RAFFLES INSTITUTION

2020 YEAR 5 PROMOTION EXAMINATION

2 October 2020 Time: 2 hr 30 min

H2 PHYSICS

Section A

INSTRUCTIONS TO CANDIDATES

There are 3 sections in this paper.

Section A consists of **15** multiple-choice 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 Optical Mark Sheet.

You are advised to attempt Section A first. The Optical Mark Sheets will be collected after the first **30** minutes.

Section B consists of **5** structured questions. You are to write your answers in the spaces provided.

Section C consists of **1** long structured question and **1** data analysis question. You are to write your answers in the spaces provided.

Attempt ALL questions in Sections A, B and C.

There are 8 printed pages, inclusive of the cover page and data & formulae page, in this booklet.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	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	=	$T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas 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	λ	=	$\ln 2 / t_{1/2}$

1 The energy E of a photon of light of frequency f is given by the equation

$$E = hf$$

where h is the Planck constant.

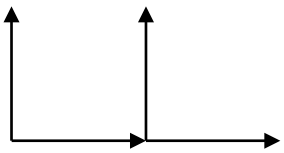
What are the base units of h?

A kg m s^{-2} **B** kg m^2 s^{-3} **C** kg m^2 s^{-2} **D** kg m^2 s^{-1}

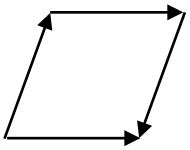
2 Each of the following diagrams shows four vectors of equal magnitude.

In which diagram is the magnitude of the resultant vector different from the rest?

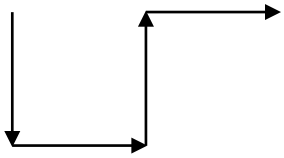
A



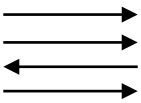
B



C



D

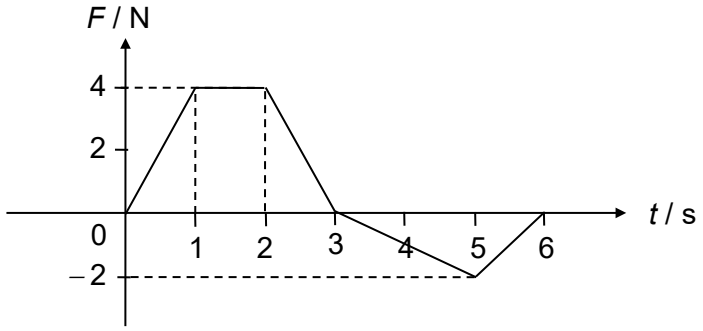


3 Ball P is dropped from rest at a height of 25 m. At the same time, ball Q is thrown vertically upwards from the ground directly below Ball P. They collide after 1.5 s.

What is the initial speed of ball Q?

A 2.0 m s^{-1} **B** 15 m s^{-1} **C** 17 m s^{-1} **D** 31 m s^{-1}

4 The graph shows the variation with time t of force F acting on a 4.0 kg mass moving in a straight line. The velocity of the mass at time t = 1 s is 1.8 m s^{-1}.



What is the velocity of the mass at t = 5 s?

A 1.0 m s^{-1} **B** 2.6 m s^{-1} **C** 2.8 m s^{-1} **D** 3.8 m s^{-1}

5 Which of the following statements is correct?

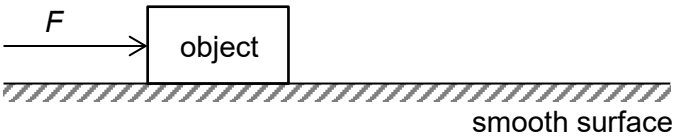
A A floating object in equilibrium displaces an amount of fluid that is of the same volume as the object.

B A floating object in equilibrium displaces an amount of fluid that is of the same mass as the object.

C When no net force acts on a partially submerged object, it must be in equilibrium.

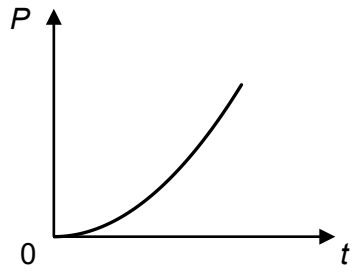
D When an object is sinking in an incompressible fluid, the upthrust it experiences increases as it sinks.

