m s^{-2} [1]

(b) The trap-jaw ant is able to project itself into the air by directing its open jaws downwards and closing them. By doing so, it is able to reach a height of 8.30 cm and cover a horizontal distance of 3.10 cm when it returns to the ground. Effects of air resistance are negligible.

(i) Determine the vertical component of the ant's initial velocity.

$$v_y^{\,2} = u_y^{\,2} + 2a_y s_y$$

$$u_y = \sqrt{v_y^{\,2} - 2a_y s_y}$$

$$= \sqrt{0-2(-9.81)(8.3\times10^{-2})}$$

$$= 1.2761 \approx 1.28\ \text{m s}^{-1}$$

vertical velocity = ... m s^{-1} [2]

(ii) Hence or otherwise, determine the magnitude and direction of the ant's initial velocity.

Taking time from ground to maximum height,

$v_y = u_y + a_y t$

$t = \dfrac{v_y - u_y}{a_y} = \dfrac{0 - 1.2761}{-9.81}$ [1]

$= 0.13008$ s

Time of entire trajectory = 0.13 × 2 = 0.26 s

$s_x = u_x t$

$u_x = \dfrac{s_x}{t} = \dfrac{3.10 \times 10^{-2}}{0.26016}$

$= 0.1192$ m s^{-1}

$u = \sqrt{u_x^{\ 2} + u_y^{\ 2}}$

$= 1.286 \approx 1.29$ m s^{-1}

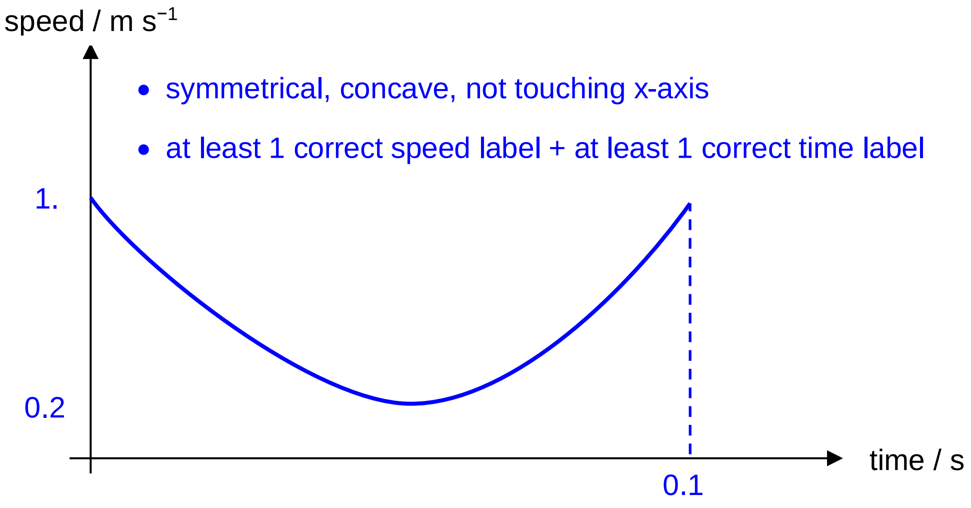
$\theta = \tan^{-1}\dfrac{u_y}{u_x} = \tan^{-1}\dfrac{1.286}{0.1192}$

$= 84.7°$

magnitude of velocity = ... m s^{-1}

direction = ... [3]

(c) On the axes below, sketch the speed-time graph of the ant's trajectory, from the moment it leaves the ground to the moment it touches the ground again. Include appropriate values on the axes.



[2]

For Examiner's Use

2 **(a)** **(i)** *The gravitational field strength on the surface of Mars is 3.7 N kg*$^{-1}$. Explain what this statement means.

The gravitational force exerted per unit mass acting on a test mass placed at the surface of Mars is 3.7 N kg^{-1}.

.... [1]

(ii) A satellite is orbiting about Mars. The satellite is constantly attracted towards Mars by gravitational attraction. Explain why the satellite does not fall towards Mars.

The satellite is moving in a direction that is tangent to a circle with its centre at Mars. The gravitational attraction provided the centripetal force for the satellite to move in a circle around Mars. [1]

(iii) The mean radius of Mars is 3.4×10^6 m and the orbital period of the satellite is 24.6 hours. Using information from **(a)(i)**, determine the height of the satellite above Mars' surface.

Gravitational force on the satellite provides the centripetal force for the satellite to orbit about Mars.

Using Newton's Second Law, $\Sigma F = ma$

$F_G = ma_c$

$$\frac{GMm}{r^2} = mr\omega^2$$

$$\frac{GM}{r^2} = r\left(\frac{2\pi}{24.6 \times 60 \times 60}\right)^2 \cdots [1]$$

From (a)(i), Gravitational field strength at the surface of Mars is given by

$$g = \frac{GM}{{R_E}^2}$$

$$3.7 = \frac{GM}{(3.4 \times 10^6)^2} \cdots [2]$$

Sub [2] into [1] to solve for r gives: $r = 2.0406 \times 10^7$

Height above surface = $r - R_E$

$= 2.0406 \times 10^7 - 3.4 \times 10^6$

$= 1.70 \times 10^7$ m

height = ... m [3]

For Examiner's Use

(b) Fig 2.1 shows the variation with distance r from the centre of Mars of the gravitational field, g, due to Mars.

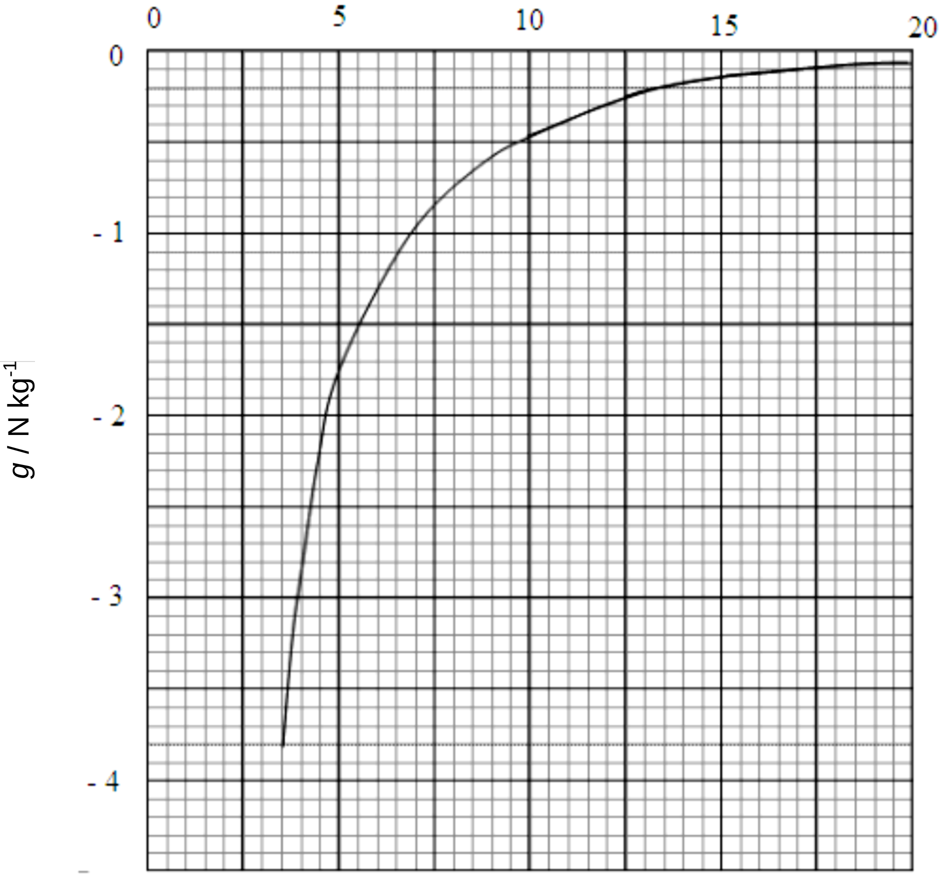


Fig 2.1

(i) Use Fig. 2.1 to estimate the energy required for a mass of 1.0 kg to escape from the gravitational field of Mars, starting at the planet's surface.

estimated no of squares = 206 (accepted range: 202-210)
1 square : $(0.5 \times 10^6) \times 0.1 = 5 \times 10^4$ J kg^{-1}

estimated energy required for a mass of 1 kg to escape from the gravitational field of Mars = estimated area
$= 206 \times 5 \times 10^4$
$= 1.0 \times 10^7$ J

energy required = ... J [2]

(ii) Hence calculate the escape speed for the 1.0 kg mass.

By using conservation of energy,

$(E_p + E_k)$ at earth's surface $= (E_p + E_k)$ at infinity
(As v_{esc} is minimum speed required to escape the field,
let E_k at infinity and E_p at infinity $= 0$)

$$-\frac{GM_E m}{R_E} + \frac{1}{2}mv_{esc}^2 = 0 + 0$$

$$-1.0 \times 10^7 + \frac{1}{2}mv_{esc}^2 = 0 + 0$$

$$v_{esc} = \sqrt{2\left(1.0 \times 10^7\right)} = 4470\ m\ s^{-1}$$

escape speed = ... m s^{-1} [2]

(iii) State and explain whether your answer to **(b)(ii)** will be different for a 100 kg instead of a 1 kg mass.

Since the escape speed from Mars is independent of the mass of the satellite, the escape speed remains the same for a 100 kg mass instead. [1]

3 (a) (i) State the *First Law of Thermodynamics*.

The increase in the internal energy of the system U is the sum of the heat supplied to the system Q and the work done on the system W.

[1]

(ii) Explain the meaning of the term *internal energy*.

Internal energy U of a system is the sum of the random distribution of microscopic kinetic energy and microscopic potential energy of ALL the atoms or molecules. [1]

(b) The diesel cycle is the thermodynamic cycle which approximates the pressure and volume of the combustion chamber of the diesel engine, invented by Rudolph Diesel in 1897.

An ideal gas undergoes the diesel cycle which comprises four processes:

Process A - compressing the gas in a very short time
Process B - heating the gas at constant pressure
Process C - expanding the gas in a very short time
Process D - cooling the gas at constant volume

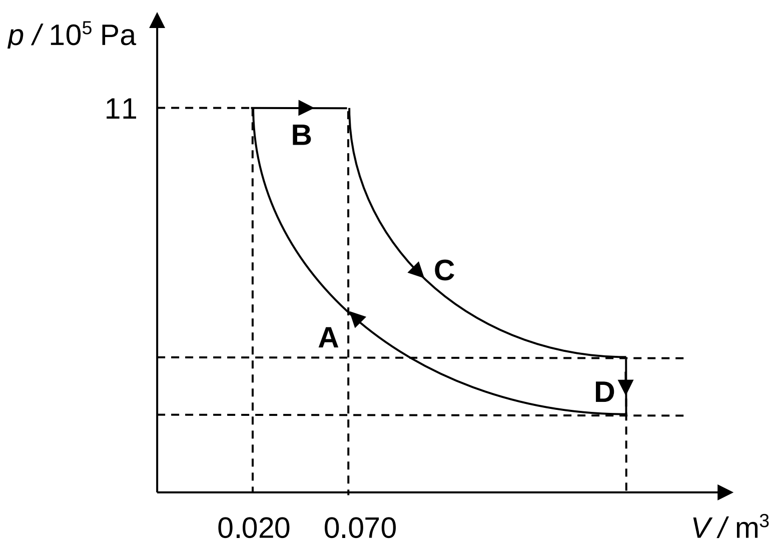


Fig. 3.1

(i) Calculate the work done by the gas during process B.

Work done by gas

= (0.070 – 0.020) x (11 x 10^5) = 55 kJ

work done by gas = ... J [2]

(ii) Table 3.1 is a table of energy changes during one cycle. Complete the table with appropriate values. [4]

Process	work done on gas, ***W*** / kJ	heat supplied to gas, ***Q*** / kJ	increase in internal energy, ***ΔU*** / kJ
A	+ 201	0	+201
B	–55	+ 74	+19
C	- 185	0	–185
D	0	- 35	–35

Table 3.1

4 **(a)** Distinguish between longitudinal and transverse waves.

A longitudinal wave is a wave in which the oscillations of the particles are **parallel** to the direction of propagation of the wave. A transverse wave is a wave in which the oscillations of the particles are **perpendicular** to the direction of propagation of the wave.

.... [2]

(b) State a phenomenon associated with transverse waves but is not observed with longitudinal waves.

Polarisation.

.... [1]

(c) Three polarisers P, Q and R are placed such that the polarising directions of P and R are perpendicular as shown in Fig. 4.1. The polariser Q is rotated about the common axis with an angular velocity ω.

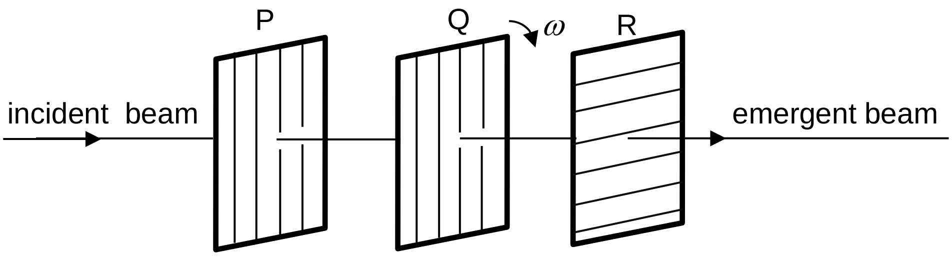


Fig. 4.1

(i) Express the angular displacement θ of polariser Q in terms of ω and time of rotation, t.

$\theta = \omega t$

[1]

(ii) The incident light on polariser P is unpolarised and has intensity I_0. Derive an expression for the intensity of the beam emerging from polariser R in terms of I_0, ω and t.

Intensity of light emerging from P is $I_P = \dfrac{I_0}{2}$.

By Malus' Law, intensity of light emerging from Q is $I_Q = I_P \cos^2 \omega t$

$$= \frac{I_0}{2} \cos^2 \omega t$$

By Malus' Law, intensity of light emerging from Q is $I_R = I_Q \cos^2\left(\dfrac{\pi}{2} - \theta\right)$

$$= \left(\frac{I_0}{2}\cos^2 \omega t\right)\cos^2\left(\frac{\pi}{2} - \theta\right)$$

$$= \frac{I_0}{2}\cos^2 \omega t \sin^2 \omega t$$

$$= \frac{I_0}{8}\sin^2 2\omega t$$

[3]

For Examiner's Use

5 A crane is used to lift a 1000 kg cement block as shown in Fig 5.1. The total mass of the crane is 5000 kg and its centre of gravity is at G.

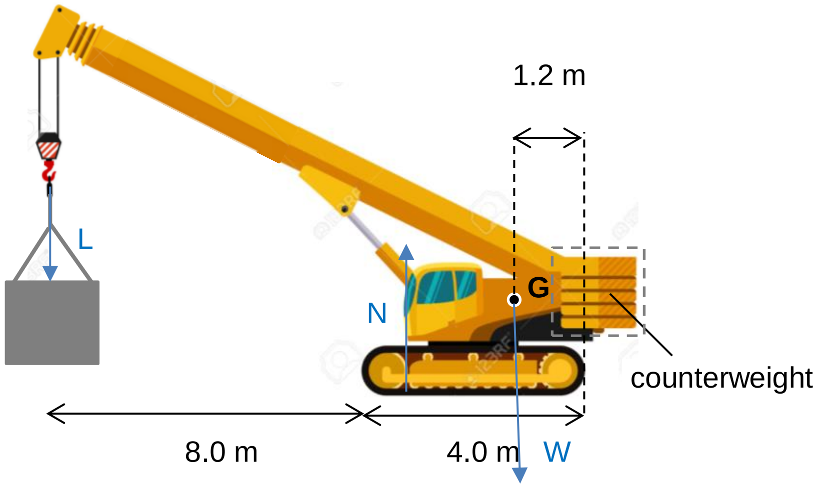


Fig 5.1

(a) Draw labelled arrows on Fig 5.1 to show all the forces acting on the crane. Pay attention to the position of these forces. [2]

(b) Calculate the magnitude of the force exerted by the ground and its perpendicular distance from G.

$\uparrow \sum F = N + (-W) + (-L) = 0$

$N = 5.9 \times 10^4$ N

Moments about G $= -N\,d + L \times (8.0 + 2.8) = 0$

$d = 1.8$ m

magnitude of force = ... N

perpendicular distance = ... m [3]

(c) Calculate the maximum load the crane can lift without tipping over.

At tipping point, N is at the front wheel.

Taking moments about N:

$W \times 2.8 - L_{max} \times 8.0 = 0$

$L_{max} = 1.7 \times 10^4$ N

= weight of 1750 kg

maximum load = ... kg [2]

(d) The crane has a heavy counterweight right at the rear end. Explain its purpose and why it is at the rear end of the crane.

From (c), the maximum load is determined by the anticlockwise of W about the front.

The counterweight increases W the total weight of the crane.

It is at the rear of the crane to maximize the perpendicular distance of W.

Thus it allows the crane to lift greater loads. [2]

6 A projectile is fired from the ground at an angle 35° above the horizontal with speed 23 m s^{-1} as shown in Fig. 6.1. At the top of the trajectory, the projectile splits into two fragments of masses *m* and 2*m*, and they separate in opposite directions.

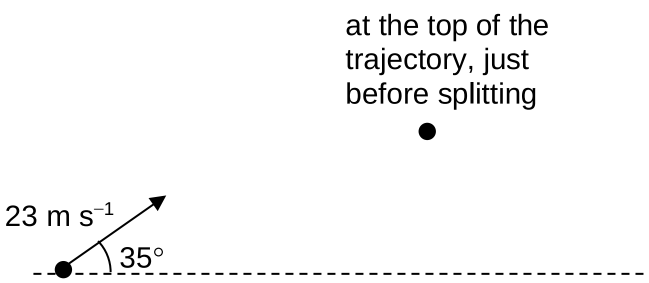


Fig. 6.1

(a) Calculate the speed of the projectile just before splitting.

$$v_y = 0$$
$$v_x = u\cos\theta$$
$$= 23\cos 35°$$
$$= 18.8 \text{ m s}^{-1}$$

speed = ... m s^{-1} [1]

(b) Given that the fragment of mass *m* returns to the point of projection, prove that the speed of the fragment of mass 2*m* after splitting is 37.7 m s^{-1}.

By conservation of linear momentum,

$$3mv = -mv_1 + (2m)v_2$$
$$2v_2 = 4v \quad (\because v_1 = v)$$
$$v_2 = 2v$$
$$= 2(18.8)$$
$$= 37.7 \text{ m s}^{-1}$$

[2]

(c) Calculate the distance between the two fragments upon landing on the ground.

Taking up as positive,

$$v_y = u_y + a_y t$$

$$0 = u_y + a_y t$$

$$t = \frac{u_y}{g}$$

$$= \frac{u \sin\theta}{g}$$

$$= \frac{23 \sin 35°}{9.81}$$

$$= 1.33 \text{ s}$$

$$d = vt + 2vt$$

$$= 3vt$$

$$= 3(18.8)(1.34)$$

$$= 76.0 \text{ m}$$

distance = ... m [3]

For Examiner's Use

Section B

*Answer **ONE** question from this section.*

7 **(a)** Fig. 7.1 shows the force-extension graph of a light spring.

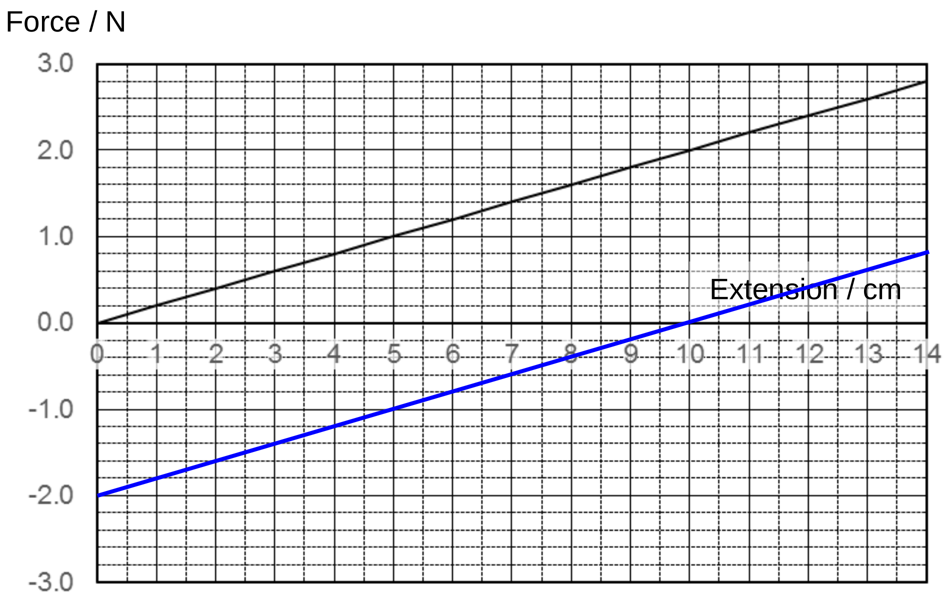


Fig. 7.1

A 0.200 kg mass is freely suspended from a fixed point O using the spring, as shown in Fig. 7.2.

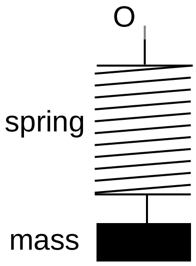


Fig. 7.2

(i) On Fig. 7.1, draw the graph to show the variation of the resultant force on the mass with extension of the spring when there are no forces acting on it other than its weight and that exerted by the spring. [2]

(ii) The mass is initially held with the spring extended by 12.0 cm and then released. Explain how your graph in **(i)** shows that the subsequent motion of the mass is simple harmonic.

The resultant force on the mass is proportional in magnitude to its displacement from its equilibrium point because the graph is a straight line passing through (10.0,0.0). So its acceleration is also proportional to the displacement. When the extension is larger than 10.0 cm (below equilibrium), the resultant force is positive (upwards). When the extension is smaller than 10.0 cm (above equilibrium), the resultant force is negative (downwards). So acceleration is opposite in direction to displacement.

[2]

For Examiner's Use

(iii) By finding the gradient of the graph, show that the natural frequency of the mass-spring oscillator is 1.6 Hz.

$\Sigma F = m\,a = m\,\omega^2\,x$

Gradient = $m\,\omega^2 = (2.8-0.0)/(14.0-0.0) = 0.20\ \text{N cm}^{-1} = 20\ \text{N m}^{-1}$

$\omega = (20 / 0.20)^{1/2} = 10\ \text{s}^{-1}$

$f = \omega / 2\pi = 1.6$ Hz

[3]

(iv) Calculate the maximum speed of the mass and the extension of the spring when this speed is attained.

$x_0 = 0.020$ m

$v_0 = \omega\,x_0 = 10 \times 0.020 = 0.20\ \text{m s}^{-1}$

extension = 10.0 cm

maximum speed = ... m s^{-1}

extension of spring = ... m [3]

(b) The mass-spring oscillator in **(a)** is now vertically oscillated using a mechanical vibrator of variable frequency. The amplitude of the oscillator varies with the frequency of the vibrator as shown in Fig. 7.3.

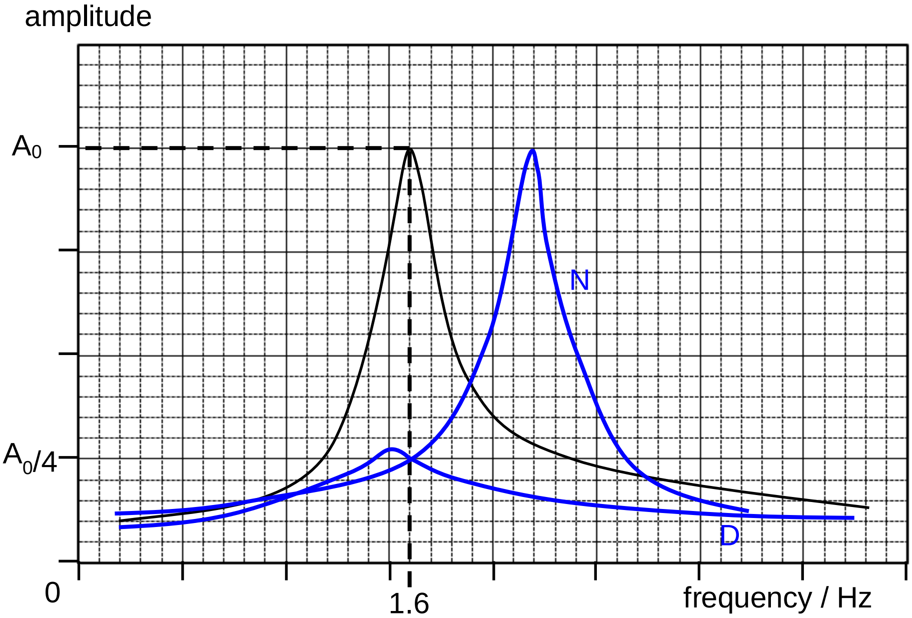


Fig. 7.3

(i) The amplitude is very large within a very narrow range of frequencies. Explain why this is so.

When the driver frequency is close to the natural frequency of the oscillator, there is maximum transfer of energy to the oscillator or resonance.

When system is very lightly damped, resonance is very sharp. [2]

(ii) The amplitude of the oscillator at 1.6 Hz can be decreased to ¼ of its original value by increasing the degree of damping. Draw another frequency response graph on Fig. 7.3 to show this. Label this graph D. [2]

(iii) Suggest how the effect in **(b)(ii)** can be achieved in practice for a mass-spring oscillator.

Increase resistance to motion by using a fluid more viscous than air e.g. water or by increasing surface area e.g. attach light card to mass.

[1]

(iv) The amplitude of the oscillator at 1.6 Hz can also be decreased to ¼ of its original value by modifying the natural frequency of the oscillator. Draw another frequency response graph on Fig. 7.3 to show this. Label this graph N. [2]

(v) Suggest how the effect in **(b)(iv)** can be achieved in practice for a mass-spring oscillator.

Increase/decrease mass or change spring to one having a different spring constant.