6 A constant force F is applied to an object that is initially at rest on a large smooth surface.

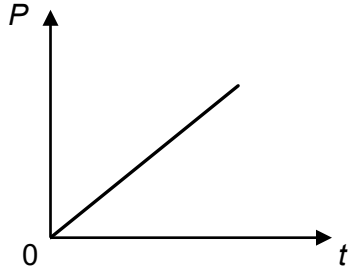


Which graph shows the variation with time t of the power supplied P?

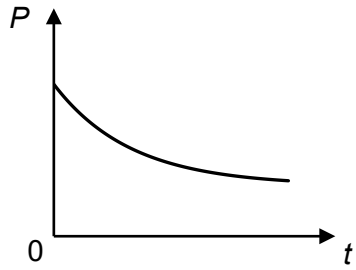
A



B



C



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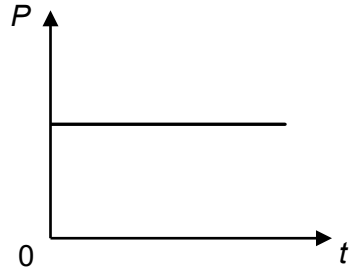
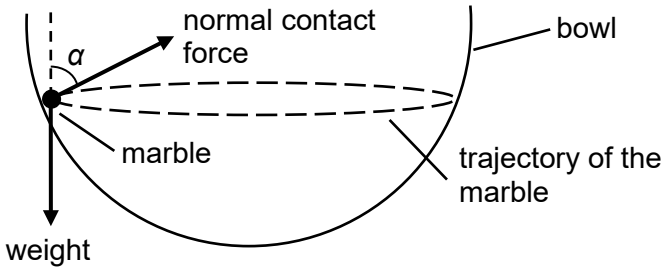


7 A smooth hemispherical bowl is placed on a horizontal surface. A marble undergoes horizontal uniform circular motion in the bowl.



The forces acting on the marble are its weight and the normal contact force due to the bowl.

Which of the following statements is true?

A The magnitude of the weight is always larger than that of the normal contact force.

B The magnitude of the normal contact force is always larger than that of the weight.

C The magnitudes of the weight and normal contact force are the same.

D The angle α determines whether the magnitude of the weight or that of the normal contact force is larger.

8 Two identical satellites A and B orbit around the Earth in circular orbits of radii r_1 and r_2 respectively.

What is the ratio $\frac{\text{kinetic energy of satellite A}}{\text{kinetic energy of satellite B}}$?

A $\frac{r_1}{r_2}$ **B** $\frac{r_2}{r_1}$ **C** $\sqrt{\frac{r_1}{r_2}}$ **D** $\sqrt{\frac{r_2}{r_1}}$

9 An astronaut landed on a planet of mass ten times and radius two times that of the Earth.

Which of the following statements about the astronaut is correct?

A The weight of the astronaut on the planet is 2.5 times his weight on Earth.

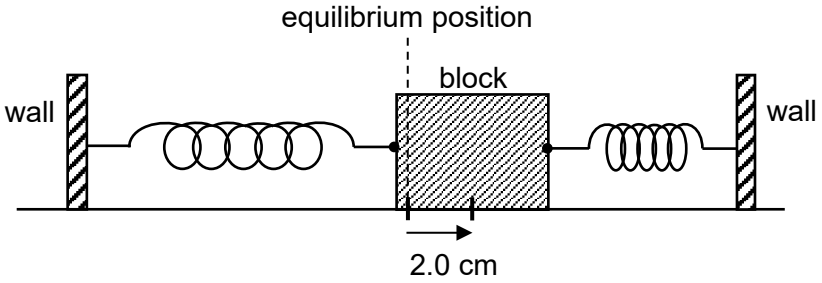
B The weight of the astronaut on the planet is 5 times his weight on Earth.

C The maximum height reached by the astronaut when he jumps vertically on the planet is 0.2 times of that on the Earth.

D The maximum height reached by the astronaut when he jumps vertically on the planet is 2.5 times of that on the Earth.

10 A block of mass m, attached to two walls by two springs under tension, is displaced to the right by 2.0 cm as shown. After being released from rest, it oscillates in simple harmonic motion at an angular frequency ω.

The effective force constant of the springs is $m\omega^2$.

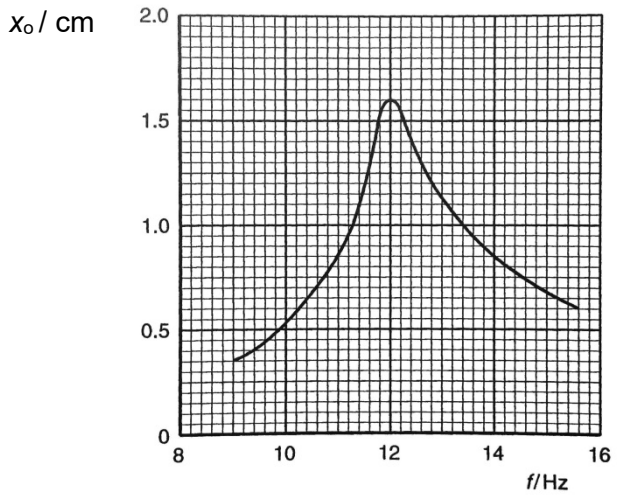


What is the shortest distance that the block moves from the point of release such that its potential energy is the same as its kinetic energy?

A 0.6 cm **B** 1.0 cm

C 1.4 cm **D** 2.0 cm

11 The variation with frequency f of the amplitude x_o of the forced oscillations of a spring mass system is as shown.



Which of the following statements is **not** correct?

A At 12 Hz, the rate of gain of energy is equal to the rate of loss of energy by the system.

B Increased damping reduces the sharpness of the resonance peak.

C Decreased damping lowers the frequency at which the system responds with the highest amplitude.

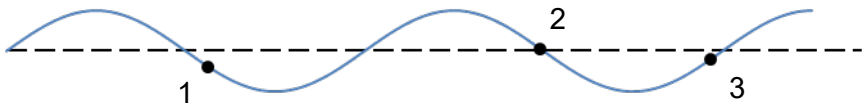
D Damping decreases the amplitude of the oscillations at all driving frequencies.

12 A point source of sound emits energy equally in all directions at a constant rate.

When the power of the source is doubled, how far should a person who was originally 3.0 m from the source be now if he wishes the sound to be as loud as before?

A 2.1 m **B** 3.5 m **C** 4.2 m **D** 6.0 m

13 The diagram below shows an instantaneous position of a string as a transverse progressive wave travels along it from left to right.

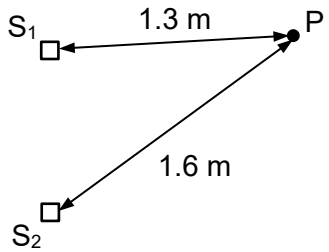


Which of the following shows the directions of the velocities of the points 1, 2 and 3 on the string?

	1	2	3
A	↑	↑	↓
B	↑	↓	↑
C	↓	↑	↓
D	↓	↓	↑

14 Two generators, S_1 and S_2, generate water waves of wavelengths 0.10 m. Point P is 1.3 m away from S_1 and 1.6 m away from S_2.

When S_1 is operating by itself, it produces waves of amplitude 2A at P.
When S_2 is operating by itself, it produces waves of amplitude A at P.



When both S_1 and S_2 are operating in phase, what is the amplitude of the waves at P?

A A **B** 1.5A **C** 2A **D** 3A

15 When a stationary wave is formed in a resonance tube open at both ends, which statement is correct?

A There is always a node in the middle of the tube.

B There is always an even number of antinodes.

C There is always an odd number of antinodes.

D The number of antinodes is always more that the number of nodes by one.

Name: ______________________ (   ) CT Group: 21S0 ____

RAFFLES INSTITUTION

2020 YEAR 5 PROMOTION EXAMINATION

2 October 2020

H2 PHYSICS

Section B

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section B in the spaces provided in this booklet.