[1]

(c) Describe an example in which resonance is desirable.

e.g. musical instruments, magnetic resonance imaging, radio receiver

[2]

8 A ball of mass 2.0 kg is released from point A on a **rough** curved plane. It moves through a vertical height of 80 m and a distance *d* along the curved plane until it reaches point B with a speed of 3.6 m s^{-1}.

From point B it slides down a **smooth** straight plane inclined at angle of 30° and distance 0.500 m before it hits the spring at point C. The ball compresses the spring and comes to a stop at point D. The spring has a spring constant of 1500 N m^{-1}.

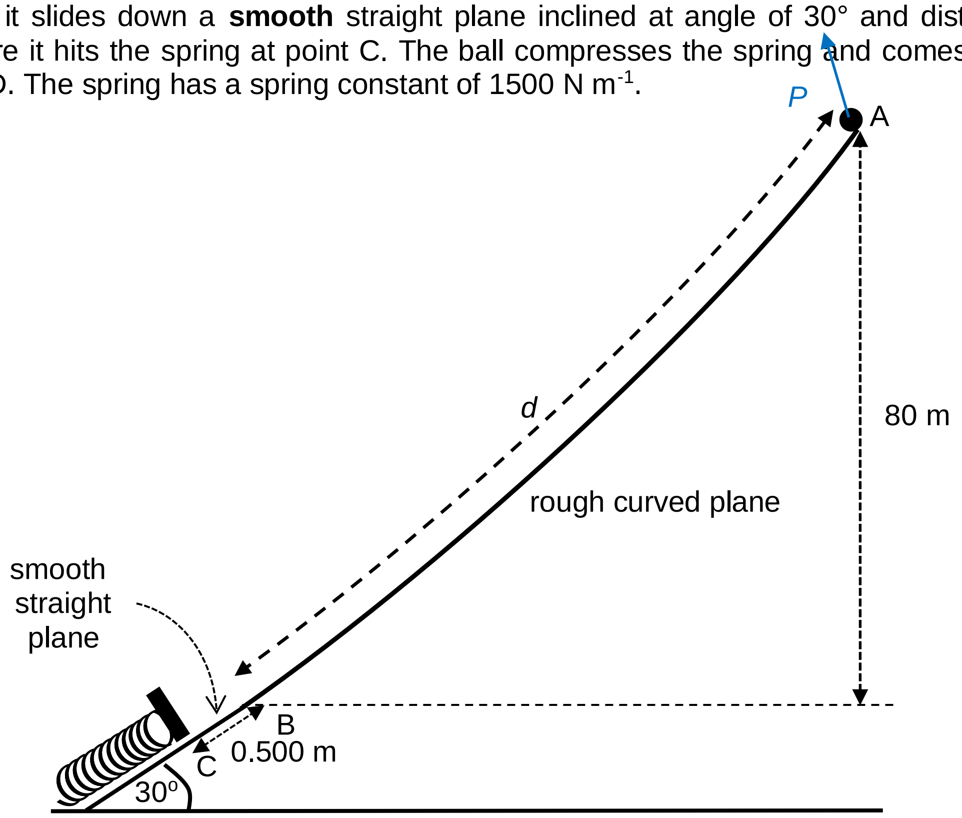


Fig. 8.1

(a) **(i)** On Fig. 8.1, draw an arrow labeled as *P* to show the total contact force of the curved plane on the ball at point A. [1]

(ii) Explain why the work done on the ball by *P* as it moves from A to B is not *P* x *d*.

The component of *P* perpendicular to the displacement does not do any work.

The component of *P* parallel to the displacement does negative work.

Hence work done on the ball is not *P* x *d*.

[2]

(b) Calculate the work done by friction force along the curved plane AB.

$$\sum E_i + W_f = \sum E_f$$

$$mgh - W_f = \frac{1}{2}mv^2 \text{ [1]}$$

$$W_f = mgh - \frac{1}{2}mv^2 = (2.0x9.81x80) - \frac{1}{2}x2.0x3.6^2$$

$$= 1560J \text{ [1]}$$

work done = ... J [2]

For Examiner's Use

(c) Given that the ball has a specific heat capacity of 380 J kg^{-1} K^{-1}, calculate the increase in the temperature of the ball at point B. State an assumption made in your calculation.

$$mc\Delta\theta = W_f$$

$$\Delta\theta = W_f / mc = 1560 / 2.0x380 = 2.05^oC$$

Assumption: (1) All the work done by friction (heat evolved) caused the temperature of ball to increased, OR (2) The ball does not lose heat to the environment.

increase in temperature = ... °C [3]

(d) (i) Given that e is the maximum compression of the spring, write down an expression, in terms of e, for the loss of height of the ball from point B until it comes to rest at point D.

Loss of height = (0.500 + e) sin 30° = 0.25 + 0.5e

[1]

(ii) Use energy considerations show that the value of e is 0.16 m.

$$\sum E_i + W_{ext} = \sum E_f$$

$$W_{ext} = 0$$

$$\frac{1}{2}mv^2 + mg(L+e)\sin\theta = \frac{1}{2}ke^2 [1]$$

$$\frac{1}{2}ke^2 - mge\sin\theta - (\frac{1}{2}mv^2 + mgL\sin\theta) = 0 [1]$$

$$750e^2 - 9.81e - 17.9 = 0$$

$$e = 0.16m$$

[3]

(e) (i) Taking the gravitational potential energy at point D to be zero, fill in Table 8.2 with the values of kinetic energy E_k, gravitational potential energy E_G, elastic potential energy E_P, and total energy E_T of the ball at points B, C and D. [3]

	Kinetic energy E_k	Gravitational potential energy E_G	Elastic potential energy E_P	Total energy E_T
Point B	$\frac{1}{2}mv^2=13.0$	$mg(h+e)\sin\theta$ $=6.47$	0	19.5
Point C	E_{KB} + $mgh\sin\theta$ = 17.9	$mge\sin\theta =1.57$	0	19.5
Point D	0	0	$\frac{1}{2}ke^2$ = 19.5	19.5

Table 8.2

(ii) On the Fig. 8.3, sketch labeled graphs to show the variation with distance along the line BCD of

1. the kinetic energy E_k,
2. the gravitational potential energy E_G,
3. the elastic potential energy E_P, and
4. total energy E_T of the ball.

[4]

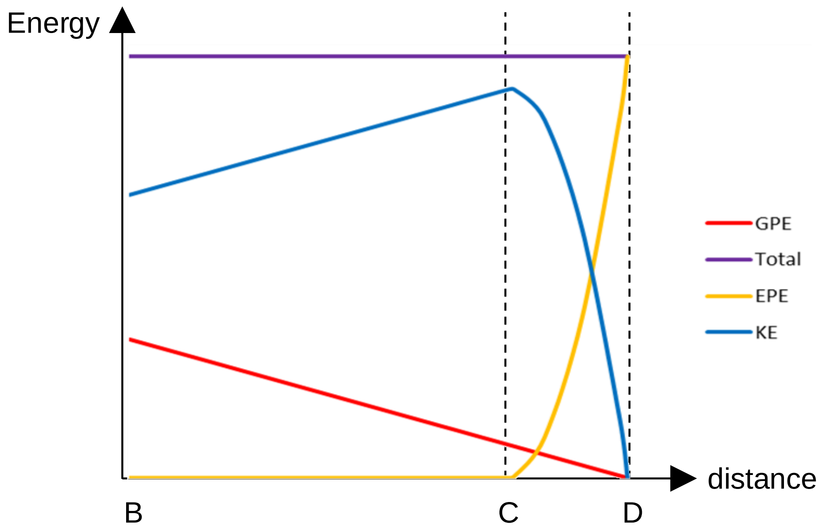


Fig 8.3

(f) "*Due to conservation of energy, the conversion of energies is reversible. If the spring is compressed at point D by the same amount as stated in* ***(d)(ii)*** *and released, the ball can be projected up the plane to reach point A.*"

Explain whether you agree with the above statement.

The total energy at A is greater than that at D due to energy dissipated from the system by friction.

Hence the system with lesser total energy will not be be able to rise up to point A. [1]

Section C

Answer the question from this section.

9 A student wishes to determine the Young modulus E of wood from the period of oscillation of a loaded wooden rule, as shown in Fig. 9.1.

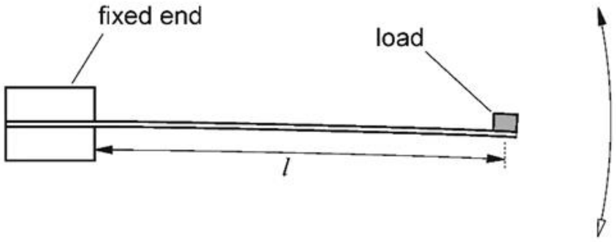


Fig 9.1

An equation relating the period of oscillation T to the overhanging length l of the rule is

$$T^2 = \frac{k\,l^3}{E}$$

The constant k is given by

$$k = \frac{16\pi^2 M}{w\,d^3}$$

where M is the mass of the load, w is the width of the rule and d is the thickness of the rule.

Design a laboratory experiment to determine the Young modulus of wood. You should draw a diagram showing the arrangement of your equipment. In your account, you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) how to analyse the data,

(e) how to determine E,

(f) the safety precautions to be taken.

[12]

1. Aim

- Independent variable (IV): Overhanging length of rule L
- Dependent variable (DV): Period of oscillation of rule T
- Constants: Use the same rule or use a rule with the same width and thickness [D1]

2. Apparatus labelled in Diagram

- Diagram showing the cantilever is fixed using either g-clamp & bench / retort stand & clamp [M1]
- Load must be secured to the rule using string, glue or tape [M1]

3. Procedure or Method of Data Collection

1. Set up the apparatus as shown in the diagram
2. Measure mass of load using an electronic balance and record as M. [M3]
3. Measure width and thickness of rule using vernier caliper/micrometer and record as w and d respectively. [M3]
4. Measure overhanging length of rule using a metre rule and record as L. [M4] Alternatively, read off the markings on the rule at the position of the clamp and record as L_1. Read off the markings on the rule at the position of the load and record as L_2. Calculate the overhanging length of rule using $L = L_1 - L_2$. [M4]
5. Displace the loaded metre rule downwards and set it into oscillation.
6. Start timing after the oscillations have stabilised. [D8]
7. Measure the time taken for 20 oscillations using a stopwatch and record as t_1.
8. Repeat steps 5-7 and record down t_2. [M2]
9. Calculate the average timing for 20 oscillations and record as t. [M2]
10. Calculate the period of an oscillation T using T = t/20. [M2]
11. Repeat steps 4-10 to obtain 5 more sets of values of T and L for decreasing values of L. L can be varying by shifting the loaded rule leftwards towards the clamp such that the overhanging length is shorter. [M5]

4. Analysis

- Plot a graph of T^2 against L^3 where k/E is the gradient and y-intercept is zero. [A1]
- If graph is a straight line, passing through the origin, the equationis true. [A1]
- Calculate k and then determine Young's modulus using E = k/gradient. [A2]

5. Additional Details

- As the rule may not be uniform, take repeated measurements of d and w along rule and find average to account for the random error. [D2]
- Place a pair of light gates at the equilibrium position of the loaded rule as shown in the diagram. The light gates are connected to a datalogger and computer. From the intensity-time graph reflected on the screen, determine the timing between the 1st and 21st minimum. Record this as the time taken for 20 oscillations, t. Calculate the period of an oscillation T using T = t/20. [D3]
- Use small amplitude or small angle oscillations to ensure equation is valid. [D4]

- Conduct preliminary experiments to check that the magnitude of the load is large enough to obtain a measurable value of T. [D5]
- Place a horizontal rod clamped with a retort stand at the equilibrium position of the loaded metre rule. This acts as a reference/fiducial marker to indicate when to start and stop timing. [D6]
- Measure the width of the load using vernier caliper/micrometer and records as b. Locate the centre of the load at b/2. This must be accounted for in determining the overhanging length L, where the effective overhanging length $L_{eff} = L - b/2$. [D7]

6. Safety Precautions

- Place cushion/sand trays just below the load in case the load falls.
  Alternatively, keep a safe distancefrom exerpiment/feet away from the bottom of the load in case it falls. [S1]

End of Paper

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

SOLUTION

PHYSICS

9749/01

Paper 1 Multiple Choice

5 October 2016

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and tutor's name on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

This document consists of **18** printed pages.

[Turn over

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm\omega\sqrt{(x_o^{\,2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$

radioactive decay	x =	$x_o \exp(-\lambda t)$
decay constant	λ =	$\ln 2 / t_{1/2}$

1	2	3	4	5	6	7	8	9	10
B	B	D	C	B	C	B	A	D	B
11	12	13	14	15	16	17	18	19	20
A	A	D	C	C	A	D	C	A	A
21	22	23	24	25	26	27	28	29	30
C	B	D	B	C	A	B	B	B	D

1 A student performs a simple experiment to determine the value of an unknown quantity *X*.

It is known that *X* is affected by the acceleration of the body in the experiment.

X is found to be = –2.45 N.

Which of the following provides evidence that *X* is a vector quantity?

A The negative sign in *X* only.

B The unit of *X* only.

C *X* is affected by acceleration which is a vector quantity.

D Both the negative sign in *X* and the unit of *X*.

Ans: B

Learning points:

- **A vector or scalar is already deduced by the quantity which is based on certain units. Hence the unit can provide evidence for the what quantity the value represent.**
- **A scalar quantity can also have negative value although the negative sign did not represent a direction.**
- **A scalar quantity can still be affected by a vector quantity. E.g. Work done = Force x displacement.**

2 A flat head drill bit is used to drill holes of a small depth. The drill bit can drill holes with a diameter of (40.0 ± 0.5) mm. The depth of the hole has an uncertainty of ±1 mm.

If the percentage uncertainty of the volume of the hole is less than 10%, what is the minimum depth, in mm, which the drill bit can make?

A 15 **B** 14 **C** 13 **D** 12

Ans: B

$V = \pi r^2 h$

$$\frac{\Delta V}{V} = \frac{2\Delta r}{r} + \frac{\Delta h}{h}$$

h = 13.3

Hence the minimum depth is 14 mm.

3 An artillery gun sited at the top of a cliff fires a shell horizontally so as to hit a target 2.0 km horizontally away from the bottom of the cliff.

If the cliff is 180 m high, the initial velocity of the shell is

A 54 m s^{-1} **B** 99 m s^{-1} **C** 110 m s^{-1} **D** 330 m s^{-1}

Ans: D
$y = u_y t + ½ a_y t^2$
$180 = 0 + ½ (9.81) t^2$
$t = 6.1$ s
$u_x t = 2000$
$u_x = 330$ m s^{-1}

4 In order that a train can stop safely, it passes a signal showing a yellow light before it reaches another signal showing a red light. The train driver applies the brake at the yellow light and this results in a uniform deceleration, and the train stops exactly at the red light.

The distance between the red and yellow lights is *x*.

What must the minimum distance between the lights be, without changing the deceleration of the train, if the train speed is increased by 20 %?

A 1.20*x* **B** 1.25*x* **C** 1.44*x* **D** 1.56*x*

Ans: C

$v^2 = u^2 – 2as$, $v = 0$

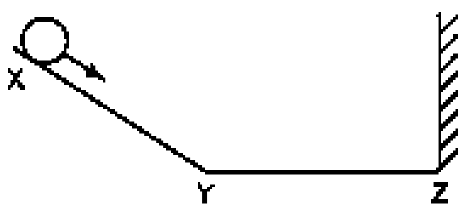
$(u_1)^2 = 2ax$

$(u_2)^2 = 2ax_2$, and $u_2 = 1.2\, u_1$
hence, $(1.2u_1)^2 = 2ax_2$ ……….(2)

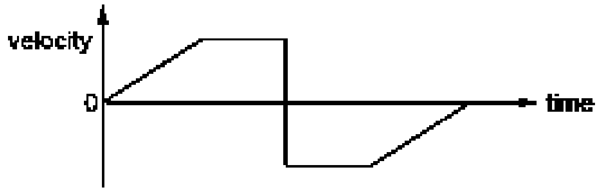
from (1) & (2), $\dfrac{1.44\, u_1^2}{u_1^2} = \dfrac{2\,a\,x_2}{2\,a\,x}$

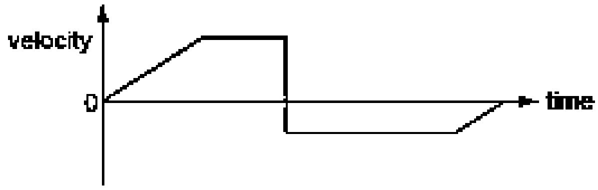
$x_2 = 1.44x$

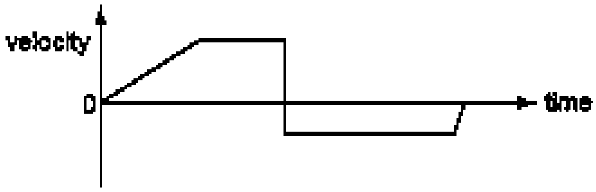
5 A ball is released from rest on a smooth slope XY.
It moves down the slope, along a smooth horizontal surface YZ and rebounds inelastically at Z. Then it moves back to Y and comes to rest momentarily somewhere on XY.

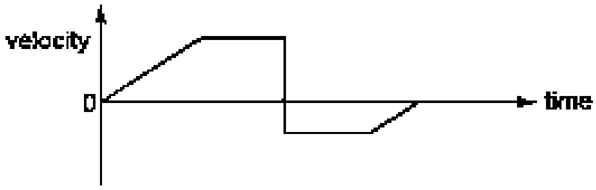


Which velocity-time graph represents the motion of the ball?

A


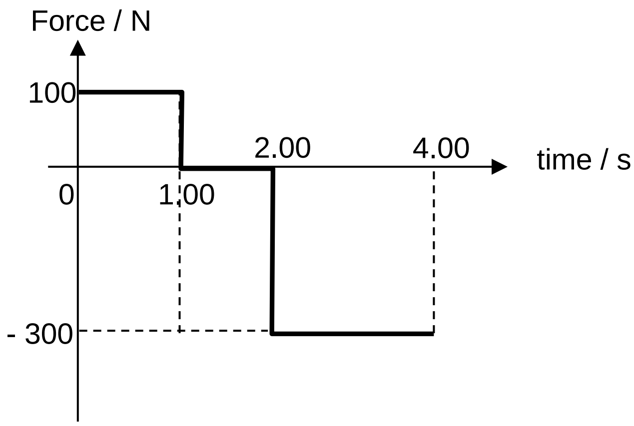
B


C


D


Ans:B
X to Y, acceleration is constant at g sin θ
Y to Z, speed is constant.
Z to Y, speed is constant but lower, will take longer time to travel same distance, because of inelastic collision at wall.
Y to stop, acceleration is the same as from X to Y

6 An object, initially moving with a velocity 92.0 m s^{-1}, experiences a force which varies with time as shown below.



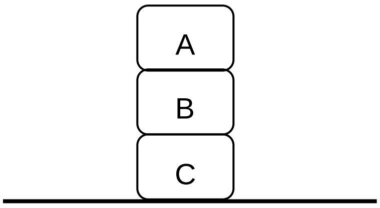
If the object has a mass of 8.50 kg, what is the final velocity of the object after 4.00 s?

A 174 m s^{-1} **B** 163 m s^{-1} **C** 33.2 m s^{-1} **D** -151 m s^{-1}

Area under graph = Impulse
$(100)(1)+(-300)(2) = m\ (v_2 - v_1)$
$v_2 = 33.2\ m\ s^{-1}$

Answer : C

7 Three objects A, B and C are stacked on top of one another on the ground.



Which of the following statements is correct?

A The force exerted by object B on object C is equal to the weight of object B.

B The force exerted by object C on object B is greater than the force exerted by object A on object B.

C The weight of object A and the force exerted by object B on object A are an action-reaction pair of forces.

D The normal contact force exerted by the ground on object C is equal to the weight of object C.

Consider A only,
There are 2 forces acting on A, the weight of A is equal to the force exerted by B on A.
Consider B only,
There are 3 forces acting on B, the sum of weight of B and the contact force exerted by A on B is equal to the force exerted by C on B.
Consider C only,
There are 3 forces acting on C, the sum of weight of C and the contact force exerted by B on C is equal to the force exerted by ground on C.

The force exerted by object B on object C is equal to the weight of object B. (False)

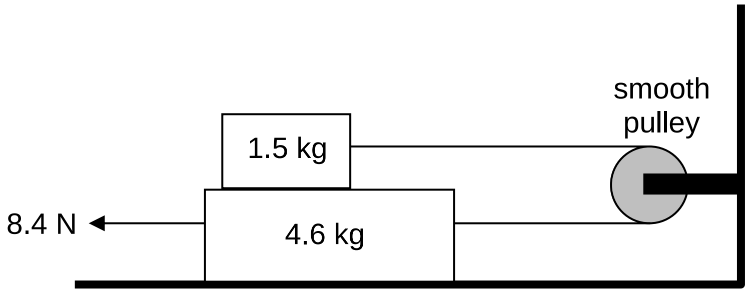
The force exerted by object C on object B is greater than the force exerted by object A on object B. (True)

The weight of object A and the force exerted by object B on object A are an action-reaction pair of forces. (False, the nature of the 2 forces are different so they cannot be action-reaction pair)

The normal contact force exerted by the ground on object C is equal to the weight of object C. (False)

Answer : B

8 The diagram below shows 2 blocks connected together via a light inextensible string over a smooth pulley. The top block has a mass of 1.5 kg and the mass of the bottom block is 4.6 kg. The bottom block is pulled with a force of 8.4 N. Assume that all surfaces (except the pulley) exert a constant frictional force of 1.8 N.



What is the initial acceleration of the 1.5 kg block?

A 0.49 m s^{-2} **B** 0.79 m s^{-2} **C** 1.1 m s^{-2} **D** 1.4 m s^{-2}

Consider only 1.5 kg mass, $F_{net} = ma$ (→+ve)
$T - f = ma$
$T = 1.8 + 1.5\,a$

Consider only 4.6 kg mass, $F_{net} = ma$ (←+ve)
$8.4 - 2f - T = ma$
$8.4 - 3.6 - 1.8 - 1.5a = 4.6a$
$a = 0.49$ m s^{-2}

Answer: A

9 An object, made from two equal masses joined by a light rod, falls with uniform speed through air. The rod remains horizontal.

Which of the following statements is true?

A It is not in equilibrium because it is falling steadily.

B It is not in equilibrium because it is in motion.

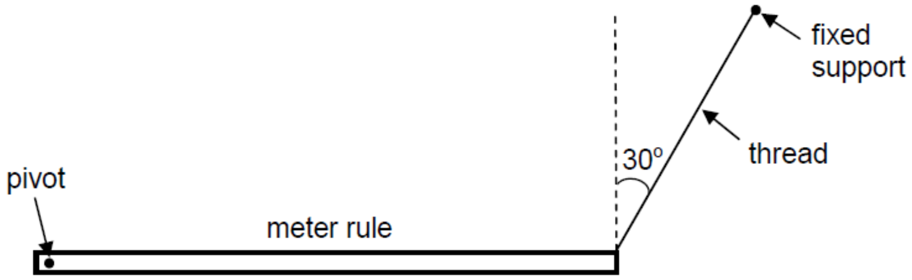
C It is not in equilibrium because there is a resultant torque.

D It is in equilibrium because there is no resultant force and no resultant torque.

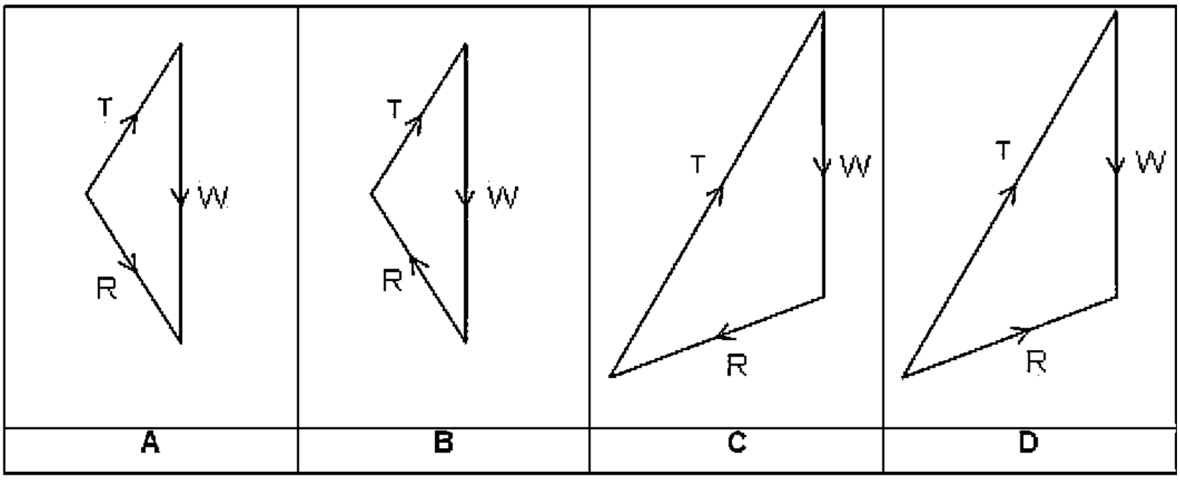
Ans: D

10 A pivoted metre rule is supported in equilibrium horizontally by a thread inclined at 30° to the vertical.

The three forces acting on the rule are its weight W, the tension T in the thread, and the reaction force R at the pivot.

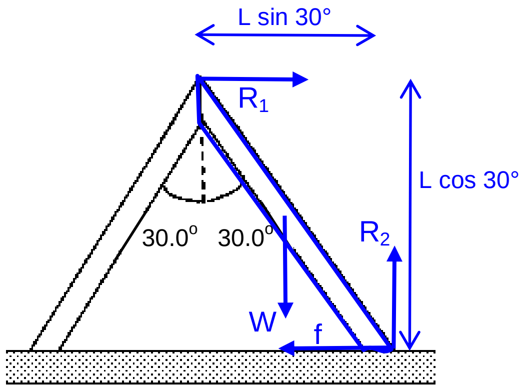


Which of these diagrams, drawn to scale, represents the magnitudes and directions of these three forces?