For Examiner's Use		
Section A	MCQ	/ 15
Section B	16	/ 10
	17	/ 8
	18	/ 10
	19	/ 10
	20	/ 12
Section C	21	/ 14
	22	/ 16
Deductions		
Total		/ 95

There are **11** printed pages, inclusive of the cover page, in this booklet

16 A smooth rectangular board ABCD is inclined at an angle θ to the horizontal as shown in Fig. 16.1.

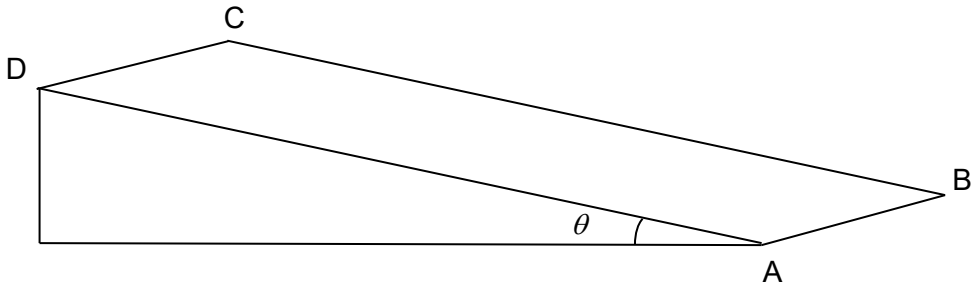


Fig. 16.1

A small mass is projected up the board with a velocity *u* from point A at an angle of 60° from AB. The trajectory of the mass, as viewed perpendicularly to the plane ABCD, is shown in Fig. 16.2. The displacement along AB of the mass when it leaves the board is 0.24 m.

The *x* and *y*-directions are parallel to AB and AD respectively.

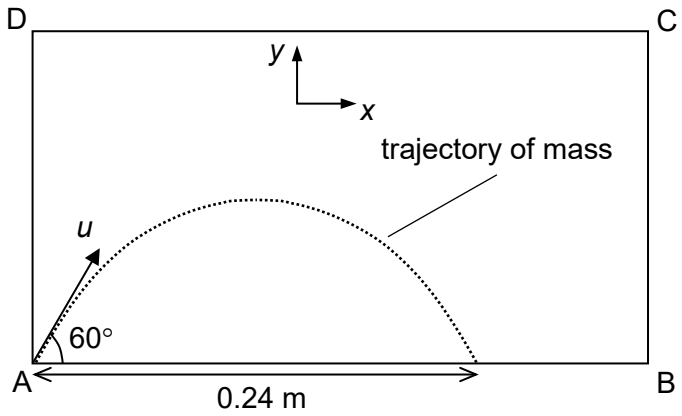


Fig. 16.2

(a) Explain why the path of the mass on the board is parabolic.

.....

.....

..... [2]

(b) **(i)** State the component in the *y*-direction of the initial velocity of the mass in terms of *u.*

..... [1]

(ii) State the component in the *y*-direction of the acceleration of the mass in terms of *g* and θ.

..... [1]

(iii) The mass reached the top of its trajectory in 0.25 s. Show that

$$u = 2.8 \sin \theta$$

[1]

(iv) Hence, calculate θ.

θ = ... ° [3]

(c) The board ABCD is tilted such that the angle θ to the horizontal is increased. The same small mass is projected up the board with the same velocity u from point A at the same angle of 60° from AB.

Sketch on Fig. 16.2 the path of the mass as it moves from point A to the point it leaves the board.

[2]

17 An object of mass 0.40 kg is placed at a distance *r* from the centre O of a flat disc rotating horizontally with an angular speed ω, and undergoes circular motion with the disc, as shown in Fig. 17.1.

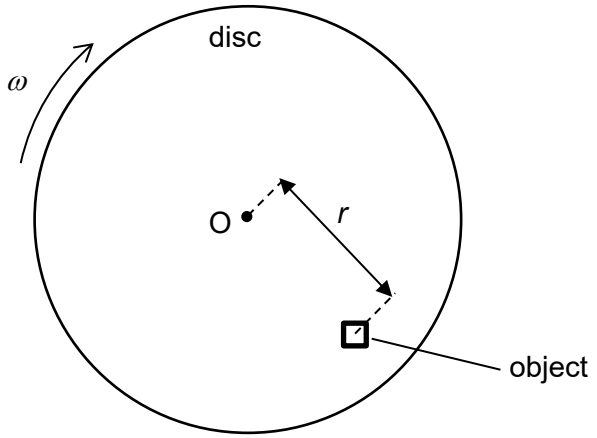


Fig. 17.1 (top view)

To determine the maximum frictional force acting on the object, the angular speed ω is slowly increased until the object starts to slide. For different values of *r*, this value of ω is recorded. The variation with $\frac{1}{r}$ of ω^2 is shown in Fig. 17.2.

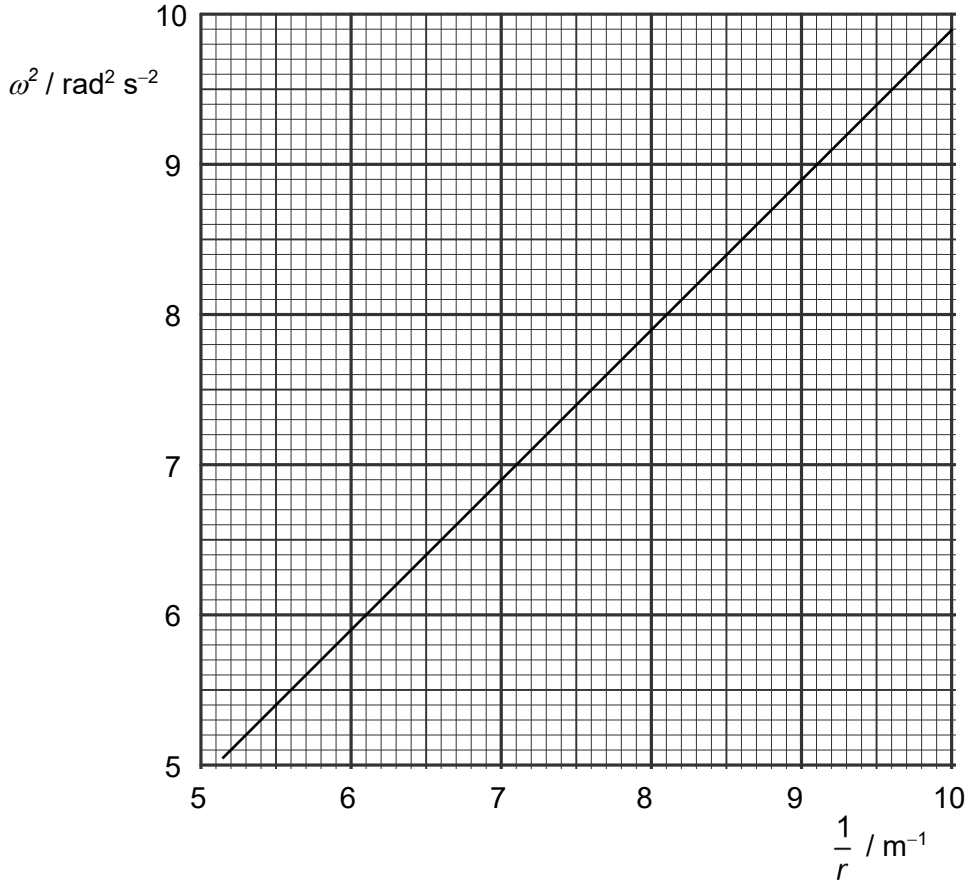


Fig. 17.2

(a) **(i)** On Fig. 17.1, draw an arrow to show the direction of the frictional force acting on the object.

[1]

(ii) Explain the direction of the frictional force in **(a)(i)**.

.....

..... [1]

(b) **(i)** Determine the gradient of the line in Fig. 17.2.

gradient = ... [2]

(ii) Suggest, with a reason, the physical significance of the gradient.

.....

..... [2]

(c) Using your answers in **(a)** and **(b)**, determine the maximum frictional force acting on the object.

maximum frictional force = ... N [2]

18 **(a)** Define *gravitational field strength.*

.....

..... [1]

(b) Fig. 18.1 shows two stars A and B, each of mass 5.0×10^{30} kg separated by 2.0×10^{12} m.

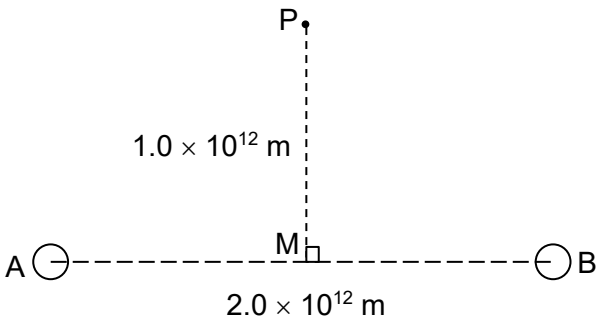


Fig. 18.1

P is a point 1.0×10^{12} m from the mid-point M of the two stars.