Ans: B
Since the metre rule is in equilibrium, all forces must add to zero vectorially, i.e. the 3 vectors must form a closed triangle with the directions of the arrows going in the same sense (clockwise in this case). That leaves options B or C.
For C, W and R would result in a net anti-clockwise moment about the point where the thread attaches to the rule, thus C is out.

11 The diagram below shows an inverted "V" made of two uniform boards. Each board weighs 200 N.



Each side has the same length and makes a 30° angle with the vertical. Assuming that the frictional force at the point of contact between the two boards is negligible, the magnitude of the static frictional force that acts on the lower end of each leg of the inverted "V" is

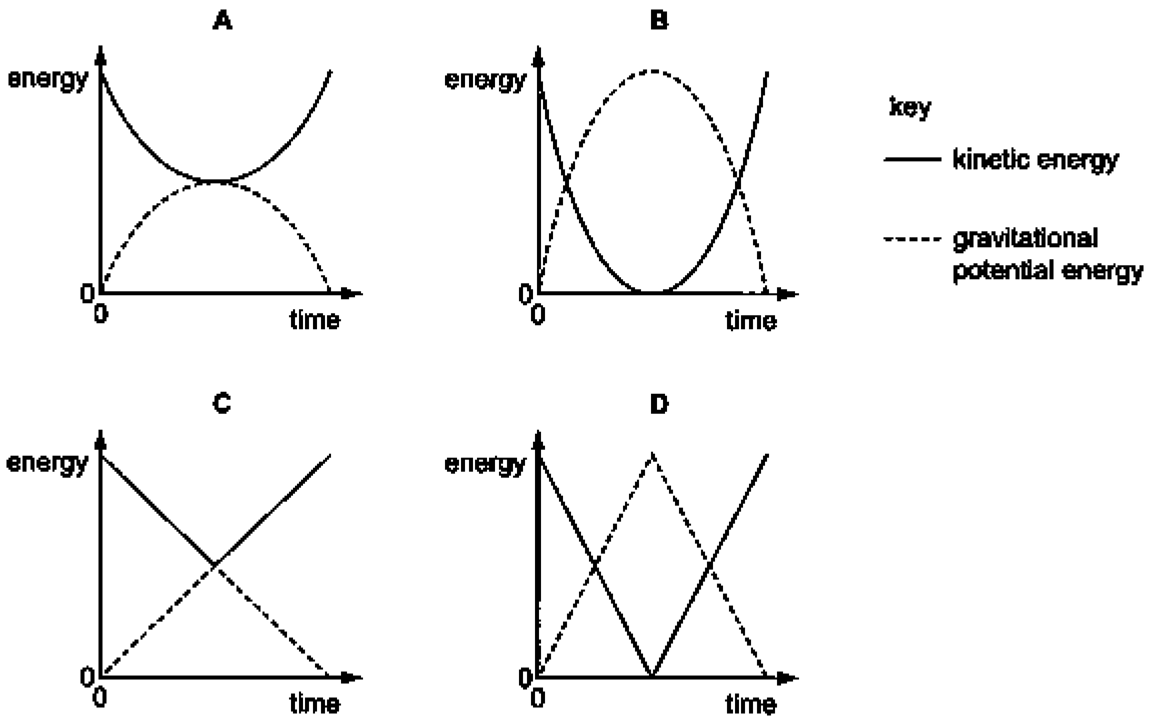
A 58 N **B** 115 N **C** 225 N **D** 346 N

Ans: A

Considering vertical forces on each board
$R_2 = W$

Taking moments of the forces on ONE leg about the top of the board
$f\,(L \cos 30°) + W\,(\tfrac{1}{2} L \sin 30°) = R_2\,(L \sin 30°)$
$f\,(0.866) + 200\,(\tfrac{1}{2})(0.5) = 200\,(0.5)$
$f = 58$ N

12 A goalkeeper kicks a football so that it leaves the pitch at an angle of 45° to the horizontal. Which graph below represents the variation of kinetic energy and gravitational potential energy of the football during the time of flight? Assume that air resistance can be ignored.



Ans: **A**

$GPE = mgh$

$$= mg\left(u_y t - \frac{1}{2}gt^2\right)$$

Hence the graph of GPE against time has the shape of a negative quadratic function, while the graph of KE against time must be such that the total energy of the football remains constant at all times. KE can never be zero as the horizontal speed of the football has a constant non-zero value.

13 A car of mass *m* has an engine which can deliver power *P*. What is the minimum time in which the car can be accelerated from rest to a speed *v*?

A $\dfrac{P}{mv}$ **B** $\dfrac{2P}{mv^2}$ **C** $\dfrac{mv^2}{P}$ **D** $\dfrac{mv^2}{2P}$

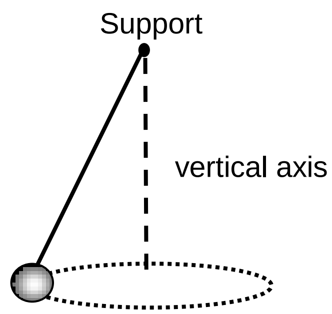
Ans: **D**

Energy supplied to car = Gain in KE of car

$P.t = \dfrac{1}{2}mv^2$

$t = \dfrac{mv^2}{2P}$

14 A pendulum is swung in such a way that it performs uniform circular motion along the horizontal plane as shown.



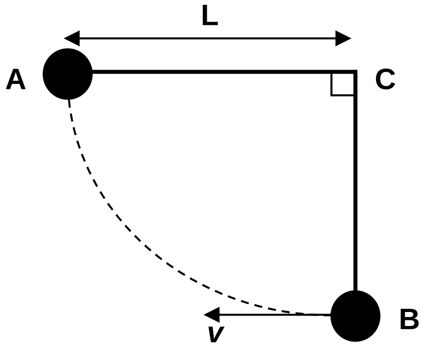
Which of the following statements about the motion is correct?

A The momentum of the bob is conserved because there is no net force acting on it.
B The bob is in equilibrium because the tension in the string balances its weight.
C The kinetic energy of the bob is constant because no work is done on it.
D The acceleration is constant because the tension is constant.

Ans: C

The resultant force on the bob is the centripetal force. No work is done by the centripetal force as it is perpendicular to the direction of motion at any instant.

15 A simple pendulum consists of a bob of mass m at the end of a light and inextensible thread of length L. The other end of the thread is fixed at C. The bob swings upwards in a vertical plane through point B with velocity v such that it is just able to reach A.



What is the tension in the thread as the bob passes point B?

A mg **B** $2mg$ **C** $3mg$ **D** $4mg$

Ans: C

At B, $T - mg = mv^2/L$ ----- (1)

Since the bob is only just able to reach A, at A, velocity = 0
By conservation of energy,

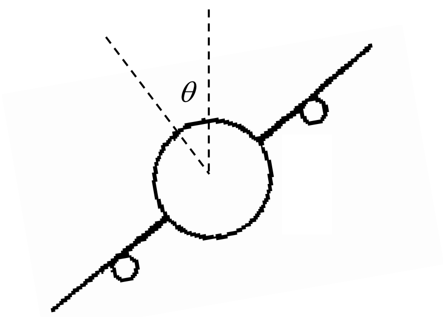
$$E_B = E_A$$
$$\tfrac{1}{2} mv^2 = mgL$$
$$v^2 = 2gL \quad \text{---- (2)}$$

Substituting (2) into (1),

$$T - mg = m(2gL)/L$$
$$T = 3mg$$

16 When the aircraft Concorde is moving in a horizontal plane at a constant speed of 650 m s^{-1}, its turning circle has a radius of 80 km.

When making a turn to the left, what should be the angle of tilt θ, from the vertical, as shown in the diagram below?



A 28° **B** 33° **C** 40° **D** 62°

MCQ 16: A

Reasoning:

$L \cos \theta = mg$
$L \sin \theta = mv^2/r$
$F_{centripetal} / W = v^2/rg = \tan \theta$

$\theta = \tan^{-1} (650)^2/(80 \times 10^3)(9.81) = 28°$

17 The acceleration due to gravity on the surface of a planet of radius r is g. A satellite is revolving at the altitude $2r$ above the surface of the planet. The orbital period of the satellite can be expressed as

A $2\pi\sqrt{\frac{r}{g}}$ **B** $2\pi\sqrt{\frac{3r}{g}}$ **C** $2\pi\sqrt{\frac{9r}{g}}$ **D** $2\pi\sqrt{\frac{27r}{g}}$

Ans: **D**

$$\frac{GMm}{(3r)^2} = m(3r)\left(\frac{2\pi}{T}\right)^2$$

$$T = 2\pi\sqrt{\frac{27r^3}{GM}} = 2\pi\sqrt{\frac{27r}{g}}$$

18 A satellite of mass 1 kg is moved from an orbit where the gravitational potential is –80 MJ kg^{-1} to another orbit where the gravitational potential is –40 MJ kg^{-1}.

What is the increase in its total energy?

A –40 MJ **B** –20 MJ **C** 20 MJ **D** 40 MJ

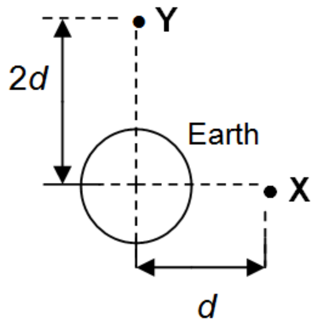
Ans: **C**

$E_T = \frac{1}{2}E_P$ (since $E_P = -\frac{GMm}{r}$ and $E_P = -\frac{GMm}{2r}$)

Hence $E_{T,i} = -40$ MJ and $E_{T,f} = -20$ MJ.

Increase in total energy = 20 MJ.

19 X and Y are two points above the Earth's surface and at distances of d and $2d$ respectively from the centre of the Earth as shown below.



The gravitational potential at Y is -400 kJ kg^{-1}. When a 2.00 kg mass is taken from Y to X, the work done on the mass by the external force is

A –800 kJ **B** –400 kJ **C** 400 kJ **D** 800 kJ

Ans: **A**

$\phi_Y = -\dfrac{GM}{2d} = -400 \text{ kJ kg}^{-1}$

Hence $\phi_X = -\dfrac{GM}{d} = -800 \text{ kJ kg}^{-1}$

Work done by external force = $= m(\phi_X - \phi_Y) = 2.00(-800 + 400) = -800$ kJ

20 A mass attached to the lower end of a vertical spring performs simple harmonic motion.

Which of the following statements is correct?

A When the kinetic energy of the oscillator is equal to its potential energy, the oscillator is neither at the rest position nor at its maximum displacement position.

B The kinetic energy of the oscillator is a maximum when the tension in the spring is a maximum.

C The velocity of the mass is zero when its acceleration is zero.

D The acceleration of the mass is a maximum when it passes through the centre of its oscillation.

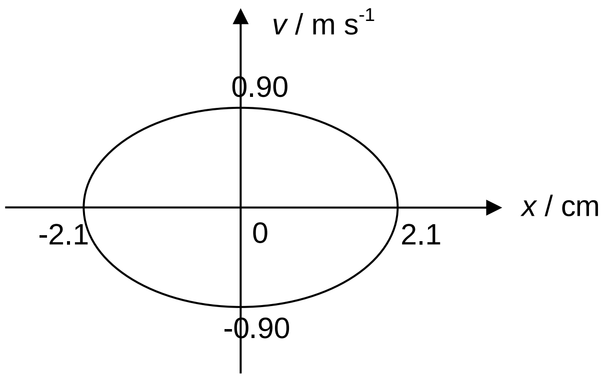
Ans: A

Option B:
The kinetic energy of the oscillator is *zero* when the tension in the spring is a maximum.

Option C:
The velocity of the mass is at a *maximum* when its acceleration is zero.

Option D:
The acceleration of the mass is *zero* when it passes through the centre of its oscillation.

21 The figure below shows how the velocity v of a simple harmonic oscillator varies with its displacement x.



What is the frequency of the oscillation?

A 0.0030 Hz **B** 0.30 Hz **C** 6.8 Hz **D** 43 Hz

Ans: C

From the graph, we have x_0 = 2.1 cm = 0. 021 m and v_{max} = 0.90 ms^{-1}.
We have $v_{max} = \omega x_0$

Thus, $\omega = \frac{0.90}{0.021}$ = 42. 9 $rads^{-1}$.
But $\omega = 2\pi f$
$f = \frac{\omega}{2\pi} = \frac{42.86}{2\pi}$ = 6.82
= 6.8 Hz (2 s.f.)

22 How does damping help lessen damage caused to buildings during an earthquake?

A It reduces the resonant frequency of the building.
B It reduces the amplitude of oscillation of the building.
C It reflects the energy from the earthquake back into the Earth's crust.
D It changes the frequency of the earthquake such it is not equal to that of the building's frequency.

Ans: B
Damping reduces the amplitude of oscillation by dissipating energy from the earthquake.

23 There is one temperature, about 0.01 ^{0}C, at which water, water vapour and ice can co-exist in equilibrium.

Which statement about the properties of the molecules at this temperature is correct?

A Ice molecules have more microscopic potential energy than the water molecules.

B The mean kinetic energy of the water molecules is greater than the mean kinetic energy of the ice molecules.

C Water vapour molecules are less massive than water molecules.

D Water vapour molecules have the same mean square speed as ice molecules and water molecules.

Ans: D

A is incorrect since solids have less microscopic potential energy than liquids.
B is incorrect. Since they are at the same temperature, they have the same mean kinetic energy.
C is incorrect since they are the same molecule.
D is correct. Since they are at the same temperature and they have the same mass, they will have the same mean square speed.

24 Which of the following is not an assumption of the kinetic theory of gases?

A The volume of each particle is negligible compared to the volume of the gas.

B The mean kinetic energy of a particle is proportional to its thermodynamic temperature.

C No energy is lost when the particles collide with the walls of the container.

D The particles exert negligible forces of attraction and repulsion on each other.

Ans: B

25 A partially inflated and sealed balloon is placed inside a bell jar. The jar is then evacuated (air is taken out of the jar but not the balloon) with no change in temperature.

Which of the following statements is correct?

A The volume of the balloon decreases.

B The pressure inside the balloon increases.

C The air particles inside the balloon make less collisions per unit time with the walls of the balloon.

D The air particles inside the balloon move faster.

Ans: C

With no change in temperature, the root mean square speed of the air particles remain constant. Since the pressure in the jar decreases, the balloon will expand, causing an increase in volume and a decrease in the pressure (Boyle's Law). The air particles inside the balloon must be making less collisions per unit time with the walls of the balloon.

26 A long piece of wire has a resistance of 2.0 Ω. It is cut into 40 equal lengths and these are connected in parallel to form a multi-stranded cable.

What is the resistance of the cable?

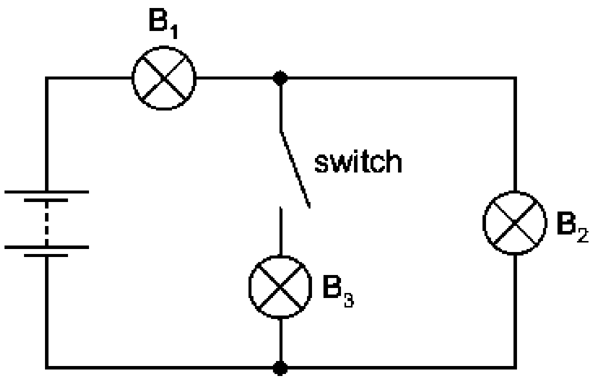
A 1.3×10^{-3} Ω **B** 0.05 Ω **C** 80 Ω **D** 3.2×10^{3} Ω

Ans: A

Resistance of each wire = 2.0 / 40 = 0.05 Ω

When it is connected in parallel, total resistance = R/n as each wire has same resistance of 0.05 Ω.

27 B_1, B_2 and B_3 are three identical lamps. They are connected to a battery with zero internal resistance as shown.



Initially the switch is closed. The switch is then opened and lamp B_3 goes out.

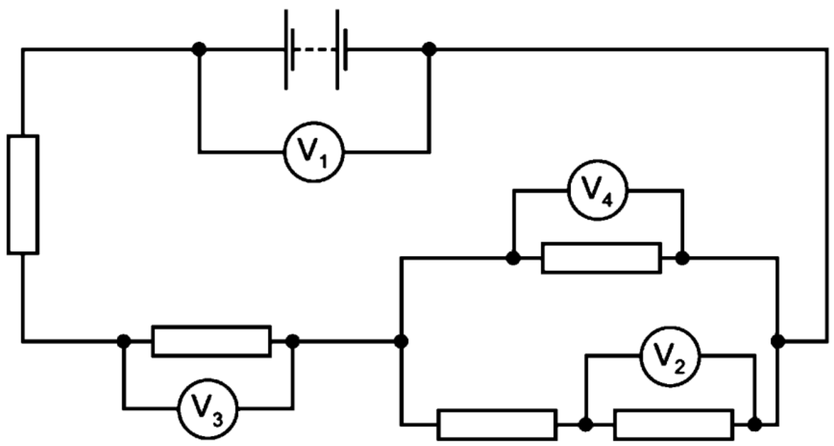
What happens to the brightness of lamps B_1 and B_2 when the switch is opened?

	brightness of lamp B_1	brightness of lamp B_2
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

Ans: B

When the switched is open, the p.d. across lamp B_2 will incease.

28 In the circuit shown, all the resistors are identical.



The reading on voltmeter V_1 is 8.0 V and the reading on voltmeter V_2 is 1.0 V.

What are the readings on the other voltmeters?

	reading on voltmeter V_3 / V	reading on voltmeter V_4 / V
A	1.5	1.0
B	3.0	2.0
C	4.5	3.0
D	6.0	4.0

Ans: B

The common convenient method to determine p.d. is potential divider.

29 A mechanical wave of frequency 300 Hz travels along a railway line at 6 km s^{-1}. Two points on the railway line which are 250 cm apart are out of phase by

A 0 rad **B** π / 4 rad **C** π / 2 rad **D** π rad

Ans: **B**

$$\lambda = \frac{v}{f} \quad \Rightarrow \quad \lambda = 20\,m$$

$$\phi = \frac{0.250}{20} \times 2\pi = \frac{\pi}{4}\,rad$$

30 A plane wave of amplitude *A* is incident on a surface area *S* placed so that it is perpendicular to the direction of travel of the wave. The energy per unit time intercepted by the surface is *E*.

The amplitude of the wave is reduced to 0.5 *A* and the area of the surface is increased to 2*S*. How much energy per unit time is intercepted by this surface?

A 4 *E* **B** 2 *E* **C** *E* **D** 0.5 *E*

Ans: **D**

since $I = \frac{P}{A}$ & $I \propto x_0^2$,

$$\frac{P}{A} \propto x_0^2 \quad \Rightarrow P \propto A x_0^2$$

Hence $\frac{P'}{P} = \frac{A' x_0'^2}{A x_0^2} \quad \Rightarrow \quad \frac{E'}{E} = \frac{2S(0.5A)^2}{S(A)}$

$$\therefore E' = 0.5E$$

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**

CLASS		TUTOR'S NAME	

PHYSICS

9749/02

Paper 2 Short Structured Questions

5 October 2016

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
Total	

This document consists of **15** printed pages.

[Turn over

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{(x_o^{\ 2} - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$

radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \ln 2 / t_{1/2}$

For Examiner's Use

1 The rate of flow of thermal energy $\frac{Q}{t}$ in a material is given by

$$\frac{Q}{t} = \frac{CA(\Delta T)}{x}$$

where A is the cross-sectional area of the material,
x is the thickness of the material,
ΔT is the temperature difference across the thickness of the material, and
C is a constant.

(a) Determine the base units of C.

$$[C] = \frac{[Q][x]}{[t][A][\Delta T]} = \text{kg m}^2\text{ s}^{-2}\text{ m s}^{-1}\text{ m}^{-2}\text{ K}^{-1} = \text{kg m s}^{-3}\text{ K}^{-1}$$

Examiner's Comments:
It is disappointing that quite a number of student thought that Q represent charge or did not realise that J is not a base units.

base units = ... [2]

(b) An experiment is conducted to determine the value of C. The rate of flow of thermal energy $\frac{Q}{t}$ is found for different values of x, for the same conductor, same A and same ΔT.

The graph of $\frac{Q}{t}$ is plotted against $\frac{1}{x}$ as shown in Fig. 1.1.

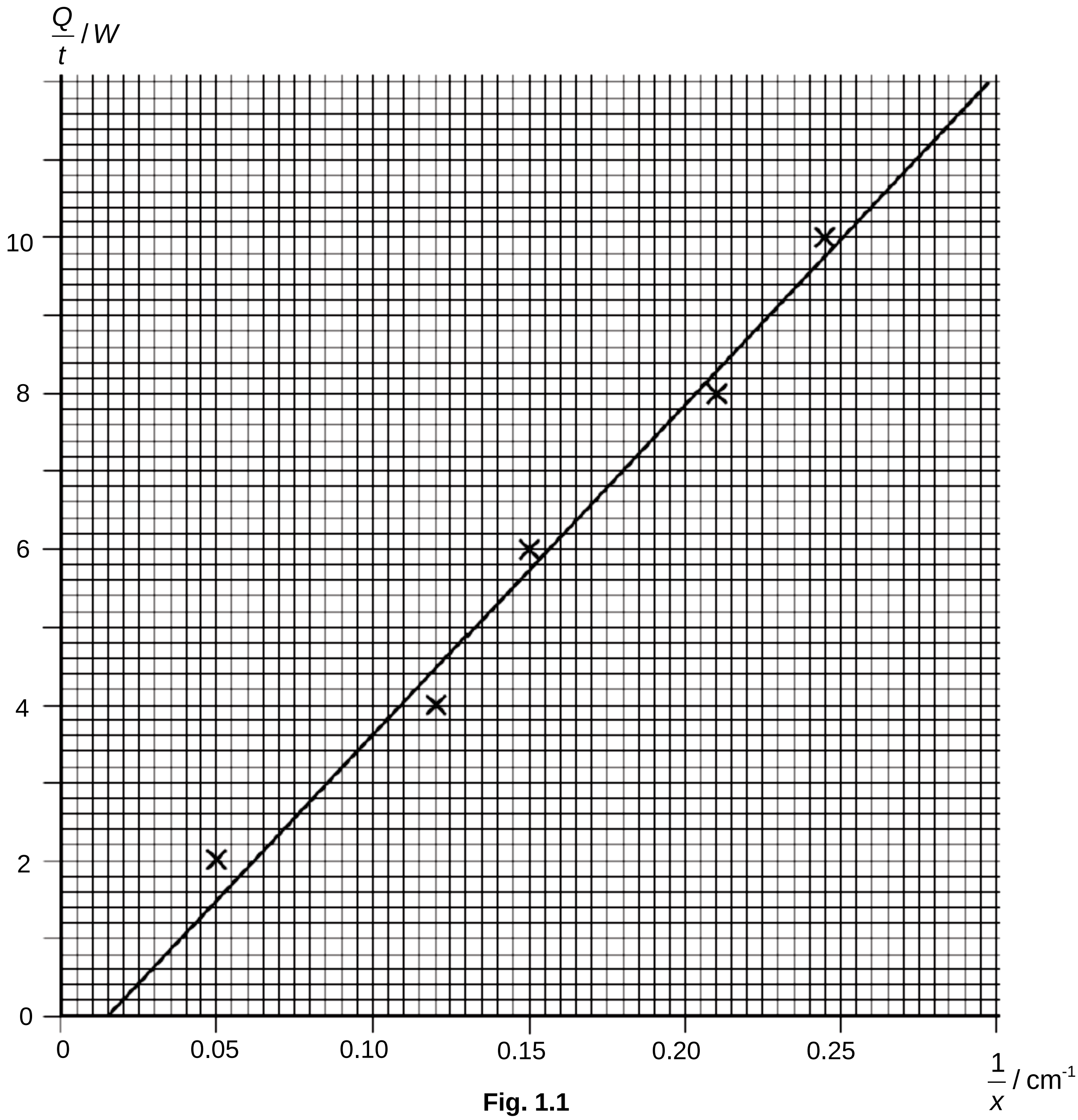


Fig. 1.1

(i) State the feature of the graph that indicates the presence of random error in the experiment.

The plotted points are spread /scatter along the best fit line.

.... [1]

Examiner's Comments:
A large number of students are able to state correct feature of the graph.

(ii) With reference to Fig 1.1, state and explain whether the accuracy of *C* is affected by the presence of systematic error in the experiment.

The evidence of systematic error is seen by the graph shift by a fixed value to the right. The best fit should pass through the origin if there is no systematic error. Since the gradient of the straight line is equal to $CA\Delta T$ and the gradient is not affected by the presence of systematic error, the accuracy of C are not affected.

[2]

Examiner's Comments:

Only a small number of students are able to explain clearly how the gradient of the graph is not affected by the systematic error. Most students did not give enough details on either of the following

1)How C is calculated from the gradient OR

2)Feature of graph with reference to presence of systematic error.

(iii) Different types of materials are known to have different values of *C*. Suggest one possible factor that could affect the value of *C*.

Density of material, atomic spacing of atoms/particles in the materials,

[1]

Examiner's Comments:

Students need to realise that quantities listed in the given expression should not be considered a factor affecting C. They affect the rate of transfer of thermal energy but not C. Stating the meaning of C is also not a considered a factor as the question ask for factor affecting C and not suggesting what could C represent.

2 (a) Define linear momentum.

Linear momentum is defined as the product of a body's mass and its linear velocity.

[1]

Examiner's Comments:

A few students got mixed up stating that the direction of momentum is in the direction of the force, which is incorrect.

(b) Fig. 2.1 shows an airboat of mass 420 kg which is propelled forward by a propeller generating a column of air backward.

For Examiner's Use

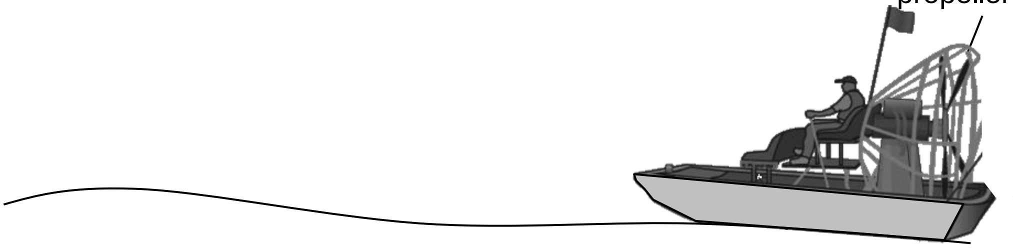


Fig. 2.1

(i) By using Newton's laws, show that the forward thrust acting on the airboat is given by

$$F = \pi r^2 \rho v^2$$

where ρ is the density of air, r is the effective radius of propeller and v is the speed of the air moving backward. [3]

By Newton's second Law,

(taking the direction to the left or forward direction to be positive)

The force acting on air by propeller = Rate of change of momentum of air

$= (-mv - mu)/t$

$= -\, v\, m/t$, as u = 0 [1]

$= -\,(v)\rho\pi r^2 v$

$= -\,\rho\pi r^2 v^2$ [1]

By Newton's 3rd Law,

force acting on propeller by air = - force acting on air by propeller [1]

F $= \rho\pi r^2 v^2$ forward. (shown)

Examiner's Comments:

Only a small number of students are able to show the final expression with no mistakes.
There were a few very serious mistake such as applying F = ma or F = dp / dt
F which is the forward thrust on airboat will be equal to the rate of change of momentum of the airboat, which is undetermined in this question.

Most students made 1 or more of the following mistakes

1) Direction of the force applied is not considered , as well as velocity
2) Initial velocity condition or that change in velocity = v
3) applying N3L with no consideration of direction
4) abusing the symbol use where m or r can be used again to represent a different quantity in the equation
5) sudden inclusion of –ve sign just to balance equation

For Examiner's Use

(b ii) $\sum F = ma$

$\rho \pi r^2 v^2 = ma$

$a = (1.2)(\pi)(0.7^2)(20^2)/420 = 1.76$ m s^{-2}

Examiner's Comments:

A few students did not show substitution or show inability of using calculator correctly.

acceleration = ... m s^{-2} [2]

(iii) By considering the airboat and the air generated as a system, explain why the total momentum of this system is not conserved when the airboat is moving at a constant speed.

The external forces acting on the system will be weight, upthrust and drag force due to water. Since mg is counter by U, hence the drag force will results in a **net external force** acting on the system. Therefore, total momentum is not conserved.

Examiner's Comments:
Most students misunderstood the question. You need to explain why the total momentum is not conserved.
The condition is that a net external force acts on the system. And you need to identify this net external force which is drag force due to water.
You need to examine all the external forces acting on the system, and only a few manage to do so.
Common mistakes

1) kinetic energy is not conserved and so momentum is not conserved.(What about the case of inelastic collision ?)
2) The air exerts a force on the airboat and so a resistive force opposed it for net force to be zero. (airboat and air generated is a system so air cannot exert a force on the system, that is internal force.)
3) The air is blew away from the propeller, so there is a decrease in mass and thus momentum must decrease and not conserved. (The airboat and air column generated is a system so the mass of air is not lost, as it is always part of the system.)

3 **(a)** Define the *moment* of a force.

The moment of a force about a point is defined as the product of the force and the perpendicular distance from the line of action of the force to that point. [2]

(b) State the two conditions necessary for a body to be in static equilibrium.

1. the resultant force acting on the body must be zero, and

the resultant moment exerted on the body about any point must be zero.

For Examiner's Use

2. ....

.... [2]

Examiner's comment:
Definitions must be learnt completely and properly. Interchanging words/phrases or rephrasing may cause a change in meaning of the definition. Leaving words/phrases out renders the definition incomplete or incorrect.

(c) A torque wrench is a type of spanner for tightening a nut and bolt to a particular torque, as illustrated in Fig. 3.1.

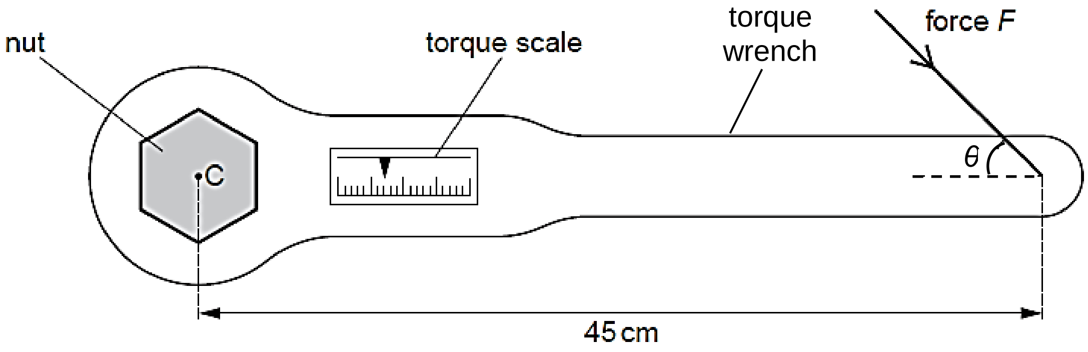


Fig. 3.1

The wrench is put on the nut and a force is applied to the handle. A scale indicates the torque applied.

The wheel nuts on a particular car must be tightened to a torque of 130 N m. This is achieved by applying a force F to the wrench at a distance of 45 cm from its centre of rotation C. This force F may be applied at any angle θ to the axis of the handle, as shown in Fig. 3.1.

For the minimum value of F required to achieve this torque,

(i) state the value of the angle θ that should be used, and explain your reasoning.

θ = ...90°.......... ° [1]

Reasoning:

The value of the torque is F sin θ (0.45). Thus, in order to obtain the required torque of 130 Nm, F is a minimum when sin θ is maximum.

]

Examiner's comment:
There are actually a number of points that lead to the conclusion that the best angle is 90°:
1. the required torque τ is fixed at 130 Nm
2. d is also fixed at 0.45 m
3. Since τ = F d sin ϴ, for F to be a minimum, sin ϴ must be maximum.

There are many other ways of expressing the above points.

For Examiner's Use

(ii) Calculate the magnitude of *F*.

130 = F × 0.45
F = 290 N

F = ... N [2]

4 **(a)** Define *gravitational field strength*.

The gravitational field strength at a point in a gravitational field is defined as the gravitational force per unit mass acting on a test mass placed at that point.

.... [1]

Examiner's Comments:
It is important to use the term "per unit mass", instead of "one kg".

Gravitational field strength is different from gravitational field, hence it should NOT be described as a region of space.

Some students appeared to be totally confused with the different terms introduced in this topic, giving definitions of gravitational potential, Newton's law of universal gravitation or even a mix of gravitational field strength and gravitational potential definitions!

(b) **(i)** Show that a body projected from Earth (assumed to be stationary) with a speed v equal to or greater than $\sqrt{\frac{2GM_E}{R_E}}$ will never return to Earth.

It is given that M_E = mass of Earth and R_E = radius of Earth. [1]

In order for the body not to return to Earth, it must have sufficient energy to escape from Earth's gravitational field.

Let the body's minimum speed of projection from the surface of Earth be v, such that it will never return to Earth.

$$E_{k,i} + E_{p,i} = E_{k,f} + E_{p,f}$$

$$\frac{1}{2}mv^2 - \frac{GM_E m}{R_E} = 0 + 0$$

$$v = \sqrt{\frac{2GM_E}{R_E}}$$

Examiner's Comments:
A number of students approached this question by stating that the KE of the body should be greater or equal to its GPE at the surface of Earth. This is not acceptable as it does not show the application of conservation of energy. Students must show the understanding that in order for the body not to return to Earth, its total energy at infinity must be greater or equal to zero.

For Examiner's Use

(ii) Fig. 4.1 gives the values of the radius *R* and mass *M* of the Earth and Sun.

	***R* / m**	***M* / kg**
Earth	6.0×10^{6}	6.0×10^{24}
Sun	7.0×10^{8}	2.0×10^{30}

Fig. 4.1

The speed *v* mentioned in **(b)(i)** is known as the escape speed from Earth. Given that the escape speed from Earth is 1.1×10^{4} m s^{-1}, determine the escape speed from Sun.

Since $v \propto \sqrt{\dfrac{M}{R}}$,

$$\frac{v_S}{v_E} = \sqrt{\frac{M_S}{M_E}} . \sqrt{\frac{R_E}{R_S}}$$

$$\frac{v_S}{1.1 \times 10^{4}} = \sqrt{\frac{2.0 \times 10^{30}}{6.0 \times 10^{24}} . \frac{6.0 \times 10^{6}}{7.0 \times 10^{8}}}$$

$$v_S = 5.88 \times 10^{5} \text{ m s}^{-1}$$

OR

$$v_s = \sqrt{\frac{2GM_s}{R_s}}$$

$$= \sqrt{\frac{2(6.67 \times 10^{-11})(2.0 \times 10^{30})}{7.0 \times 10^{8}}}$$

$$= 6.17 \times 10^{5} \text{ m s}^{-1}$$

escape speed = ... m s^{-1} [1]

(c) Two stars of mass *M* and 2*M*, a distance of 3*R* apart, rotate in circles about their common centre of mass *O*, as shown in Fig. 4.2.

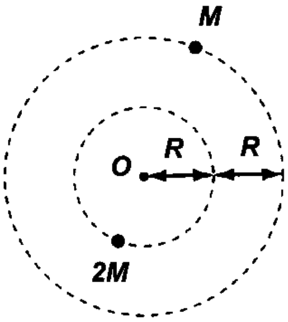


Fig. 4.2

The period of this binary star system is 3.42×10^{5} s. The value of *M* is 3.14×10^{30} kg.

(i) Show that the gravitation force of attraction between the two stars is given by $\dfrac{1.46 \times 10^{50}}{R^{2}}$. [1]

For Examiner's Use

$$F_g = \frac{G(2M)(M)}{(3R)^2}$$
$$= \frac{2(6.67\times10^{-11})(3.14\times10^{30})^2}{9R^2}$$
$$= \frac{1.46\times10^{50}}{R^2}$$

Examiner's Comments:
Students are reminded once again that it is IMPORTANT to show full substitution of values when solving a problem.

(ii) Determine the distance R.
Consider mass 2M.

The gravitational force exerted by M on 2M provides the required centripetal force for 2M to move in a circle.

$$\Sigma F_r = mr\omega^2$$
$$\frac{1.46\times10^{50}}{R^2} = 2(3.14\times10^{30})R\left(\frac{2\pi}{3.42\times10^5}\right)^2$$
$$R = 4.10\times10^9 \text{ m}$$

Examiner's Comments:
Students must remember to write the above statement on the source of the required centripetal force before proceeding to write the equations, without which full credit will not be given.

R = ... m [3]

For Examiner's Use

(d) An astronaut in a space capsule orbits around the Earth in a circular path. The astronaut appears to float inside the capsule. A student suggests that the astronaut floats because there is no gravitational force acting on him.

State and explain whether the student's suggestion is valid.

The student's suggestion is invalid. The astronaut cannot have zero gravitational force acting on him because it is his weight that provides the required centripetal force for him to orbit around the Earth.

The astronaut appears to float because both he and the space capsule experience the same centripetal acceleration. Hence there is no contact force between them.

....

.... [2]

<u>Examiner's Comments:</u>

No credit is given for simply stating that the suggestion is invalid. Students are expected to **<u>explain</u>** <u>why there is no gravitational force</u> acting on the astronaut (instead of just stating it), as well as the <u>reason for the astronaut appearing to float</u> inside the capsule.

While explaining the source of the centripetal force required for orbit, some students got confused with the astronaut and the capsule. The question clearly mentioned the astronaut but a number of students proceeded to explain why there is a gravitational force exerted on the capsule instead. The gravitational force exerted on the capsule is <u>different</u> from the gravitational force exerted on the astronaut, since they are unlikely to have the same mass (although they have the same centripetal acceleration since they are orbiting together).

The gravitational force exerted on the capsule only provides for the centripetal force required for the capsule to orbit, not the centripetal force for the astronaut! The centripetal force for the astronaut can only come from the gravitational force exerted on the astronaut himself. Some students incorrectly used the terms "astronaut" and "capsule" interchangeably.

Not many students can fully explain why the astronaut floats inside the capsule. Many wrongly stated that the astronaut floats because the resultant force exerted on him is zero. If the resultant force exerted on the astronaut were zero, then there cannot be any centripetal force acting on him to allow him to orbit in space! Some stated that the centripetal acceleration of the astronaut is g, without explaining why.

Merely stating that the astronaut is falling freely, is weightless, or has no apparent weight, are not satisfactory explanations of why he appears to float inside the capsule. Since the astronaut is inside the capsule, the acceleration of the capsule has to be taken into account as well.

By considering <u>both the astronaut and capsule as one system</u> and applying Newton's second law of motion, one can conclude that the acceleration of both astronaut and capsule must be g. Then by analysing the free body diagram of the astronaut alone and applying Newton's second law again, it can be determined that the normal contact force exerted by the capsule on the astronaut must be zero, and this is the reason for the astronaut appearing to float (because there is no contact between him and the capsule).

For Examiner's Use

5 A small boat parked at the dock bobs up and down in the water as shown in Fig. 5.1.

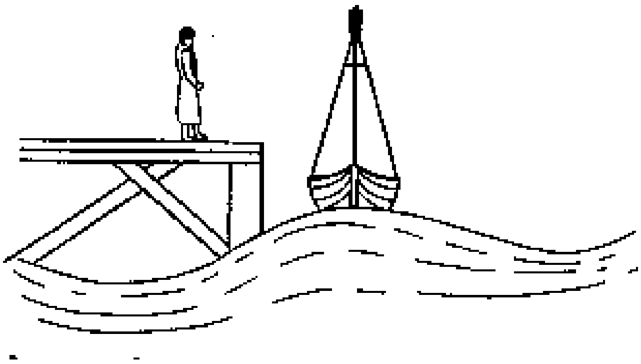


Fig. 5.1

A boy standing at the dock observes that the boat exhibits simple harmonic motion. The boat's displacement *y*, in metres, follows a sinusoidal relationship with respect to time *t*, and is described by the equation

$$y = 0.30\cos\left(\frac{\pi t}{3}\right)$$

The water waves travel at a speed of 30 m s^{-1} and the mass of the boat is 1.2×10^3 kg.

(a) Define *simple harmonic motion*.

Simple harmonic motion (S.H.M.) is defined as the oscillatory motion of a body/object/oscillator whose acceleration *a* is always directed towards a fixed point and is directly proportional to its displacement *x* from that fixed point.

.... [1]

Examiner's Comments:
Parts a) to c) of this question are generally well done.

(b) State the amplitude of motion of the boat.

amplitude = 0.30 m [1]

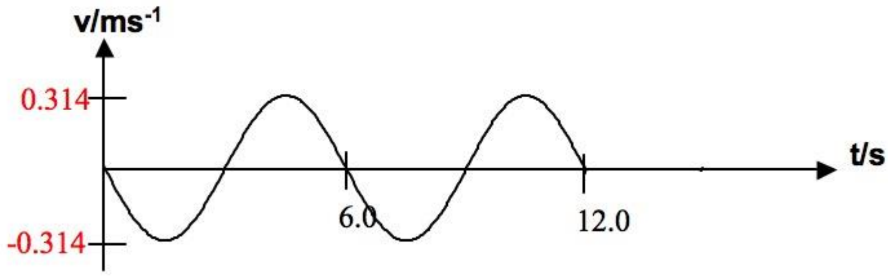
(c) Determine the frequency of oscillation of the boat.

$$\omega = 2\pi f = \frac{\pi}{3}$$

$$f = \frac{1}{6} = 0.17\ \text{Hz}$$ [0.167 – 0.17Hz]

frequency = …………………… Hz [2]

(d) Draw a clearly-labeled velocity versus time graph on Fig. 5.2 to represent two cycles of motion of the boat.



Marking Criteria:
[1] Negative sine curve with 2 cycles drawn.
[1] Period calculated and labeled
[1] Maximum velocity labeled and general presentation of the graph

Fig. 5.2

Examiner's Comments:
This part is poorly done.
Many students mistake the wave speed ($30 ms^{-1}$) as the maximum oscillatory speed. General presentation of the graph is poor, including details like drawing a sine curve with constant period and constant amplitude. It is surprising that some students did not remember v=dy/dt, which requires a differentiation of the displacement equation to obtain a negative sine function.

[3]

(e) Hence determine the total energy of the boat.

$$v = -0.10\pi \sin\left(\frac{\pi t}{3}\right)$$

$$v_o = 0.10\pi \text{ ms}^{-1}$$

Show understanding that the total energy is equal to the maximum kinetic energy of the system.

$$E_{total} = E_{K,\max} = \frac{1}{2}mv_o^2 = 59 \text{ J}$$ [58 – 59.5J]

Examiner's Comments:
This part is poorly done.
No credit is given for students who mistake the wave speed ($30 ms^{-1}$) as the maximum oscillatory speed in the calculation of maximum kinetic energy: No ECF.

Many students did not state explicitly the relationship between maximum oscillatory kinetic energy and the total energy of the boat.

total energy of the boat = …………………… J [2]

H

NANYANG JUNIOR COLLEGE
JC 1 END-OF-YEAR EXAMINATION
Higher 2

CANDIDATE NAME	**SOLUTION**
CLASS	
TUTOR'S NAME	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

30 September 2016

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in Section A and Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
Section B	
7	
Total	

This document consists of **23** printed pages.

[Turn over

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} $(1 / (36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm / r$
temperature	T/K	=	T/°C + 273.15
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o^{\ 2} - x^2\right)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage	x	=	$x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\mu_o I / 2\pi d$
magnetic flux density due to a flat circular coil	B	=	$\mu_o NI / 2r$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$

radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \ln 2 / t_{1/2}$

Section A

1 **(a)** One of the equations of motion may be written as $v = u + at$.

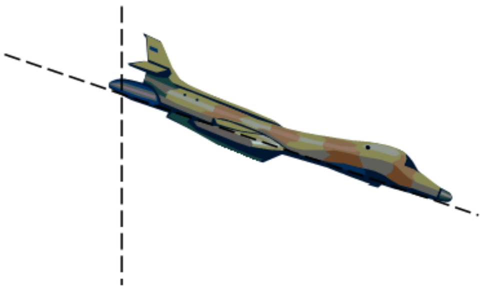
(i) Name and define the quantity represented by the symbol *a*.

a is the acceleration of the body, defined as the rate of change of velocity of the body with time. [1]

(ii) The quantity represented by the symbol *a* may be either positive or negative. State the significance of having a negative value of *a* with positive value of *u*.

A negative value of a, with a positive value of u, means that the motion of the body is a deceleration (or that the speed of the body is decreasing). [1]

(b) A dive bomber, diving at an angle of 53° with the horizontal, releases a bomb at an altitude of 730 m. The bomb hits the ground 5.0 s after being released.



(i) Show that the bomber is diving at a speed of 150 m s^{-1}.

$$y = u_y t + \frac{1}{2} a_y t^2$$

$$730 = u_y (5.0) + \frac{1}{2}(9.81)(5.0)^2$$

$$u_y = 120 \text{ m s}^{-1}$$

$$u_y = u \sin 53°$$

$$u = \frac{u_y}{\sin 53°} = \frac{120}{\sin 53°} = 150 \text{ m s}^{1}$$

[2]

(ii) Calculate the final velocity of the bomb just before it strikes the ground.

$$u_x = u \cos 53° = 150 \cos 53° = 90 \text{ m s}^{-1}$$

$$v_y = u_y + a_y t = 120 + (9.81)(5.0) = 169 \text{ m s}^{-1}$$

$$v = \sqrt{169^2 + 90^2} = 190 \text{ m s}^{-1}$$

$$\theta = \tan^{-1}\frac{169}{90} = 62°$$

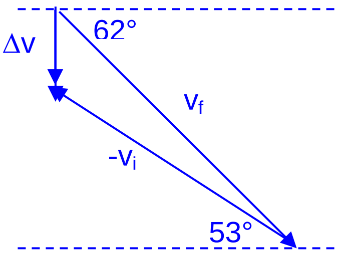
velocity = ... m s^{-1}

direction = 62° below the horizontal [2]

For Examiner's Use

Examiner's Comments:
(b) (i) and **(ii)** are very fundamental projectile questions that students should be proficient in doing.

(iii) **1.** Sketch a vector diagram (not drawn to scale) to show the change in velocity of the bomb between the moment of release and when it strikes the ground. [1]



Examiner's Comments:
Calculating the change in any vector quantity involves constructing vector diagrams.
Some students, knowing that the only force causing acceleration would be gravitational force, were able to draw the change in the velocity accurately in the vertical direction.
A number of students left out the arrow heads and labels, causing the diagram to be incomprehensible.

2. Hence calculate the magnitude of the change in velocity of the bomb between the moment of release and when it strikes the ground.

$$\Delta v=\sqrt{190^2+150^2-2(190)(150)\cos 9^\circ}=48\ \text{m s}^{-1}$$

Examiner's Comments:
There were a large number of students subtracting just the numbers, showing that they did not understand that a change in a vector quantity meant the directions had to be taken into consideration, so just subtracting the magnitudes is definitely incorrect.

2 On a frictionless airtrack, cart A of mass 200 g moves towards cart B with velocity 2.0 cm s^{-1}, while cart B of mass 300 g moves towards cart A with velocity 5.0 cm s^{-1}, as illustrated in Fig. 2.1.

Magnetic repulsion prevents the bumpers from making contact even at the point of closest approach.

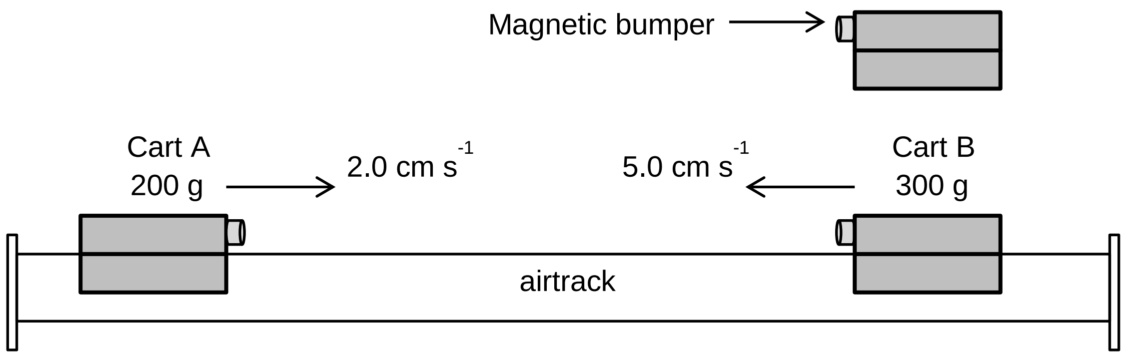


Fig. 2.1

Fig. 2.2 shows how the velocity of each cart varies with time.

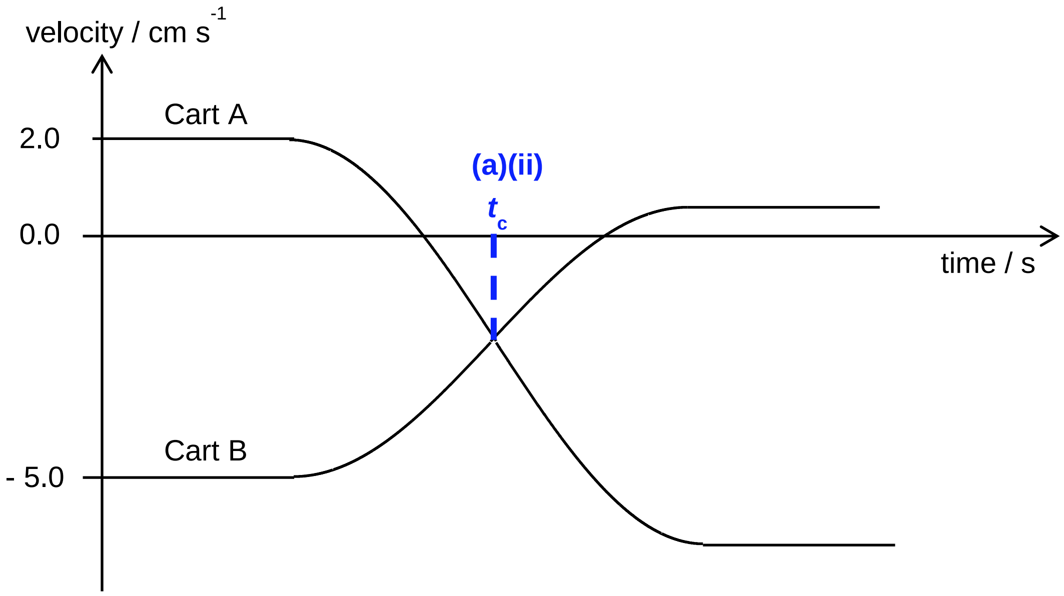


Fig. 2.2

(a) **(i)** At one instant during the interaction between the carts, they are travelling in the same direction with the same speed. Calculate this speed.

By Conservation of momentum,

Total initial momentum = Total final momentum

$m_1u_1 + m_2u_2 = (m_1+m_2)(0.200)v$

$(0.200)(2)+(0.300)(-5.0) = (0.500)v$

$v = -2.2\text{ cm s}^{-1}$

speed = 2.2 cm s^{-1}

speed = ...2.2..... cm s^{-1} [2]

For Examiner's Use

Marker's Comments:
There are a few common mistakes made by a number of students,
They forget that momentum is a vector and add them without consideration.
Momentum is a vector due to the product component velocity, which is a vector. Speed is just the magnitude and the negative sign should not be there.
As the calculation is when the interaction occurs, only conservation of momentum holds, not the conservation of kinetic energy. Thus, relative speed of approach and relative speed of separation cannot be apply even though this is an elastic collision.
There are a number of mistake for students who used
change of momentum in A = - change in momentum in B
as they do not correctly substitute the equation with the correct velocities, they did not get the correct answer.
Carelessness of a number students who cannot understand their own handwriting as well as mixing up masses with velocities and those who are unable to use the calculator correctly.