(i) Calculate the magnitude of the gravitational field strength at P.

gravitational field strength = ... N kg^{-1} [4]

(ii) Calculate the gravitational potential at point P.

gravitational potential = ... J kg^{-1} [2]

(iii) An asteroid travels in a straight line from P to M with a speed of 2.0×10^4 m s^{-1} when it moves past P.

Calculate its speed when it reaches M.

speed = ... m s^{-1} [3]

19 (a) Distinguish between *angular velocity* for a body moving in circular motion and *angular frequency* for a body undergoing simple harmonic motion.

.....

.....

.....

..... [2]

(b) A small sphere moves in uniform circular motion with radius 2.0 m at a steady frequency of 0.50 revolutions per second as shown in Fig. 19.1. A movable camera is mounted on a track such that it oscillates left and right, following the movement of the sphere in the *x*-direction.

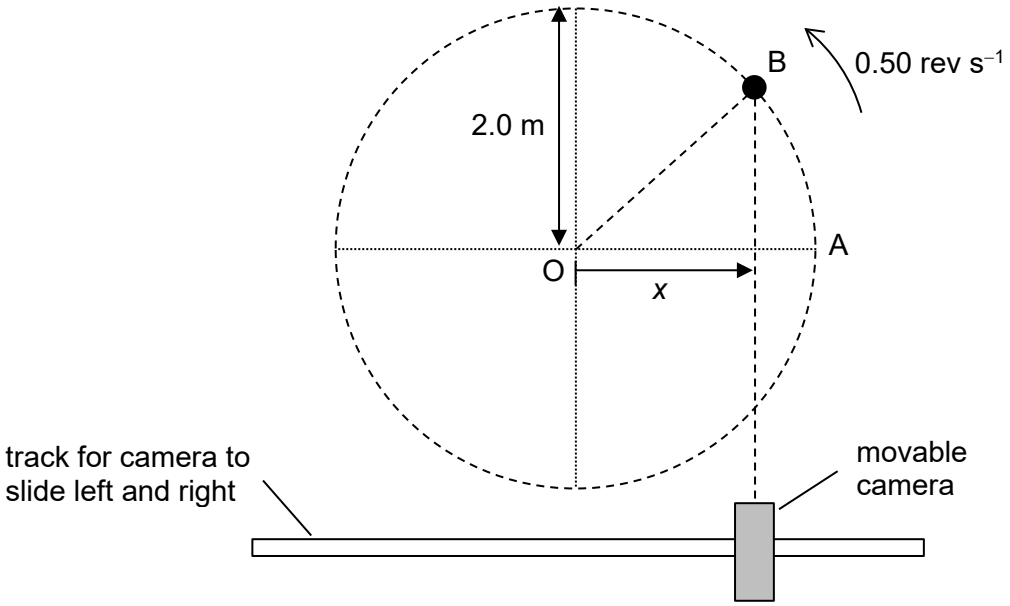


Fig 19.1

(i) The sphere is at point A at t = 0 s. It moves to point B in time t.

Show that the displacement of the sphere in the *x*-direction from point O at point B is

$$x = 2.0\cos(3.1t)$$

[1]

(ii) Hence, describe the motion of the camera.

.....

..... [1]

(iii) Calculate the period of oscillation of the camera.

period = ... s [1]

(iv) Calculate the maximum speed of the camera.

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

(v) Determine the acceleration of the camera at t = 0.25 s.

acceleration = ... m s^{-2} [3]

20 **(a)** State two conditions that are required for two-source interference fringes of light waves to be observed.

1. .....

.....

2. .....

..... [2]

(b) A double slit with slit separation 0.60 mm is situated a distance 2.4 m from a screen as shown in Fig. 20.1.