(ii) In Fig. 2.2, mark t_c on the time-axis to indicate the time at which the carts are at their distance of closest approach. [1]

Marker's Comments:
You must read and understand instruction which is to mark t_c on the time-axis. A dotted line and clear marking is required.

(iii) Determine the maximum amount of magnetic potential energy stored during the interaction between the carts.

By conservation of energy,

Energy stored in the magnetic field = loss in kinetic energy

$= KE_i - KE_f$

$$= \frac{1}{2}(0.200)(0.020)^2 + \frac{1}{2}(0.300)(0.050)^2 - \frac{1}{2}(0.500)(0.022)^2$$

$$= 2.94 \times 10^{-4}\ \text{J}$$

Marker's Comments:
If you understand the conservation of total energy and the graph given in Fig 2.2, students are able to determine the correct answer.
Most students make mistakes by calculating the KE without correct conversion of the quantities such as using v = 2.2 cm s^{-1} or mass as 200 g.
From Fig 2.2, there is no point where the sum of the final KE of the 2 masses will be 0, so assuming KE max = energy stored in magnetic field is not valid.

maximum energy = …………………… J [2]

(b) The polarity of the magnetic bumper of cart A is reversed, so the carts are now magnetically attracted to each other. As a result, the carts are always locked together after a collision. Assuming that carts A and B are initially far away from each other and moving towards each other with the same velocities as in **(a)**, the variation with time of the **total** kinetic energy of the carts is shown in Fig 2.3.

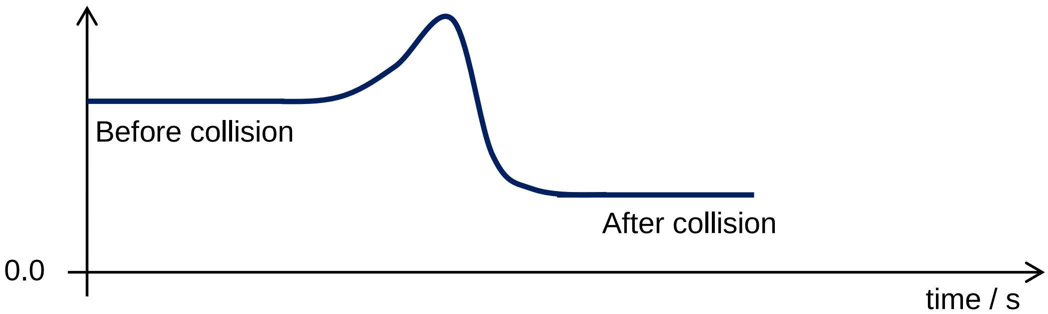


Fig. 2.3

(i) Explain why the total kinetic energy of the carts increased before the carts collided.

Before the carts are in physical contact, the total kinetic energy increases due to work done by magnetic force / the magnetic potential energy converts to kinetic energy resulting in increasing kinetic energy / Using Newton's Second law, the magnetic force exerted on the two carts results in an acceleration of the two carts and thus their velocities increased which lead to an increase in kinetic energy.

(ii) Explain why the total kinetic energy of the carts decreased after the collision.

The final total kinetic energy is lesser because some kinetic energy is converted to heat/internal energy in an inelastic collision.

....

Marker's Comments:
Inelastic collision is a conclusion, not an explanation, thus, the loss is usually a conversion of kinetic energy to internal energy.
Conversion to sound energy is not acceptable, as it is too insignificant.
Stating that kinetic energy is lost to the surrounding is too vague.
Magnetic energy is present when 2 magnets are in close vicinity, but once they move closer, the magnetic energy decreased. (For example, when you move a mass nearer to earth, the gpe decreased, it does not increase) Thus, after collision, the magnetic energy will be at its minimum, so it does not increase from the loss in kinetic energy.

3 (a) Define *work done*.

The work done by a force on a body is defined as the product of the force and the .....

displacement of the body in the direction of the force. [1]

Examiner's Comments:
Many students used the term "distance", instead of "displacement", which caused them to lose the mark.

For Examiner's Use

(b) A body of mass m is raised through a height h at constant speed near the surface of Earth, where the gravitational field strength is g.

Derive an expression for its gain in gravitational potential energy in terms of m, h and g.

Let F_{ext} be the upward force required to raise the body at constant speed.
As the mass is raised to a height near the surface of Earth, g can be assumed to be constant.

Since the speed is constant, $F_{ext} = mg$

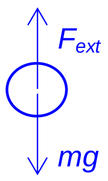
OR

By Newton's 2nd law of motion:

$\Sigma F = ma$

$F_{ext} - mg = 0$

$F_{ext} = mg$



Gain in GPE of body = work done by F_{ext} on body
$= F_{ext}\,(h)$
$= mgh$

Examiner's Comments:
Since the mass is raised through a distance near the surface of Earth, we can assume that the gravitational field strength g is constant. And since the speed of the mass is constant, its acceleration must be ZERO. A good number of students wrote that the acceleration of the mass is equal to the acceleration of free fall g, which shows a complete lack of understanding of the term "constant speed"!

Many also failed to appreciate that there is more than one force acting on the mass. In order to raise the mass, an external upward force must be acting on the mass, in addition to the weight of the mass acting in the opposite direction.

[2]

(c) A 4.00 kg mass slides down a frictionless plane with an initial speed v. The frictionless plane is inclined at an angle of 30°, as shown in Fig. 3.1.

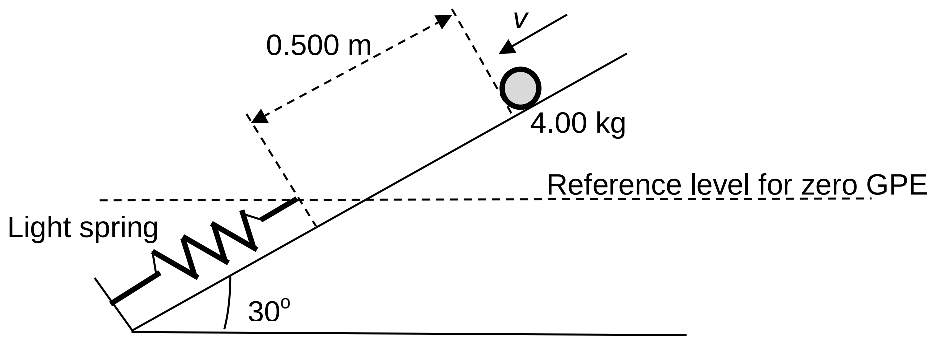


Fig. 3.1

After sliding down a distance of 0.500 m, the mass comes into contact with a light spring that is initially at its natural length and has a spring constant of 5000 N m^{-1}. The mass then slides down an additional 0.100 m before it comes to rest momentarily.

The gravitational potential energy (GPE) is taken to be zero at the reference level shown in Fig. 3.1.

(i) Calculate the gravitational potential energy of the mass at its initial position before sliding down the plane.

$$\text{GPE} = mgh$$
$$= (4.00)(9.81)(0.500\sin 30^{\circ})$$
$$= 9.81 \text{ J}$$

<u>Examiner's Comments:</u>
It should be noted that the value of GPE cannot be negative, since the initial position of the mass is above the reference level for zero GPE.

gravitational potential energy = ... J [1]

(ii) Determine the elastic potential energy stored within the spring-mass system at the point of maximum compression of the spring.

$$\text{EPE} = \frac{1}{2}kx^2$$
$$= \frac{1}{2}(5000)(0.100)^2$$
$$= 25.0 \text{ J}$$

<u>Examiner's Comments:</u>
A handful of students incorrectly calculated EPE using $F.x$, where $F = kx$. They failed to recognise that as the spring is compressed, the value of F increases. Hence <u>EPE is not equal to $F.x$</u> as <u>F is not a constant</u> during compression of the spring.
The EPE has to be calculated either by considering the area under the F-x graph, or using EPE = $F_{ave}.x$, which accounts for the factor ½.

elastic potential energy = ... J [2]

(iii) Determine the value of v, the initial speed of the mass.

Loss in GPE + Loss in KE = Gain in EPE

$$(4.00)g(0.600\sin 30^{\circ}) + \frac{1}{2}(4.00)v^2 = 25.0$$

$$v = 2.57 \text{ m s}^{-1}$$

<u>Examiner's Comments:</u>
The majority of students forgot that at maximum compression, the loss in GPE of the mass-spring system is more than 9.81 J, since the mass would have travelled an additional distance of 0.100 m.

speed = ... m s^{-1} [2]

(iv) State and explain how the value of v determined in **(c)(iii)** will change, if at all, should there be friction along the slope. Assume that the maximum compression of the spring remains the same.

There will now be <u>work done by the mass against friction</u> as it slides down the plane. Since its <u>loss in GPE and the gain in EPE remain unchanged</u>, the initial speed <u>v would have to be greater</u>.

Note:
Loss in GPE + Loss in KE = Gain in EPE + <u>Positive work done by spring-mass system</u> against friction

....

....

....[1]

Examiner's Comments:

Most students realised that work will be done by the mass-spring system against friction, however many forgot that if the maximum compression of the spring is the same, then the loss in GPE and gain in EPE must also remain unchanged. Hence in order for the mass-spring system to do work against friction, it must have a larger initial kinetic energy.

It should be noted that some students do not seem to be able to differentiate between work done by mass-spring system and work done by friction. Please note that in this scenario:

1**) Mass-spring system does positive work against friction**, causing the system to lose energy.

OR

2) **Friction does negative work on mass-spring system**, causing the system to lose energy.

The two statements above are the equivalent of each other, i.e. they mean the same thing. Be mindful of the difference in the sign of work done in each case.

4 A ball is suspended from a point **O** by an inextensible string **OA** of length L as shown in the Fig. 4.1 below. It is projected from **A** with a velocity v, perpendicular to **OA**. The string remains taut throughout the motion in a vertical circle.

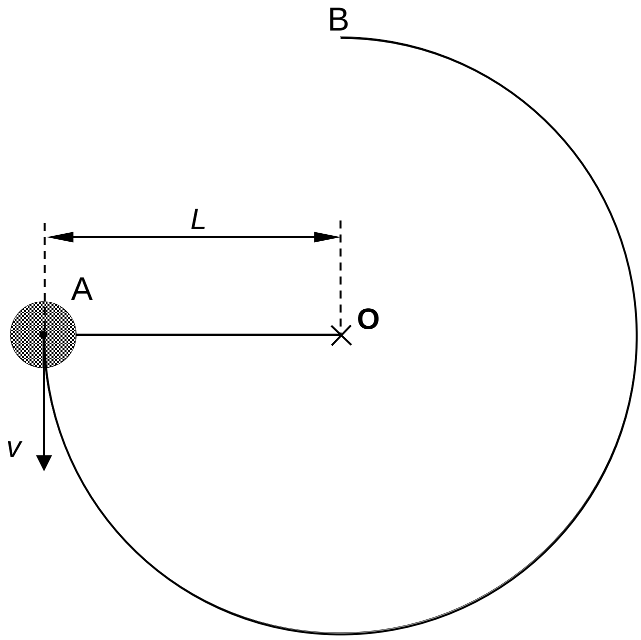
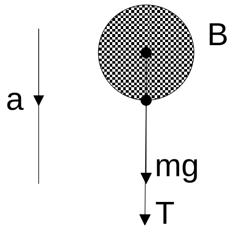


Fig. 4.1

(a) If the string is just taut when the ball reaches point **B**, determine the speed of the ball at point **B**, in terms of g and L only.



$$mg + T = \frac{mv^2}{L}$$

For ball to just reach B, the tension in the rope must be ≥ 0 N. If string is just taut, then tension in the rope is 0 N.

$$T = \frac{mv^2}{L} - mg = 0$$

$$v = \sqrt{gL}$$

speed = ... [3]

Marker's Comment

Some students wrote the first equation (Newton's second law) but did not know what else to do with it – and proceeded to try to solve the problem using energy methods. Such working is not given any credit.

Many students did not know what "the string is just taut" means for the forces involved. Some students did not even consider the forces on the ball despite the free body diagram provided.

(b) Hence determine the minimum speed v with which the ball should be projected from **A** to reach point **B**, in terms of g and L only.

conservation of energy

$KE_1 + PE_1 = KE_2 + PE_2$

$\frac{1}{2}mv^2 = \frac{1}{2}m(gL) + mgL$

$v^2 = 3gL$

$v = \sqrt{3gL}$

Marker's Comment
This part is generally well done.

minimum speed v = ... [2]

(c) If the string breaks at the *lowest point* of its motion, draw, on Fig. 4.2, the subsequent path taken by the ball. [2]

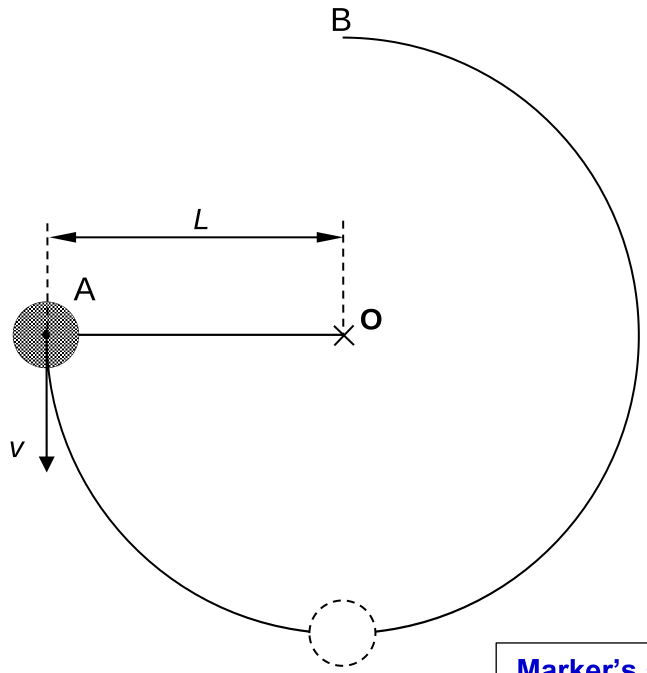
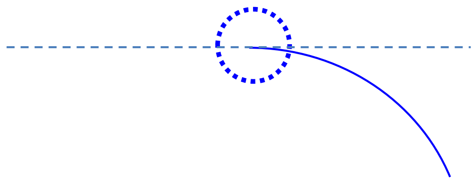


Fig. 4.2



Marker's Comment
Many students did not answer the question. They drew and labelled the velocity rather than the **path** of the ball.
Some students overestimated the proportion of the path that is tangential to the circle.
Many also did not consider the ball's subsequent motion beyond the tangential part.

Initial velocity must be in the horizontal direction pointing to the right and subsequent motion will be a parabolic path.

(d) The ball is now fixed to a light rod of the same length. State and explain clearly how the new minimum speed *v'* with which the ball should be projected from **A** for it to just reach **B**, compares with *v* in **(b)**.

Because the rod is rigid and able to support the ball, velocity of the ball at point B can now be zero.

By COE, this will translate to a smaller initial velocity to project the ball, and *v'* can now be smaller than *v*

OR

Since the rod is rigid and able to support the ball, there is now a contact force pointing in the opposite direction of the weight such that $mg - N = \dfrac{mv^2}{r}$. [2]

Hence it is now possible for velocity of the ball at point B to be zero, and therefore a smaller velocity is needed at A.

Marker's Comment
This question is poorly done. Many students did not consider how the rod is different from the string, and therefore how that would affect the forces acting on the ball (and its velocity at B).
Many students mentioned that the tension in the rod is less than the string. But if the tension of the string is already zero at B (just taut) what does that mean about the tension of the rod – is it going to be negative?!

5 **(a)** Distinguish between *electromotive force* and *potential difference*.

The potential difference between two points in a circuit is the energy converted from electrical to other forms per unit charge passing from one point to the other.

The electromotive force of a source is the energy converted from other forms to electrical energy per unit charge passing through the source.

Examiner's Comments:
There are a number of students who left out 'per unit charge' when explaining the difference.

[2]

(b) A battery of electromotive force (e.m.f.) 12 V and internal resistance *r* is connected in series to two resistors, each of constant resistance *X*, as shown in Fig. 5.1.

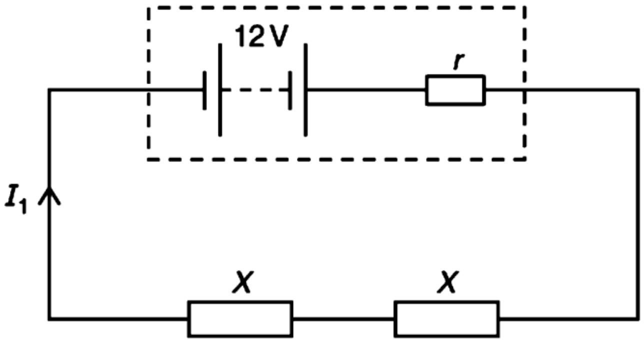


Fig. 5.1

The current I_1 supplied by the battery is 1.2 A.

The same battery is now connected to the same two resistors in parallel, as shown in Fig. 5.2.

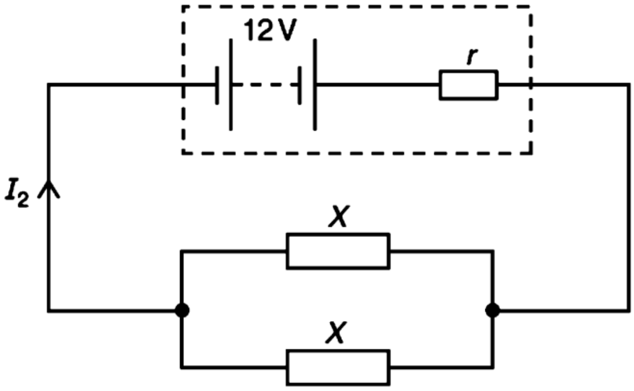


Fig. 5.2

The current I_2 supplied by the battery is 3.0 A.

(i) Determine the values of X and r.

E = V + Ir

1.2 = (2X)(1.2) + (1.2)r -----------(1)

1.2 = (X/2)(3.0) + (3.0)r -----------(2)

Solving for eq(1) and (2)

X = 4.0 Ω and r = 2.0 Ω

<u>Examiner's Comments:</u> A large number of students are able to do this part correctly.

X = ... Ω

r = ... Ω [3]

(ii) **1.** In order to determine a more accurate value of r, five more sets of different readings of the total current in the circuit are required. State the minimum additional number of resistors with resistance X required to obtain a total of seven readings.

Number = 1

number = ... [1]

<u>Examiner's Comments:</u> Only a small number of students are able deduce the correct number of resistors by considering the different possible arrangement of 1, 2 and 3 resistors to get a total of 7 readings.

For Examiner's Use

2. With more readings of the total current in the circuit available, explain how a more accurate value of *r* can be obtained from an appropriate graph plotted.

$E = V + Ir$

$\Rightarrow V = -Ir + E$

Hence by plotting a graph of terminal p.d. against internal resistance , r can be obtained since the negative gradient of the straight line plotted = r.

..... [2]

Examiner's Comments:
Students need to be aware that plotting a straight line graph is more accurate method to determine a unknown quantity compared to only taking 2 readings.

(c) **(i)** Calculate the ratio

$$\frac{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.1}}{\text{power transformed in one resistor of resistance } X \text{ in Fig. 5.2}}$$

Power dissipated in 1 resistor for Fig 5.1 = $(1.2)^2(4.0)$

Power dissipated in 1 resistor for Fig 5.2 = $(1.5)^2(4.0)$

Hence ratio = 0.64

[1]

Examiner's Comments:
Most students are able to do this part correctly. Students need to note that the ratio need to be expressed in 2 s.f. but <u>not in fractions</u>.

(ii) State and explain which of the two arrangements in Fig. 5.1 and Fig. 5.2 has a larger efficiency with regard to power transfer from the battery to both resistors, each of resistance *X*.

The efficiency can be expressed as a ratio of the resistance of the load to total resistance. Hence Fig 5.1 has a greater efficiency since load resistance is larger as they are arranged in series.
OR
The power loss due to internal resistance = I^2r. Since for Fig 5.1, the total resistance is larger resulting in smaller total current. Hence the power loss is smaller.

[2]

Examiner's Comments:
Most students are confused between the load resistors receiving maximum power vs the efficiency of the system. For efficiency , the ratio of the useful power to the total power deliver is the key consideration.

(d) The resistors in Fig. 5.1 and Fig. 5.2 are replaced by identical 12 V filament lamps.

Explain why the resistance of each lamp, when connected in series, is not the same as the resistance of each lamp when connected in parallel.

Since filament lamps are non- ohmic conductors, the resistance of filament will change with different sets of voltage and current.

.... [1]

6 Solar planet Jupiter has sixty-seven known satellites with different orbital period T (in days) and average orbital radius r (in metres). Data for six of them are shown in Fig. 6.1 below.

Satellite	T **/ days**	r **/ 10^9 m**
Sinope	758	23.7
Leda	239	11.1
Callisto	16.7	1.88
Europa	3.55	0.671
Io	1.77	0.422
Metis	0.295	0.128

Fig. 6.1

(a) Suggest why average values of r need to be taken.

The orbits of the satellites are not exact circles.

Examiner's Comments:
Many candidates simply stated 'to reduce effect of random errors'. This is too vague, your answers need to be specific to the given scenario, and in this case, specific to the orbits of the satellites and why r may not be constant.

[1]

(b) It is expected that the moons obey the relation

$$T\,r^{n} = k$$

where n and k are constants.

Explain how the relation may be verified by plotting a graph of lg T against lg r.

lg of equation gives lg $T = -n$ lg r + lg k. If the graph of lg T against lg r is linear, the relation could be valid.

Examiner's Comments:
Many candidates made the mistake of saying that the graph *will* give a straight line; it may not as the graph has not been plotted yet and the data may not give a best-fit-line that is straight. The focus should be on, firstly, stating a feature of the graph (linearity of best-fit-line) and, secondly, the implication of that feature (if it is linear, it could be valid).
Also, if any mathematical operations are needed to illustrate the feature, show your workings on one side but state *only* final form of the equation in the answer.

[2]

(c) Some of the data from Fig. 6.1 are used to plot the graph of Fig. 6.2.

For Examiner's Use

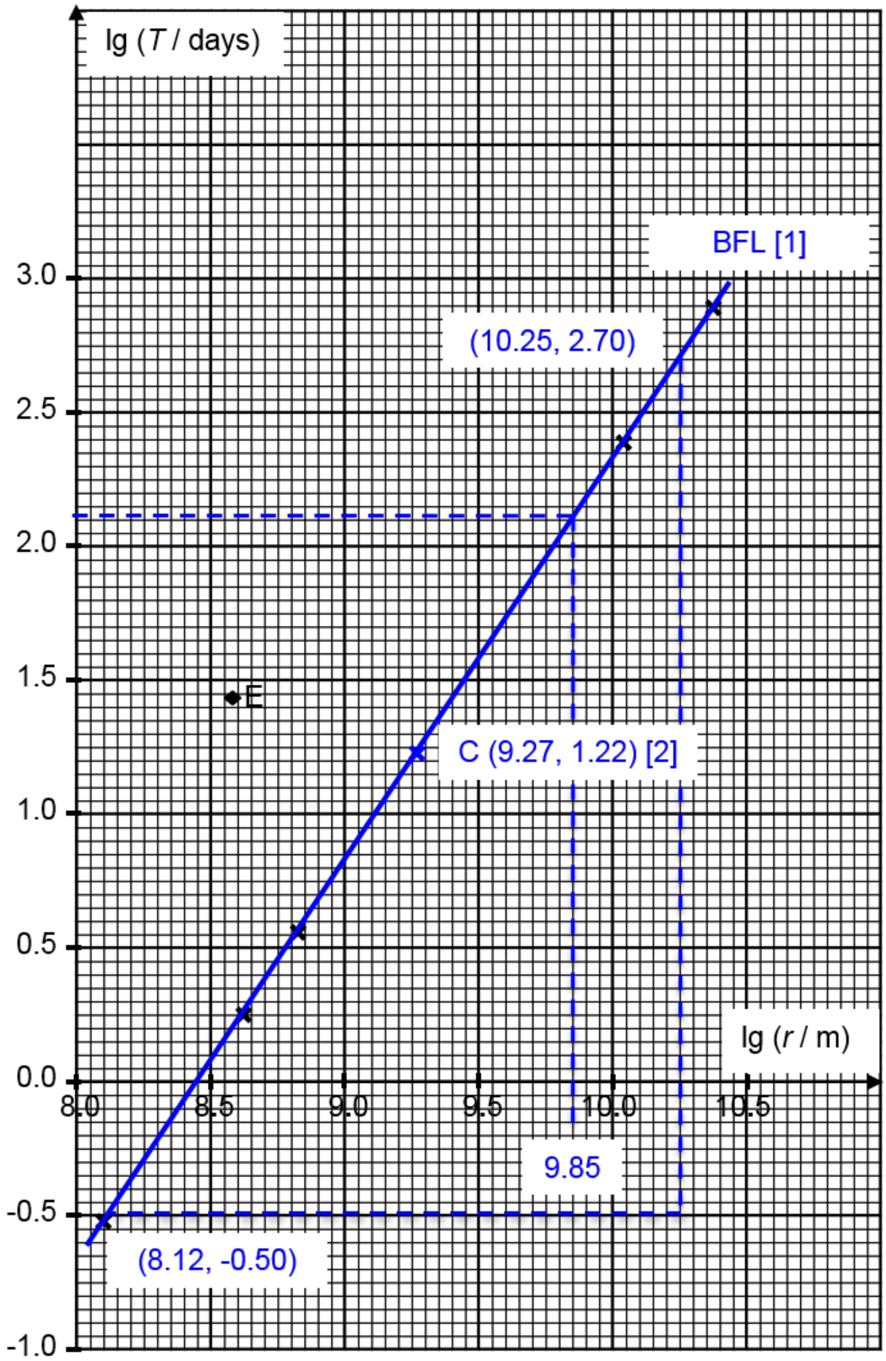


Fig. 6.2

(i) On Fig. 6.2,

1. Plot the point corresponding to Callisto. State the coordinates and label it **C**. [2]

2. Draw the line of best fit for the six points. Ignore Point **E**, the diamond data point. [1]

(ii) Determine the values of the constants n and k. Ignore their units.

Using points (10.25, 2.70) and (8.12, -0.50),

$$\text{gradient} = \frac{2.70-(-0.50)}{10.25-8.12} = \frac{3.20}{2.13} = 1.50$$

n = -1.50 (3 s.f.)

Using point (10.25, 2.70),

$2.70 = 1.50\,(10.25) + \lg k$
$\lg k = 2.70 - 16.40$
$\lg k = -12.68$
$k = 2.1 \times 10^{-13}$ (2 s.f.)

Examiner's Comments:
The skills and concepts tested in this section was identical to your practical. Many candidates lost marks because of d.p./s.f. Candidates are advised to show each step of their workings to reduce chances of making such mistakes.

n = ...

k = ... [4]

(iii) Kepler's Third Law of Planetary Motion states that $T^2 \propto r^3$. State and explain whether your answer to **(ii)** is in agreement with Kepler's Third Law.

As n is approximately -1.5, my answer is in agreement with

Kepler's Third Law, within limits of experimental error.

.... [2]

(iv) Another moon, Thermisto, has a period of 130 days. Use Fig. 6.2 to determine the orbital radius of Thermisto.

$\lg 130 = 2.114$
From Fig 7.2,
$\lg r = 9.85$
$r = 7.1 \times 10^9$ m (2 s.f.)

Examiner's Comments:
Some candidates did not determine the radius using Fig. 6.2 as instructed. They are advised to read their questions properly.

radius = ... m [2]

(v) Earth's moon has an orbital radius of 0.385×10^9 m and a period of 27.3 days. Point **E** is plotted on Fig. 6.2 using this information.

Suggest why point **E** deviates from the line of best fit drawn in **(c)(i)**.

The value of k is different for the Earth-Moon system as its mass is

different from the Jupiter-satellites system. [1]

Examiner's Comments:
Quite well-attempted; most candidates were able to provide a well-thought-through suggestion. Candidates who were not able to answer this did not recognise that since this is a gravitation phenomenon, they could use Newton's law of gravitation and circular motion to decipher the relation between k and physical quantities of this type of system.

Section B

7 **(a)** A jeweller wishes to harden a sample of pure gold by mixing it with some silver so that the mixture contains 5.0 % silver by mass.

The jeweller melts some pure gold and then adds the correct mass of silver. The initial temperature of the silver is 27 °C.

	gold	**silver**
melting point / K	1340	1240
specific heat capacity (for both solid and liquid) / J kg^{-1} K^{-1}	129	235
specific latent heat of fusion / kJ kg^{-1}	628	105

Fig. 7.1

Calculate, using the data in Fig. 7.1, the initial temperature of the melted pure gold so that the final mixture of gold and silver (both in liquid form) is at the melting point of pure gold. Assume no energy is lost to the surrounding.

Let m be the mass of the sample T_i be the initial temperature.

Energy required for silver to reach 1340 K

$$= \frac{5.0}{100} m \times 235 \times (1340 - 273.15 - 27) + \frac{5.0}{100} m \times 105 \times 10^3$$

$$= \frac{5.0}{100} m(235 \times 1039.85 + 105 \times 10^3)$$

Energy lost by gold

$$= \frac{95.0}{100} m \times 129 \times (T_i - 1340)$$

By conservation of energy,

$$\frac{95.0}{100} m \times 129 \times (T_i - 1340) = \frac{5.0}{100} m(235 \times 1039.85 + 105 \times 10^3)$$

$$T_i = 1480 \text{ K}$$

Examiner's comments:

1. Students are advised to read the question carefully. Units of kJ kg^{-1} were missed by students and the incorrect ratio for the mass of the silver and gold (i.e. mass of silver = 1/20 mass of gold) was given when the question stated that the mass of silver is 1/20 of the total mass of the mixture.
2. Students are advised to think through the question before answering. The question clearly stated the gold is initially melted (which means that the initial temperature is higher than 1340 K) yet many thought that the initial temperature is lower than 1340 K This also led to many including the latent heat of fusion for gold in their calculations, which is not needed in the answer.

For Examiner's Use

(b) State what is meant when temperature is described to be on an absolute scale.

This temperature scale is independent of the property of any particular substance and has a natural minimum which is called "absolute zero".

Examiner's comments:

Students are advised to know the lecture notes well.

(c) Explain what is meant by the statement "The internal energy of a sample of copper wire is 20000 kJ".

The sum of the random distribution of microscopic kinetic energy and microscopic potential energy of all the molecules in the sample of copper wire is 20000 kJ.

Examiner's comments:

Many students missed out the phrase "random distribution". Students are advised to know the lecture notes well.

(d) Air is mainly made up of nitrogen and oxygen. The mass of one nitrogen molecule is 4.65×10^{-26} kg while the mass of one oxygen molecule is 5.31×10^{-26} kg.

Calculate the ratio

$$\frac{\text{root mean square speed of one oxygen molecule at 200 °C}}{\text{root mean square speed of one nitrogen molecule at 100 °C}}$$

Assume both nitrogen and oxygen are ideal gases.

$$\frac{1}{2}mc_{rms}^2 = \frac{3}{2}kT$$

$$c_{rms} = \sqrt{\frac{3kT}{m}}$$

$$c_{rms} \propto \sqrt{\frac{T}{m}}$$

$$\frac{c_{O_2}}{c_{N_2}} = \sqrt{\frac{m_{N_2}T_{200}}{m_{O_2}T_{100}}}$$

$$= \sqrt{\frac{4.65\times10^{-26}(200+273.15)}{5.31\times10^{-26}(100+273.15)}}$$

$$= 1.05$$

Examiner's comments:

1. It can be seen that many students do not know their content well as many were trying to derive equations or did not attempt to answer the question. Students are advised to know their content well (especially for this topic) because of the varied ways that this topic can be tested.
2. Students who used the correct equation often made careless mistakes (e.g. forgetting to convert the temperature to kelvin, multiplying the temperature by the wrong mass, incorrect manipulation of the equation). Students are advised to check their working thoroughly.

(e) Fig. 7.2 shows the compression of an ideal gas at 27 °C such that no thermal energy enters or leaves the gas.

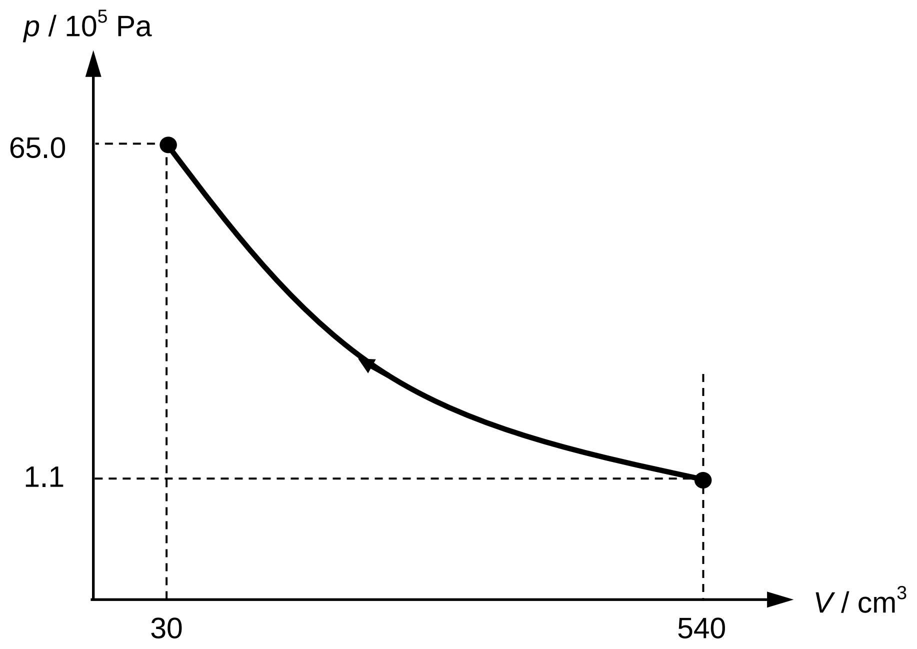


Fig. 7.2

(i) Calculate the temperature of the gas after the compression.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{1.1\times10^5 \times 540\times10^{-6}}{273.15+27} = \frac{6.5\times10^6 \times 30\times10^{-6}}{T_2}$$

$$T_2 = 990 \text{ K}$$

Examiner's comments:

1. There were a number of students who applied the 1st Law of Thermodynamics to the question without recognising that the ideal gas equation can also be applied to the start point and end point.
2. Many students did not convert the temperature to kelvin when using the ideal gas equation. There are also a number who associated the 27 °C to the wrong point. Lastly, students need to check their calculations as many got the wrong answer because of errors in their calculations.

(ii) Using the First Law of Thermodynamics, explain why the temperature of the air changed during the compression.

Since no thermal energy enters or leave the gas, there is no heat absorbed by the gas. Since the volume of the gas decreases, work is done on the gas, causing an increase in the internal energy of the gas. Since the gas is assumed ideal, the increase in internal energy causes a rise in the mean kinetic energy of the air particles. Since temperature is proportional to the mean kinetic energy of the air particles, the temperature changes.

Examiner's comments:

1. Many students stated the law but did not use the law to explain the phenomenon. Students are reminded that just stating the law does not mean that you have applied the law.
2. Many students state that there is no heat absorbed/released from the system without any reference to the question. Others just wrote that an increase in internal energy will lead to an increase in temperature without explaining why. Since this is a 4 mark question, details need to be provided in order to earn the mark.

(f) The gas in the cylinder of a diesel engine undergoes a cycle of changes in pressure, volume and temperature. One such cycle, for an ideal gas, is shown in Fig. 7.3.

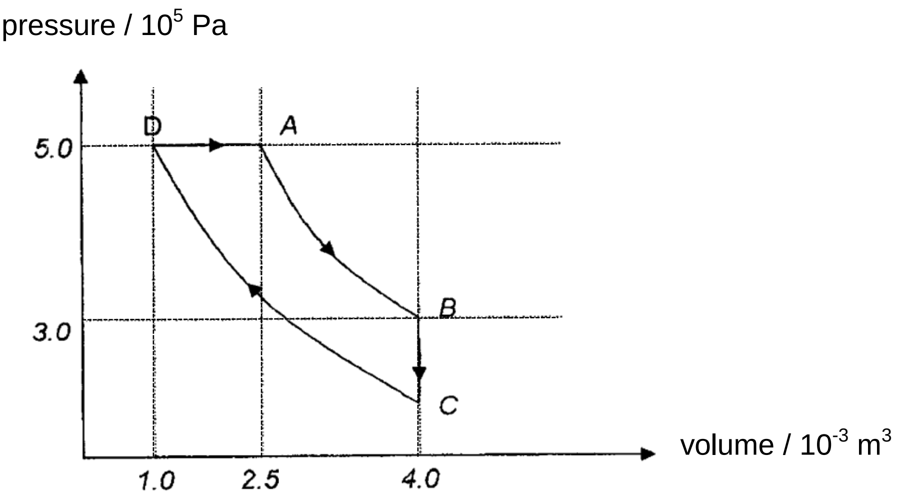


Fig. 7.3

Using Fig. 7.3, fill in the blanks in Fig. 7.4. [3]

Section of cycle	Heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A to B	0	- 300	- 300
B to C	- 450	0	- 450
C to D	0	650	650
D to A	850	-750	100

Fig. 7.4

Examiner's comments:

1. Many students made careless mistakes resulting in the loss of marks.
2. Many students were unable to complete the last row of the table. Students are reminded that this is a *p*-*V* diagram so the area under the graph gives the work done on the gas.

2015 H2 Promo P1 Ans Key

1 C	**9** B	**17** A	**25** A
2 D	**10** C	**18** B	**26** B
3 D	**11** A	**19** D	**27** A
4 C	**12** B	**20** A	**28** C
5 C	**13** C	**21** C	**29** C
6 D	**14** C	**22** A	**30** B
7 C	**15** A	**23** D	**31** B
8 A	**16** A	**24** D	**32** C

NANYANG JUNIOR COLLEGE
JC1 PROMOTIONAL EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

PHYSICS 9646/02

Paper 2 Structured Questions

6 October 2015

1 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 8**
2	**/ 8**
3	**/ 8**
4	**/ 9**
5	**/ 8**
6	**/ 7**
Total	**48**

This document consists of **12** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\,\pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega \sqrt{\left(x_o^{\,2} - x^2\right)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	=	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{1/2}}$

1 **(a)** Distinguish between an *accurate* and a *precise* experiment in terms of its systematic and/or random errors.

An accurate experiment is one in which the systematic error is small. [1]

A precise experiment is one in which the random error is small. [1]

[2]

Examiner's comment:
Many students are still confused between these four terms: accurate, precise, systematic error and random error. It is incorrect to state that an accurate experiment has random error and precise experiment has systematic error.

(b) In an experiment to determine the acceleration due to free fall g, a student releases a ball from rest at the top of a building and measures the time taken for the fall. Although he uses a measuring tape, with a precision of 1 mm, he reported the height as (75.0 ± 0.1) m. The experiment is repeated twice with the duration of fall stated as $(3.8\text{ s} \pm 3\%)$.

(i) Suggest a reason why the student reported the uncertainty for the height as 0.1 m, instead of 0.001 m.

The measuring tape may not be taut and/or vertical due to strong wind. This may lead to errors in the measurement of the height. Hence, the uncertainty is reported to 10 cm, instead of 1 mm. [1]

Examiner's comment:
Many students state that the error is large or difficult to measure properly. But they did not state exactly WHY it is difficult to measure. The height of building is large is not a sufficient reason.
Some other students state that the conversion of unit causes the uncertainty to change. This is incorrect.

(ii) Determine the acceleration due to free fall g using the data given above.
Since the ball is released from rest, $u = 0$,

$$s = ut + \frac{1}{2}at^2$$
$$= \frac{1}{2}gt^2$$

$$g = \frac{2s}{t^2}$$
$$= \frac{2(75.0)}{3.8^2}$$
$$= 10.4 \text{ m s}^{-2}$$

acceleration due to free fall, g = ………………………………… m s^{-2} [2]

Examiner's comment:
Some students forget to use the kinematics equation. Do not forget that this motion has an acceleration that is constant.

(iii) Write down the expression for the fractional uncertainty of g, and hence, determine its value.

$$g = \frac{2s}{t^2}$$

$$\frac{\Delta g}{g} = \frac{\Delta s}{s} + 2\left(\frac{\Delta t}{t}\right)$$

$$= \frac{0.1}{75.0} + 2\left(\frac{3}{100}\right)$$

$$= 0.0613$$

fractional uncertainty of g = ... [2]

(iv) Hence, calculate the absolute uncertainty Δg of the acceleration due to free fall.

$$\frac{\Delta g}{g} = 0.0613(10.4)$$

$$= 0.6 \text{ m s}^{-2}$$

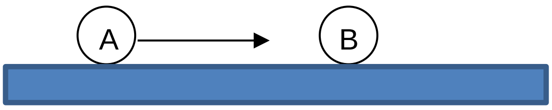
absolute uncertainty of g = ... m s^{-2} [1]

2 **(a)** State the principle of conservation of linear momentum.

When bodies in a system interact, the total momentum remains constant provided no resultant external force acts on the system.

....[1]

(b) A billiard ball A collides head-on with a stationary billiard ball B of mass 150 g as shown below.



The force exerted on ball B by ball A varies with time as shown in Fig. 2.1.

Fig. 2.1

Calculate the

(i) impulse delivered to ball A,

impulse = area under graph

$$= \frac{1}{2}\left(12.0\times10^{-3}\right)(8.0)$$

$$= 0.048 \text{ N s}$$

Examiner's comment:

There seems to be a common misconception that impulse is only delivered from t = 0 to t = 9.5 s (when F is increasing). Candidates fail to appreciate that force delivered to an object can be varying.

impulse = ... N s [2]

(ii) velocity of ball B after the collision.

$$\Delta p = m\Delta v$$

$$= m(v-u)$$

$$= mv \quad (\because u = 0)$$

$$v = \frac{\Delta p}{m}$$

$$= \frac{0.048}{150\times10^{-3}}$$

$$= 0.32 \text{ m s}^{-1}$$

velocity = ... m s^{-1} [2]

(c) Ball B travels towards the edge of the table. When ball B reaches the table edge, its speed drops to zero as it rolls off from the table edge. A net is placed 1.0 m below the table to catch the ball. Ball B lands on the net and is brought to a complete stop in 0.50 s. Calculate the average force exerted on the net by ball B.

$$v^2 = u^2 + 2as$$
$$= 2(9.81)(1.0)$$
$$v = 4.43 \text{ m s}^{-1}$$

$$F = \frac{\Delta p}{t}$$
$$= \frac{m\Delta v}{t}$$
$$= \frac{0.150(4.43 - 0)}{0.50}$$
$$= 1.33 \text{ N}$$

$$F_{net} = F_{\text{by net}} - W$$
$$1.33 = F_{\text{by net}} - 0.150(9.81)$$
$$F_{\text{by net}} = 2.80 \text{ N (downwards)}$$

Note: No need to indicate Newton's Third Law or the direction since question asks for magnitude only.

Examiner's comment:
F is not the force required in the question – it is the NET/RESULTANT force acting on the ball. Candidates would need to draw a FBD to determine the force exerted by the net alone on the ball.
Conceptually, students would need to use Newton's Third Law to hence find the force exerted on the net by the ball (question requirement).

average force = ... N [3]

3 A uniform glass rod of length 18 cm and mass 60 g is at rest inside a 12 cm deep glass tumbler as shown in Fig. 3. The interior wall of the tumbler is smooth while the bottom of the glass is rough.

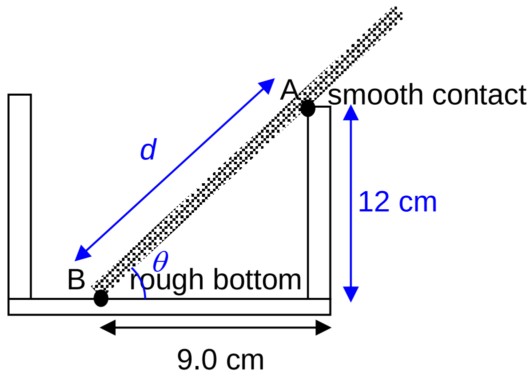


Fig. 3

(a) Calculate the magnitude of the force exerted on the glass rod at

(i) A,

Let distance AB be d, Taking moments about B,

$$d = \sqrt{9.0^2 + 12^2} = 15 \text{ cm}$$

$$(mg)\left(\frac{l}{2}\cos\theta\right) = N(d)$$

$$N = \frac{mgl\cos\theta}{2d}$$

$$= \frac{(60\times10^{-3})(9.81)(18\times10^{-2})\left(\frac{9.0}{15}\right)}{2(15\times10^{-2})}$$

$$= 0.21 \text{ N}$$

Examiner's comment:

Many candidates did not use the weight of the rod and instead used mass to find the force exerted. The majority of candidates do not know the direction in which the force acts.

Answers with the correct force **and** correct perpendicular distance will be awarded one mark (each for weight and force at A) and one mark will be awarded for the correct final answer.

force = ... N [3]

(ii) B.

Considering horizontal forces,

$$F_x = N\sin\theta$$

$$= 0.21\left(\frac{12}{15}\right)$$

$$= 0.170 \text{ N}$$

Considering vertical forces,

$$F_y + N\cos\theta = mg$$

$$F_y = mg - N\cos\theta$$

$$= (60\times10^{-3})(9.81) - 0.21\left(\frac{9.0}{15}\right)$$

$$= 0.461 \text{ N}$$

Using Pythagoras theorem,

$$F = \sqrt{F_x^{\,2} + F_y^{\,2}}$$

$$= \sqrt{0.170^2 + 0.461^2}$$

$$= 0.49 \text{ N}$$

Examiner's comment:

Many failed to see that there are two unknowns i.e. magnitude and direction of force and made futile attempt to solve for force by applying principle of moments.

One mark will be awarded for each correct component and one mark will be awarded for the correct final answer.

force = ... N [3]

(b) Determine the angle between the force in **(a)(ii)** and the glass bottom.

$$\tan\theta = \frac{F_y}{F_x}$$

$$= \frac{0.461}{0.170}$$

$$\theta = 70°$$

angle = ... ° [2]

4 Hera, of mass 50.0 kg, skies over a snow hump with a radius of curvature of 10.0 m as shown in Fig. 4.1.

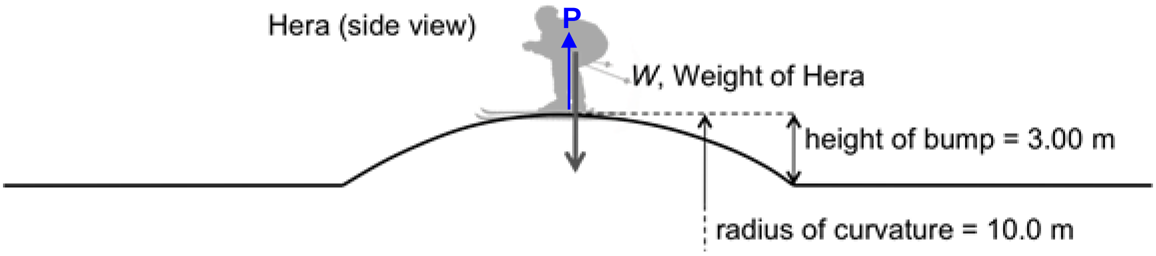


Fig. 4.1

(a) The weight of Hera, **W**, is drawn on Fig. 4.1. On the same figure, draw the force by the snow hump on her, and label it as **P**. [1]

Examiner's comment:
Many candidates did not show understanding that since Hera is undergoing circular motion, the magnitude of W must be larger than P. As such, the force vector P drawn must be shorter than the force vector W. P longer than 1.7 cm are not accepted.

(b) Assuming that Hera just loses contact with the snow hump at the peak of the hump, show that her speed at the peak is 9.90 m s^{-1}.

$$F_{net} = ma_c$$
$$W - P = \frac{mv^2}{r}$$
$$mg = \frac{mv^2}{r} \quad (\because P = 0)$$
$$v = \sqrt{gr}$$
$$= \sqrt{9.81(10.0)}$$
$$= 9.90 \text{ m s}^{-1} \text{ (shown)}$$

[2]

Examiner's comment:
Many candidates started with the third step as shown above without indicating that P = 0, thus not showing the application of physics for this scenario. Some students started with step 4 and are not awarded marks due to the lack of explanation why v = square root gr. Some students also attempted to solve the problem using kinematics equations of motion but did not realise its not applicable because acceleration is not constant.

(c) Given that the peak of the hump is 3.0 m above ground level, determine the minimum speed she must possess at the start of the hump in order to lose contact with the hump at its peak.

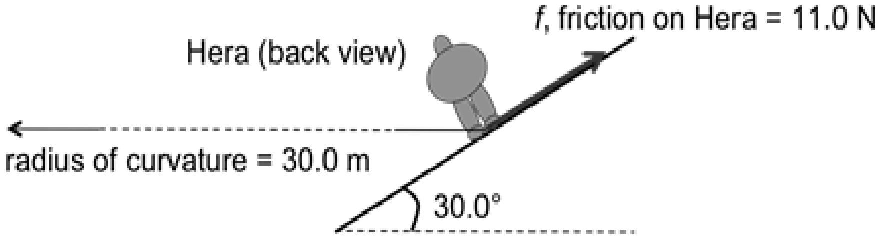
By conservation of energy,

$$KE_i = KE_f + GPE_f$$
$$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$$
$$u^2 = v^2 + 2gh$$
$$u = \sqrt{9.90^2 + 2(9.81)(3.0)}$$
$$= 12.5 \text{ m s}^{-1}$$

minimum speed = ... m s^{-1} [2]

Examiner's comment:
Many candidates neglected the fact that Hera is still moving on the peak and thus did not arrive at the correct energy equation. Some students also applied loss in KE = gain in GPE wrongly by giving the expression $\frac{1}{2}mv_f^2 - mv_i^2 = mgh$ when loss in KE should be $\frac{1}{2}mv_i^2 - mv_f^2$.

After clearing the hump, Hera proceeds to ski horizontally along a circular snow bank with a radius of curvature of 30.0 m at a constant speed, as shown in Fig. 4.2. She experiences a sideward friction of 11.0 N.



(d) Show that the normal contact force acting on Hera is 560 N.

Considering vertical forces,

$$F_{net} = 0$$

$$N\cos\theta + f\sin\theta = mg$$

$$N = \frac{mg - f\sin\theta}{\cos\theta}$$

$$= \frac{50.0(9.81) - 11.0\sin 30.0°}{\cos 30.0°}$$

$$= 560 \text{ N (shown)}$$

Examiner's comment:
Many candidates did not realise they could only get the answer by applying Newton's 2nd Law on the vertical component of forces. Some attempted to apply N2L on horizontal component of forces but erroneously substituted v = 9.90 m s^{-1} which was Hera's speed in another scenario.
Some students who approached the questions correctly failed to consider the vertical component of friction and thus were unable to arrive at the correct answer.

(e) Calculate the speed she has to maintain in order to complete the motion. Explain your working.

$$F_{net} = ma_c$$

$$N\sin\theta - f\cos\theta = \frac{mv^2}{r}$$

$$v^2 = \frac{(N\sin\theta - f\cos\theta)r}{m}$$

$$= \frac{(560\sin 30.0° - 11.0\cos 30.0°)(30.0)}{50.0}$$

$$v = 12.7 \text{ m s}^{-1}$$

Explanation of working:
The centripetal force is provided by the sum of the radial/horizontal components of *N* and *f*.

speed = ... m s^{-1} [3]

Examiner's comment:
Many candidates were able to recognise the strategy to solve this question is to apply N2L on the horizontal/radial component of forces. However, they did not properly resolve *N* and/or *f* and thus were unable to arrive at the correct answer.
Most students did not explain their workings and thus did not get the full credit even if they arrived at the correct numerical answer.

5 **(a)** The First Law of Thermodynamics can be expressed mathematically as

$$\Delta U = Q + W.$$

State what each of the symbols used in the equation above represents.

ΔU represents the increase **(not change)** in internal energy of the system, Q represents the heat supplied to the system, W represents the work done on the system.

It is rather surprising that quite a few students filled in the first law of thermodynamics without reading the instruction to link each symbol to their specific description. [1]

(b) A fixed mass of gas undergoes a cycle of changes of pressure, volume and temperature as illustrated in Fig. 5.1 below. The gas is assumed to be *ideal*.

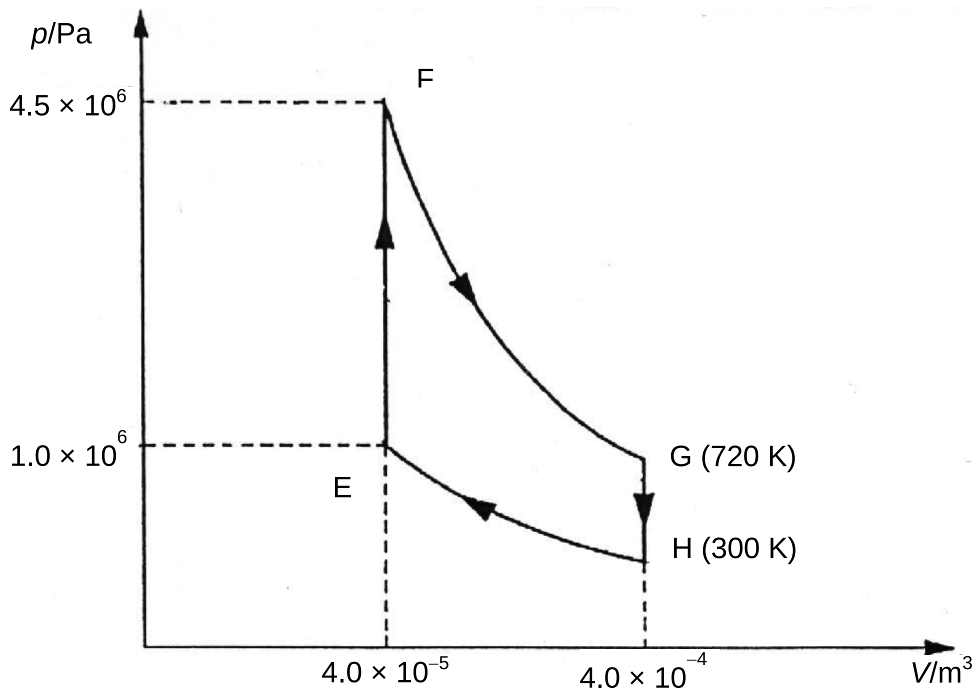


Fig. 5.1

(i) Fig. 5.2 is a table of energy changes for the process HE. Given that HE is an isothermal process, complete Fig. 5.2 using (+), (–) or (0).

Increase in internal energy of gas, ΔU	Heating supplied to gas, Q	Work done on gas, W
0	–	+

This question is poorly done.
It is surprising that many students could not determine the sign of work done on the gas, which can be done by examining the volume of the gas in the process HE.

Fig. 5.2

[1]

(ii) FG is an adiabatic process in which no heat is transferred to or from the gas. Suggest how such a process can be achieved.

An adiabatic process is one in which no heat is transferred between the system and the surroundings, i.e. $Q = 0$. This can be achieved either by

1. carrying out the process very quickly or instantaneously, or

2. having the system well-insulated from the surrounding.

There seems to be some confusion between the words "insulated" and "isolated". Many students mentioned that the system needs to be isolated or be placed in a vacuum without invoking the specific quality of such arrangements that will help make the process adiabatic. [1]

(iii) Calculate the amount of gas, in moles, involved in the cycle.

Using p, V and T data for point E,

$$pV = nRT$$

$$n = \frac{pV}{RT}$$

$$= \frac{(1.0\times10^{6})(4.0\times10^{-5})}{8.31(300)}$$

$$= 0.016 \text{ mol}$$

Note: temperature at E = temperature at H because HE is an isothermal process.

amount of gas = ………………………………… mol [2]

(iv) Find the *decrease* in internal energy of the gas for the process GH given that the molar heat capacity of the gas at constant volume is 20.8 J mol^{-1} K^{-1}.

$$\Delta U = Q + W$$
$$= Q \quad (\because W = 0)$$
$$= nC_v \Delta T$$
$$= 0.016(20.8)(300 - 720)$$
$$= -140 \text{ J} \qquad [1]$$

Since, a negative value indicates a decrease in internal energy, the decrease in internal energy is 140 J (2 s.f.). [1]

This is a poorly attempted part. Getting the numerical answer is no guarantee of marks here. Many students show confusion about the sign of the quantities. Q is the symbol for heat supplied to the system (from part 5a), hence in this situation Q should be negative.

Also, the question is very specific in wanting the students to make use of the molar heat capacity of the gas – hence any other method without its use will not be given any credit.

decrease in internal energy = ………………………………….. J [2]

(v) State and explain the net increase in internal energy of the gas through one complete cycle.

The net increase in internal energy over one cycle is always zero i.e. ΔU_{EFGHE} = 0.

Reasons: 1. For an ideal gas, the internal energy is a function temperature only.

2. The system returns to its original state (temperature) at the end of a cycle.

Many students mentioned that the increase in internal energy is zero because the process forms a closed loop -> this does not suffice as an explanation, especially when the question already mentions the words " complete cycle" – what is it about the cycle and the property of internal energy that makes the change zero? [1]

6 **(a)** Define what is meant by a longitudinal wave.

In a longitudinal wave, the oscillations of wave particles are parallel to the direction of energy transfer or direction of propagation of the wave.

Students need to take care in describing the nature of **oscillations** (using terms like displacement, vibrations) of wave **particles** (instead of waves), being **parallel** to the direction of propagation of the **wave** (and not the direction of "energy travel"). [1]

(b) Fig. 6 below shows the display on a C.R.O. as sound waves travelling to the right pass through a point in air. The time-base is set to 2 ms/div. The amplitude of the sound wave is measured on the y-axis. Take the positive direction to be rightwards.

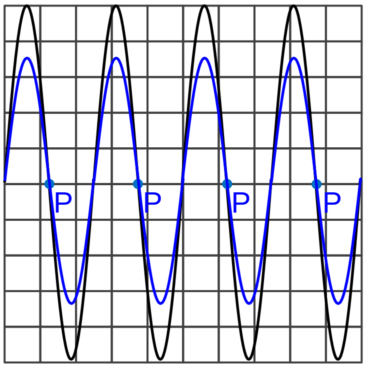


Fig. 6

(i) Determine the frequency of the sound wave.

On x-axis, 5 divisions correspond to 2 periods

$$T = \frac{5}{2}(2) = 5 \text{ ms}$$

$$f = \frac{1}{T} = \frac{1}{5\times10^{-3}} = 200 \text{ Hz}$$

frequency = ... Hz [1]

(ii) Given that the speed of sound in air is 330 m s^{-1}, calculate the wavelength of the sound wave.

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{330}{200} = 1.65 \text{ m}$$

wavelength = ... m [1]

(iii) On Fig. 6, mark a point where the sound pressure is minimum. Label it as **P**, and explain your answer.

Particles that are displaced before P in time (**right of P** in the wave, left of P in the graph) are **moving to the right**, and particles that are displaced after P in time (**left of P** in the wave, right of P in the graph) are **moving to the left**. Thus, P is a point of **rarefaction**, where pressure is minimum.

Students need to be careful to check the x-axis of the graph; the rule of thumb that "left is displaced left for rarefaction" only applies to displacement-distance graphs. [2]

(c) On Fig. 6, sketch another graph to show what happens to the wave if the area through which it passes is doubled. Explain your answer.

Since $I = \dfrac{P}{\text{area}}$, when area is doubled, I is halved.

Since $I \propto A^2$, when I is halved, A is reduced to $\dfrac{1}{\sqrt{2}}$ [2]

H

NANYANG JUNIOR COLLEGE
JC1 PROMOTIONAL EXAMINATION
Higher 2

CANDIDATE NAME	
CLASS	
TUTOR'S NAME	

PHYSICS 9646/03

Paper 3 Longer Structured Questions

29 September 2015

2 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 10**
2	**/ 10**
3	**/ 10**
4	**/ 10**
5	**/ 20**
6	**/ 20**
Deductions	
Total	**80**

This document consists of **12** printed pages.

Data

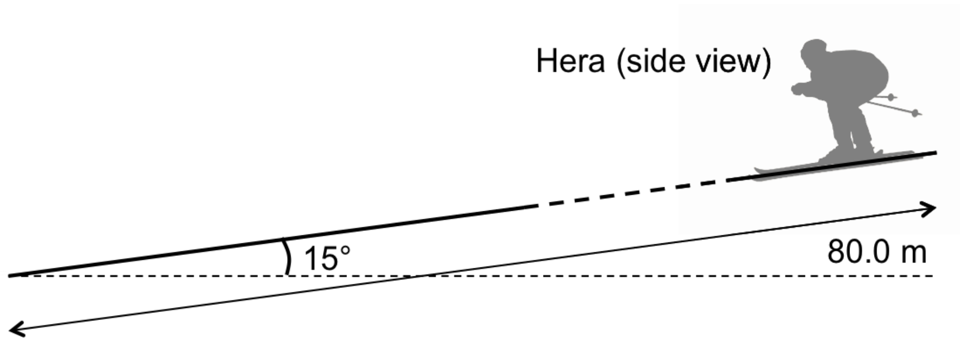
speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} Fm^{-1}
			$(1 / (36\ \pi)) \times 10^{-9}$ Fm^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm / r$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{\left(x_o{}^2 - x^2\right)}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$Q / 4\pi\varepsilon_o r$
alternating current/voltage,	x	=	$x_o \sin \omega t$
transmission coefficient,	T	=	exp(–2kd)
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** Define acceleration. [1]

(b) Hera, who has a mass of 50.0 kg, is initially at rest. She skies down a snow slope for a distance of 80.0 m before skiing off a short cliff.



(i) Calculate the acceleration of Hera while she is sliding down the slope. [1]

$\Sigma F = ma_{//}$

$mg\sin\theta = ma_{//}$

$a_{//} = g\sin\theta = 9.81\sin 15 = 2.54 \text{ m s}^{-2}$

Examiner's comment:

Many candidates began with $a_{//} = g \sin \theta$. While this gives the correct numerical answer, you should still begin with Newton's 2nd law of motion to show that you know Hera's acceleration is due to the net force that is exerted on her.

(ii) Hence show that the speed of Hera just as she leaves the slope is 20.2 m s^{-1}. [1]

$v_{//}^2 = u_{//}^2 + 2a_{//}s_{//}$

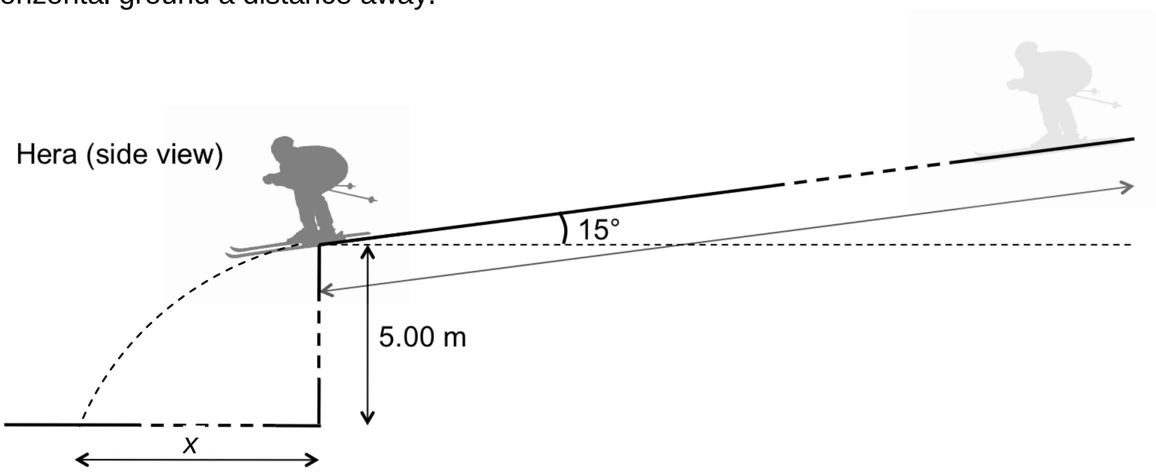
$v_{//}^2 = 0 + 2(2.54)(80.0)$

$v_{//} = 20.2 \text{ m s}^{-2}$

Examiner's comment:

Some candidates used 9.81 m s^{-2} as her acceleration and used 80.0 sin θ as her displacement. While this gives you the correct numerical answer, it is not correct physically as Hera's acceleration is not 9.81 m s^{-2} and the answer you arrive at is just the vertical component of her velocity, which is not what the question is asking for.

The snow slope ends with a 5.00 m vertical cliff. Hera skies off the cliff and lands on horizontal ground a distance away.



(iii) Calculate the time taken for Hera to land on the ground after skiing off the cliff. [2]

$$s_y = u_y t + \frac{1}{2} a_y t^2$$

$$5.0 = 20.2\sin(15°)(t) + \frac{1}{2}(9.81)(t^2)$$

$$t = 0.608\ s$$

Examiner's comment:
Some candidates substituted 20.2 m s^{-1} as her velocity and this is incorrect as you are only supposed to substitute in the vertical component of her velocity since we are only considering the vertical components of her motion.

(iv) Determine x, the horizontal distance from the edge of the cliff at which Hera lands. [2]

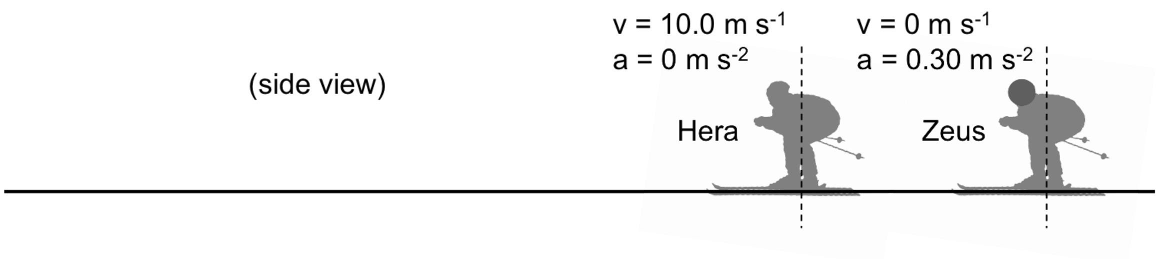
$$s_x = u_x t + \frac{1}{2} a_x t^2$$

$$s_x = 20.2\cos(15°)(t) + 0$$

$$s_x = 11.9\ \text{m}$$

Examiner's comment:
Same issue of substituting in wrong component of velocity. Also, some candidates substituted 9.81 m s^{-2} as her acceleration which is incorrect as horizontally she is not accelerating at all.

(c) After Hera lands on the ground, she continues to ski with a constant velocity of 10.0 m s^{-1}. Her friend Zeus, who was initially 20.0 m behind her, begins to ski from rest at a constant acceleration of 0.30 m s^{-2}.



Calculate the time taken for Zeus to catch up with her. [3]

Let s_z be the distance travelled by Zeus when he catches up with Hera and s_h be the distance travelled by Hera,

$$s_z = u_z t + \frac{1}{2} a_z t^2$$

$$s_z = \frac{1}{2}(0.30)(t^2)$$

$$s_z = 0.15t^2 \text{ --- (1)}$$

Consider Hera,

$$s_h = u_h t$$

$$s_h = 10.0t \text{ --- (2)}$$

Examiner's comment:
Many students were unable to recognise that Zeus travels 20 m more than Hera, to form the equation $s_z - s_h = 20$, and that the time of travel is the same for both of them. As such, they were unable to form meaningful equations to solve for the unknown.

$$s_z - s_h = 20$$

$$0.15t^2 - 10.0t = 20$$

$$t = 68.6\ s$$

2 **(a)** A car starts from rest and travels upwards along a straight road inclined at 5.0° to the horizontal, as illustrated in Fig. 2.1..

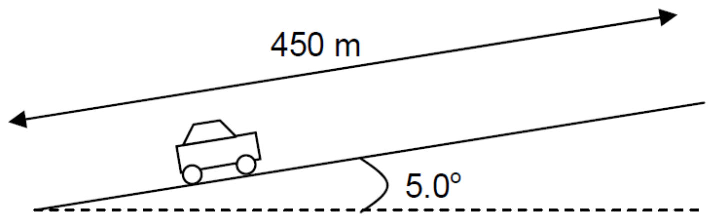


Fig. 2.1

The length of the road is 450 m and the car has a mass of 800 kg. The speed of the car increases at a constant rate to 28 m s^{-1} at the top of the slope within 32.1 s. The constant power output of the engine is 2.50×10^4 W.
Determine, for this car traveling up the slope,

(i) the gain in kinetic energy, [1]

Gain in KE = ½ mv^2 – 0 = ½ $(800)(28)^2$ = 314 000 J

(ii) the gain in gravitational potential energy. [2]

Gain in GPE = mgh – 0 = (800)(9.81)(450 sin 5.0) = 308 000 J

(iii) Determine the useful output power of the car. [2]

P = Gain in E / time = (314 000 + 308 000) / 32.1 = 19 400 W

(iv) Hence calculate the efficiency of the car engine. [1]

Efficiency = 19400 / 25000 = 77.6 %

(v) It is said that the rest of the input energy of the engine has been converted to thermal energy (heat) which is all wasted. Comment on this statement. [1]

This is not always true. In cold countries, part of the thermal energy can be channelled to warm the passenger compartment. Heat can also be converted to electrical energy.
Examiner's comment:
There must be mention of thermal energy not being completely wasted for mark to be awarded.

(b) A gramophone shown in Fig. 2.2 was used to play LP, long play record.

Fig. 2.2

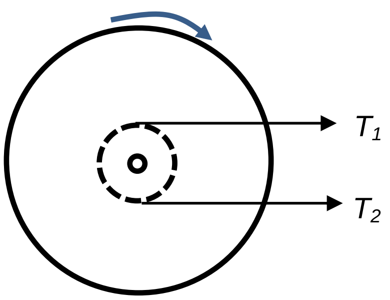


Fig. 2.3

Fig. 2.3 shows the turntable of the gramophone. The axle of the turntable (in dotted line) has a diameter of 5.0 cm. A rubber belt goes around the axle and is coupled to a motor. The tensions in the rubber belt used to turn the turntable are T_1 and T_2 respectively. Their values differ by 34.7 N.

(i) Calculate the net torque on the turntable by the rubber belt alone. [1]

$34.7 \times 2.5 \times 10^{-2} = 0.87$ N m

Examiner's comment:
Many candidates forgot to convert the length to metre and took diameter to be the radius of the turntable.

(ii) The turntable rotates at a constant rate of $33\frac{1}{3}$ revolution per minute. Calculate the work done per second by the rubber belt. [2]

Distance travelled by belt in 1 second = $33\frac{1}{3}\ \pi D = 33.3 \times \pi \times 0.050 / 60 =$ 0.0873 m
Work done by belt per second = F x distance in direction of force
= 34.7 x 0.0873 = 3.0 J
Examiner's comment:
Poorly done. Common mistakes include wrong formula for circumference of circle and no conversion made to second.

3 Spring A with spring constant *k* is attached to a body of mass *m* as shown. The spring has an unstretched length of 20.0 cm, as shown in Fig. 3.1.

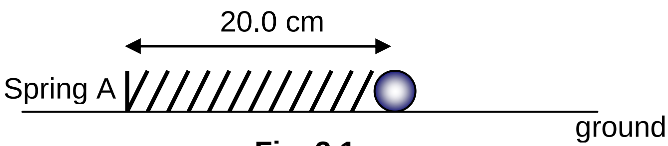


Fig. 3.1

(a) **(i)** Show that when the mass is displaced by a distance *x* and then released, its acceleration at the point of release is given by the following equation

$$a = -\frac{k}{m}x$$ [2]

Force exerted by spring with extension *x*:
$F = -kx$

According to Newton's 2nd Law,
$F = ma$

$ma = -kx$, hence $a = -(k/m)x$ (shown)

(ii) Hence give an expression for the angular velocity ω of the body's oscillation in terms of *k* and *m*. [1]

In oscillation, $a = -\omega^2 x$

Hence, $-\omega^2 x = -\frac{k}{m}x$

$$\omega = \sqrt{\frac{k}{m}}$$

(b) A second spring, Spring B, with spring constant $2k$ is attached to the mass. Spring B has the same unstretched length of 20.0 cm, as shown in Fig. 3.2.

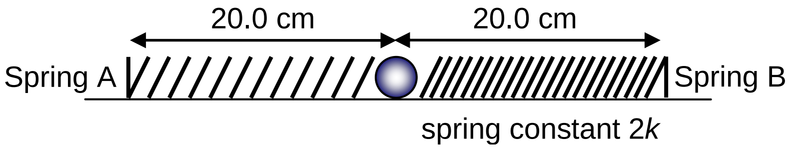


Fig. 3.2

The ball is displaced by a distance x to the left and the horizontal forces acting on the ball are as shown in Fig. 3.3.

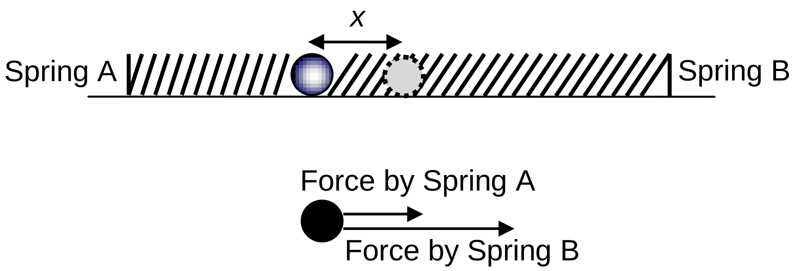


Fig. 3.3

(i) Explain why the two forces are acting in the same direction. [2]

Spring exerts **a force in a direction opposite to its extension**, hence the compressed spring and extended spring will both exert forces **in the same direction**.
OR
The **compressed/left spring** exerts a pushing **force to the right**, while the **extended/stretched/right spring** exerts a pulling **force to the right**, hence they both act in the same direction.

(ii) Given that m = 1.5 kg and k = 10 N m^{-1}, determine the period of oscillation of the mass. [2]

Taking rightward as positive,

$$2kx + kx = m\omega^2 x$$

$$\omega = \sqrt{\frac{3k}{m}}$$

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{3k}}$$

$$= 2(3.14)\sqrt{\frac{(1.5)}{3(10)}}$$

$$= 1.4 \text{ s}$$

Examiners' comments:
Many students simply applied the formula blindly without considering the FBD provided in Fig 3.3, which would have led them to consider the resultant force rather than the force due to 1 spring.

(iii) Suggest why the actual value of the period may deviate from the value calculated in **(b)(ii)**. [1]

Air resistance might cause the mass to slow down as it loses energy.
The springs used might not fully obey Hooke's Law.

(c) Stabilising systems, such as the 728-ton mass damper in Taipei 101 skyscraper, consist of a central mass that is able to undergo oscillation. They are employed to stabilise buildings in earthquake-prone regions. When the building sways, the central mass is displaced from its equilibrium position.

Explain why such systems need to be damped, and suggest an appropriate degree of damping. [2]

As the building sways, the mass is displaced and it oscillates. If this oscillation is not damped, **it will cause the building to continue swaying** / **further shocks** may result in a **forced oscillation with increasing amplitude**, which could cause the building to collapse.
Light / critical damping (heavy damping not accepted)

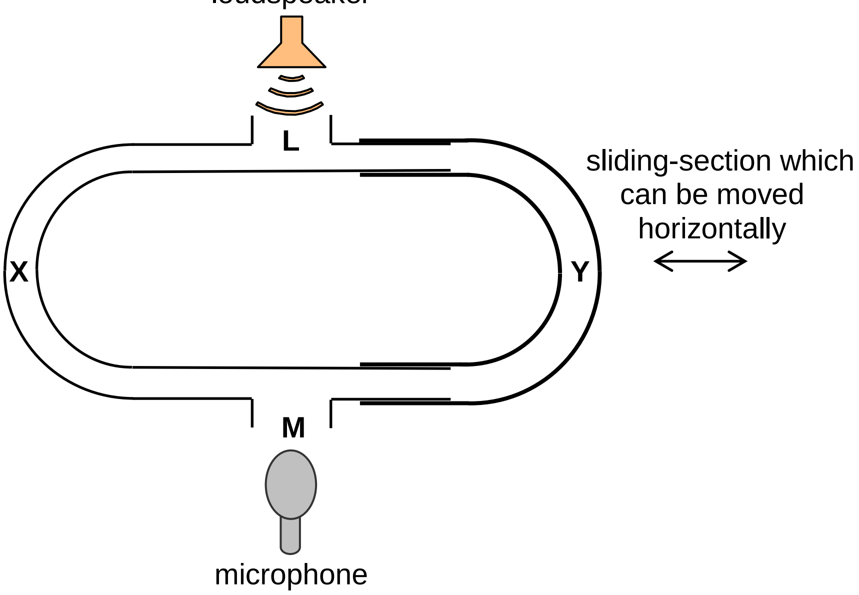
Examiners' comments:
A number of students mentioned resonance despite no driving force being mentioned in the question. In such cases they should state clearly the source of driving force.

4 (a) State the Principle of Superposition. [1]

When two waves meet, the resultant displacement is the vector sum of the displacements due to each individual wave.

Examiner's comment:
Many provided the definition of "Stationary waves" while others wrote "amplitude" instead of "displacement".

(b) Sound produced by the loudspeaker shown has a frequency of 4.0×10^3 Hz. The sound waves arrive at microphone M via two different paths, LXM and LYM. The left-tube is fixed in position, while the right-tube is a sliding-section. At position M, the sound waves from the two paths interfere.



Initially, the lengths of paths LXM and LYM are equal. The sliding-section is then pulled out horizontally by 0.020m, and the loudness at microphone M changes from a maximum to a minimum.

(i) Determine the path difference between the two waves after the sliding-section is pulled out. [1]

path difference = 2 × 0. 020 m
= 0.040 m

(ii) Calculate the speed at which sound travels through the tube. [3]

From loud to soft sound,

⇒ path difference = $\lambda/2$

⇒ $\lambda/2$ = 0. 040m

⇒ λ = 2 x path difference
= 2 x 0. 040m
= 0.080 m

∴ v = f λ = 4000 x 0.080 = 320 ms^{-1}

Examiner's comment:

Many students did not show and explain how they arrive at $\lambda/2$ = 0. 040m. Simply stating that λ = 0. 080m will not suffice.

(iii) When the opening at M is sealed, explain why a standing wave is set up in the tube. [2]

The sound waves from path LXM and LYM travel in opposite directions.
Since both waves are of equal amplitude, frequency and speed, they superpose and interfere [1]to form a stationary wave.

Examiner's comment:
Students fail to explain contextually, for eg. to explain how the waves are travelling in opposite directions by considering the paths LXYM and LYMX.

(iv) The frequencies of the sound produced by the loudspeaker ranges from 40 Hz to 4.0 kHz. Estimate the optimal diameter of the loudspeaker in order to achieve the maximum diffraction of sound waves. Explain your answer. [3]

λ_{min} = v / f = 320/4000 = 0.080 m (2 or 3 sf) allow for ecf

λ_{max} = v / f = 320/40 = 8.0 m

Optimal diameter should range from 0.080 m to 1 m (feasibility).
When the diameter of the speaker is comparable to the wavelength of the sound it produces, significant diffraction/maximum spreading of waves occurs.

5 In the design of structures such as buildings, towers or bridges, an engineer may use a cantilever beam to allow for overhanging structure without external bracing. A cantilever is a beam supported only at one end.

The engineer will make calculations to ensure that the cantilever beam is strong enough to withstand any forces applied on it and ensure that there is not too much vertical deflection. An appropriate beam can then be chosen based on the maximum allowable load to be applied.

Fig. 5.1 illustrates a cantilever of length L loaded with a point load P at its end. A vertical deflection y of the free end of the cantilever will result from the loading.

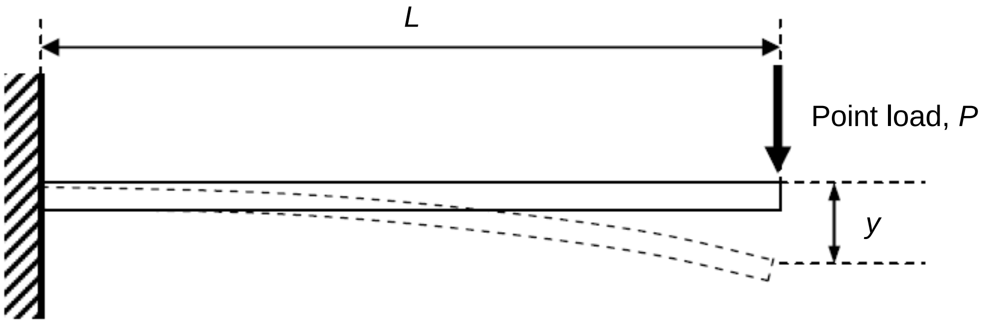


Fig. 5.1

A student was asked to investigate the behaviour of such an arrangement and found an expression for the vertical deflection of a loaded cantilever which was given by Equation 1:

$$y = \frac{4PL^3}{kbh^3} \qquad \textbf{(Equation 1)}$$

where

k is a constant
b = breadth of cantilever
h = height of cantilever

(a) The student first used two steel cantilevers to investigate the relationship between y, P and L. He first kept L constant and varied P to obtain the results as shown in Fig. 5.2.

P (N)	10	20	40	50	68 –70	90
y (mm) for Cantilever A	1.9	3.9	7.8	9.9	13.8	17.7
y (mm) for Cantilever B	10.8	16.8	28.6	34.4	46 – 47	57.9

Fig. 5.2

The graph showing the relationship between y and P for Cantilever A has been sketched on Fig. 5.3. Some of the data points of Cantilever B have also been plotted in Fig. 5.3.

(i) Complete Fig. 5.2. [1]

(ii) On Fig. 5.3, complete the plot and sketch the graph to show the relationship between y and P for Cantilever B.

Graph of Deflection *y* (mm) against Point Load *P* (N)

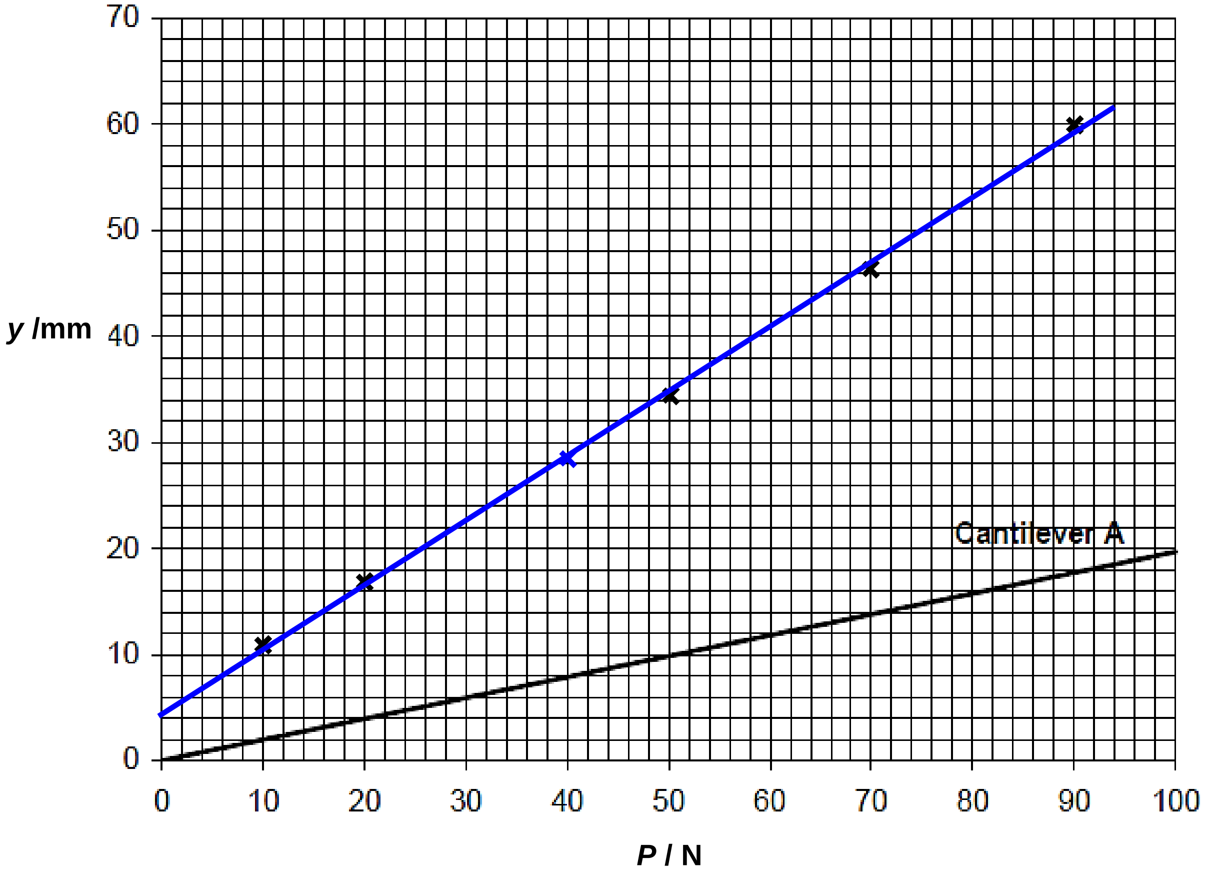
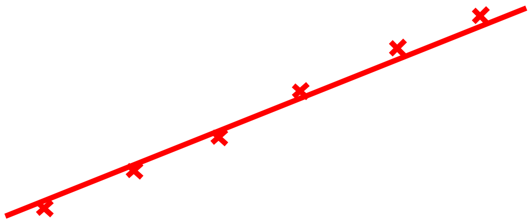


Fig. 5.3

<u>Examiner's comment:</u>
The point of (40, 28.6) must be precise to within half a smallest square. That is, for the y-coordinate of 28.6, the students can plot the point between 28 and 29. Anything out of this range is considered not precise and mark is not awarded. (In fact, a number of students plot slightly above 29, hence mark is not given.

The following best fit line is not acceptable because we can have a better best fit line which is slightly steeper than this.



[2]

(iii) Explain how the graph of Cantilever A supports Equation 1. [2]

The graph shows a **linear relationship** between *y* and *P* and it **passes through the origin**. The data support Equation 1 as *y* is proportional to *P*.

Examiner's comment:

The word 'proportional' shows a mathematical relationship between two variables. From equation 1, the students should be able to see that y is proportional to P. But this question is asking about how the graph supports this claim. Hence no mark is given when students state that y is proportional to P.

(iv) Explain how the graph suggests that the measurements for Cantilever B were subjected to systematic error. [2]

When no point load is being applied to cantilever B (P = 0), there should not be any deflection (y = 0). However, from the graph, there seems to be a deflection when P = 0 for Cantilever B, suggesting the presence of a systematic error.

(v) Hence, estimate the amount of systematic error. [1]

Any answers between 4 – 6 mm, **depending on student's graph**

Examiner's comment:

Some students are able to see that the y-intercept is the degree of the error. Some students knew that the line should touch the origin hence they tried to draw a line that touched the origin. This causes them to lose marks for having a bad line and also eliminating the clue to state the value of the error.

(vi) Suggest a reason how this error may have arisen. [1]

The elastic limit of Cantilever B might have been exceeded.
Or The cantilever was already warped before measurements were taken.

Examiner's comment:

Parallax error and faulty instrument and wrong method are not acceptable answers because these answers, if really exists, should also affect the accuracy of cantilever A graph. The expected answer must be something pertaining to only cantilever B only.

(b) The student continued his investigation by keeping P constant and varying L, obtaining the results for Cantilever A as shown in Fig. 5.4.

L / m	1.0	1.5	2.0	2.5	3.0	3.5	4.0
y / mm	1.6	5.3	12.5	24.6	42.4	67.2	99.9

Fig. 5.4

These results did not suggest direct proportionality between y and L. The student proceeded to sketch a graph showing the variation of lg y against lg L as shown in Fig. 5.5.

Graph of lg (y/mm) against lg (L/m)

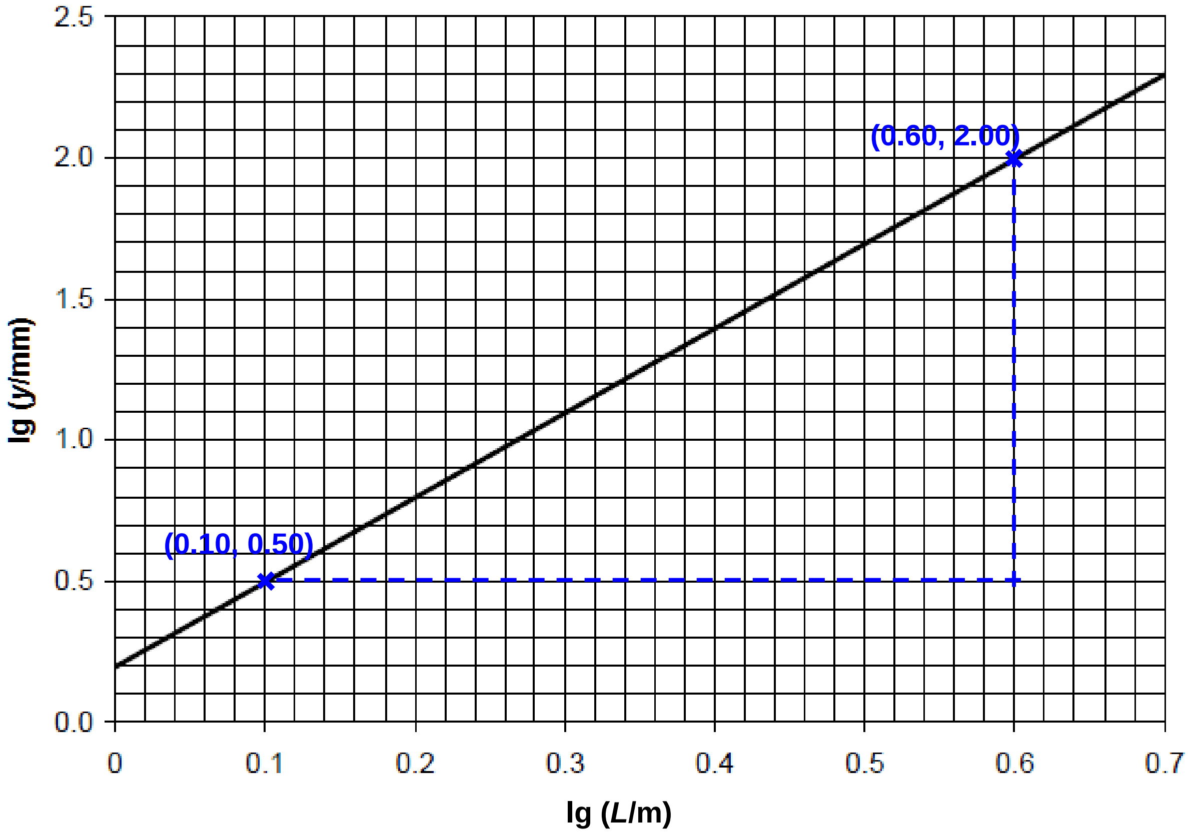


Fig. 5.5

(i) Determine the gradient of the graph. Show your working. [2]

$$\text{Gradient} = \frac{2.00 - 0.50}{0.60 - 0.10} = 3.0$$

(precision to half the smallest square, calculation to correct d.p. and s.f. and triangle should be more than half the line drawn)

Examiner's comment:

Many students did not read to the precision of half the smallest square. Hence one mark is deducted. Also, the two chosen points must be at least more than half the graph away.

(ii) Hence discuss whether the data in Fig. 5.4 support Equation 1. [2]

The data supports Eq 1 as the gradient of the graph lg y against lg L gives the order of the relation between y and L. From the data, y is proportional to L^3 which support Equation 1.

Examiner's comment:

Some students cannot relate Fig. 5.5 with the equation 1 with logarithmic treatment. Hence cannot see the reason why the gradient is 3.0. Stating that y/L^3 gives a constant value is not a good enough method hence only one mark is awarded in this case.

(c) After researching further into the subject, the student found out that the constant k in Equation 1 is known as the Young's Modulus which is a property of the material of the cantilever.

(i) Use Equation 1 to show that the S.I. unit of k is Pa. [2]

$$y = \frac{4PL^3}{kbh^3}$$

$$k = \frac{4PL^3}{ybh^3}$$

$$[k] = \left[\frac{PL^3}{ybh^3}\right] = \frac{\text{N} \times \text{m}^3}{\text{m} \times \text{m} \times \text{m}^3} = \frac{\text{N}}{\text{m}^2} = \text{Pa}$$

(ii) A steel cantilever has breadth 0.12 m, height of 0.040 m and length of 2.0 m as shown in Fig. 5.6. If a point load of 1.0 kN is applied at the end, a vertical deflection of 2.0 cm was measured at the end. Calculate the Young's Modulus of steel. [2]

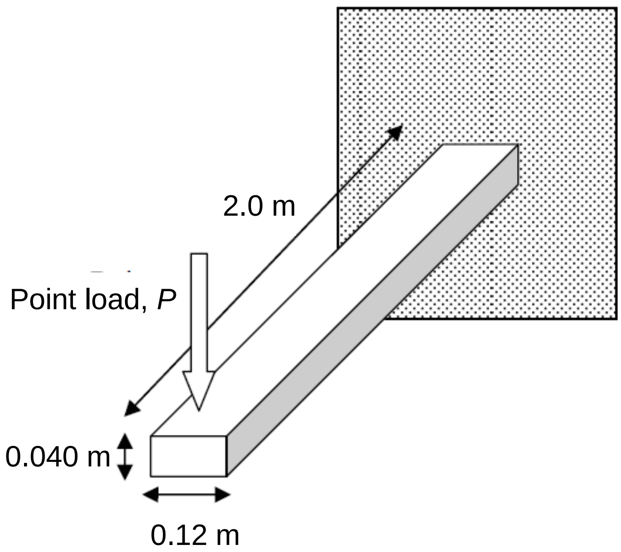


Fig. 5.6

$$k = \frac{4PL^3}{ybh^3} = \frac{4(1.0 \times 10^3)(2.0)^3}{0.020(0.12)(0.040)^3} = 2.1 \times 10^{11} \text{ Pa}$$

(iii) To increase the maximum allowable load for a given vertical deflection, the student proposed to orientate the direction of the steel cantilever in **(c)(ii)** differently to the new orientation as shown in Fig. 5.7.

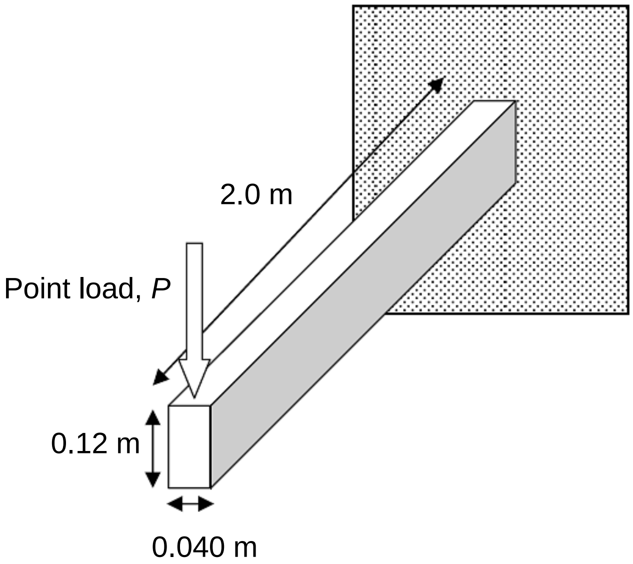


Fig. 5.7

Suggest, with reason, whether the student's proposal should be adopted. [2]

Yes, the student's proposal should be adopted. This is so as for a given deflection, *P* is proportional to the product of bh^3. With the new orientation, the product bh^3 is significantly larger. Thus, for a given deflection, the maximum allowable load will be increased.

(iv) In the construction industry, steel beams normally come in an "I" shape with a cross section as shown in Fig. 5.8.

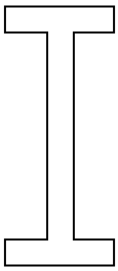


Fig. 5.8

Suggest a reason why they are designed this way instead of the rectangular cross section shown in **(c)(iii)**. [1]

Less material need to be used to construct the steel beam, cost can be saved. Reduce the weight of the beam.

6 **(a)** **(i)** Define gravitational field strength. [1]

The gravitational field strength is the <u>force per unit mass</u> acting on a test mass placed at that point.

(ii) Define gravitational potential. [1]

The gravitational potential is the <u>work done per unit mass</u> to bring a mass from infinity to that point.

<u>Examiner's comment:</u>

Some students wrongly quote gravitation potential for this section. A few also wrongly mentioned from point to infinity and energy instead of work done.

(iii) State how gravitational field strength is related to gravitational potential. [1]

Gravitational field strength is the <u>negative potential gradient</u> at the point.

<u>Examiner's comment:</u>

Some students neglect to state that it is the <u>negative</u> potential gradient.

(b) A binary star system consists of two stars P and Q, with masses M_1 and M_2 respectively, rotating about a common centre. The centres of the two stars are separated by a distance $R = 1.2 \times 10^{10}$ m. The total gravitational potential due to both stars at any point along a line joining their centres is ϕ.

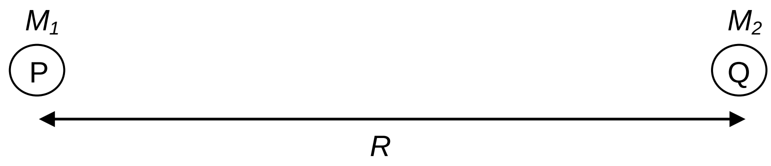


Fig. 6.1 shows how ϕ varies with the distance x from the centre of star P.

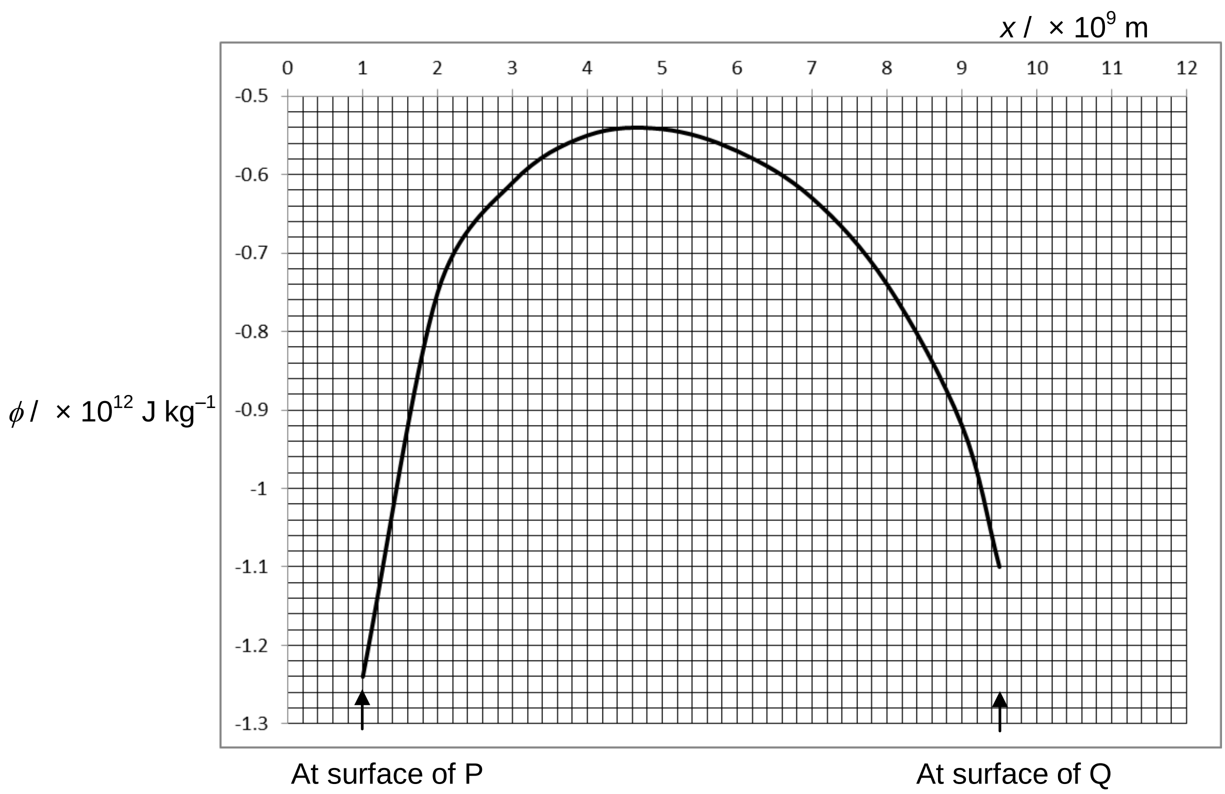


Fig. 6.1

(i) Describe the feature of the graph which shows that the masses of stars P and Q are different. [1]

Asymmetry shape of graph/magnitude of ϕ at P and Q are different. [either one]

(ii) State the kinetic energy per unit mass required by a particle to completely escape from the gravitational field of the binary star system. [1]

1.24×10^{12} J kg^{-1}

Examiner's comment:

Some students state value of potential at surface of Q while others at the peak. Both values applied at surface of P do not allow particle to escape from the gravitational field.

(iii) Calculate the minimum speed at which a particle should be ejected from the surface of Q to reach the surface of P. [3]

Ejected particle from Q require minimum kinetic energy to reach peak so as to reach P.

$(E_k + E_P)_Q = (E_k + E_P)_{peak}$ [either of above two satements]

$E_{kQ} - 1.10 \times 10^{12}$ m = 0 – 0.54×10^{12} m

$E_{kQ} = 0.56 \times 10^{12}$ m

$v_Q = \sqrt{(2 \times 0.56 \times 10^{12})} = 1.06 \times 10^6$ m s^{-1}

Examiner's comment:

Some students wrongly apply COE between surface of Q to infinity; failing to notice that ejected particle from Q require minimum kinetic energy to reach peak so as to reach P.

(iv) State the distance x from the center of P to the point at which the gravitational field strength due to the two stars is zero. [1]

4.60×10^9 m

(v) Hence determine the ratio M_1 / M_2. [3]

From part (iv), at that point the gravitational field strength due to both stars are equal in magnitude and act in opposite direction.

$$g_{M1} = g_{M2}$$

$$\frac{GM_1}{(4.60 \times 10^9)^2} = \frac{GM_2}{(1.2 \times 10^{10} - 4.60 x 10^9)^2}$$

$$\frac{M_1}{M_2} = \frac{(4.60 \times 10^9)^2}{(1.2 \times 10^{10} - 4.60 x 10^9)^2}$$

$$\frac{M_1}{M_2} = 0.386$$

Examiner's comment:

Some students wrongly use potentials to due to mass P & Q to compare.

(c) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.98×10^{24} kg concentrated at its centre.

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.0 day (8.64×10^{4} s).

Calculate, to three significant figures,

(i) the gravitational force F_G of attraction between the mass and the Earth, [2]

$$F_G = \frac{GMm}{r^2} = 9.80$$

Examiner's comment:
Many students wrongly neglect to convert to meter or to square the radius.

(ii) the centripetal force F_C on the 1.00 kg mass, [2]

$$F_c = m\omega^2 r = 0.0337$$

(iii) the difference in magnitude of the forces calculated in **(c)(i) and (c)(ii)**. [2]

$F_G - F_C = 9.77$

(d) By reference to your answers in **(c)**, suggest, with a reason, a value for the acceleration of free fall at the Equator. [2]

acceleration of free fall at the Equator = 9.77 m s^{-2}

It is the force per unit mass taken into consideration the rotation effect of the earth.