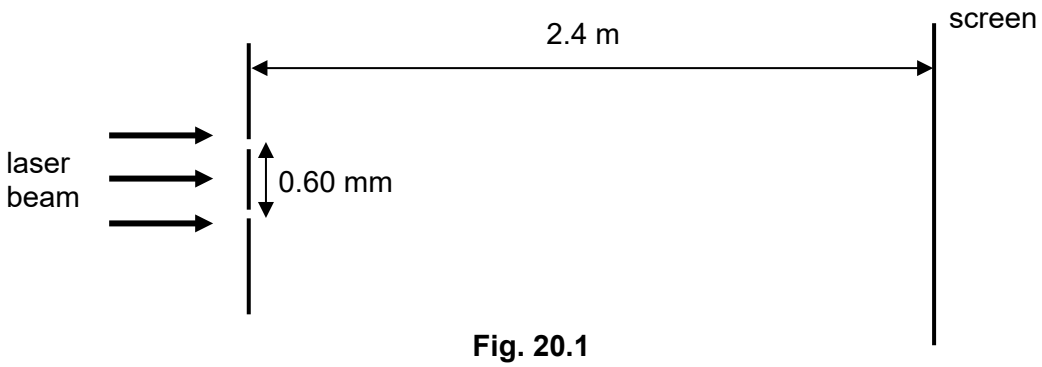


Fig. 20.1

A laser beam is incident normally on the double slit and fringes 3.0 mm apart are observed on the screen.

(i) Show that the wavelength of the laser beam is 750 nm.

[1]

(ii) Calculate the frequency of the laser beam.

frequency = ... Hz [2]

(iii) State and explain the change, if any, that would be observed in the pattern of fringes if the following adjustments were made in the experimental setup. In each case, only one adjustment is made, keeping all other arrangements the same.

1. The laser of wavelength 750 nm is replaced with coherent monochromatic violet light.

.....

.....

.....

..... [2]

2. The width of both slits in the double slit is reduced by the same amount.

.....

.....

.....

..... [2]

(c) The double slit is replaced with a diffraction grating of 500 lines per mm as shown in Fig. 20.2. Two bright spots are observed at a distance *x* from the central bright spot.

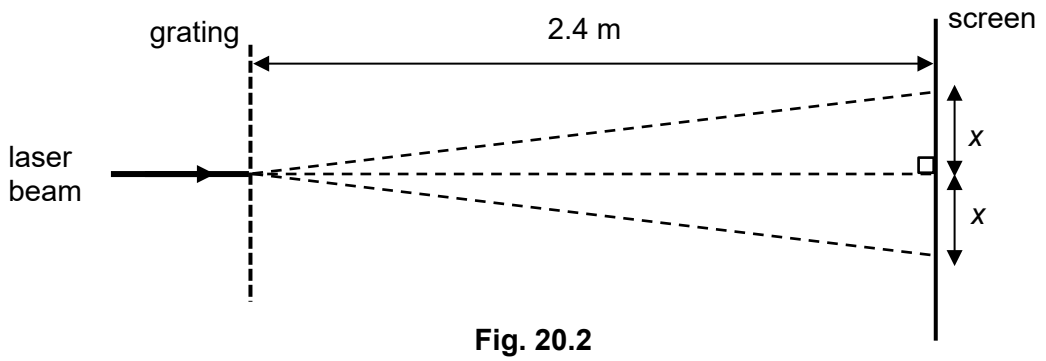


Fig. 20.2

Determine *x*.

x = ... m [3]

Name: ______________________ ( ) CT Group: 21S0 ____

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H2 PHYSICS

Section C

INSTRUCTIONS TO CANDIDATES

Write your name, index number and CT Group.

Write your answers to Section C in the spaces provided in this booklet.

For Examiner's Use		
Section C	21	/ 14
	22	/ 16

There are **8** printed pages and **1** blank page, inclusive of the cover page, in this booklet.

BLANK PAGE

Section C (30 Marks)

21 A carpenter is tasked to construct a set of book shelves using uniform rectangular wooden boards and each shelf is to be supported only at its ends.

As shown in Fig. 21.1, when a sufficiently heavy load is placed on such a shelf, its center will sag over time.

Fig. 21.1

Among other factors, the carpenter aims to choose the type of wood that has a low sag while keeping the cost of constructing the shelves low.

After some research, he found out that when a force F (this includes the weight of the shelf itself) is applied uniformly on a rectangular shelf supported only at its ends as shown in Fig. 21.2, the sag δ is related to the elasticity E of the material by the equation

$$\delta = kE^n$$

where k and n are constants and n is an integer.

Elasticity E is a measure of the ability of a material to resume its normal shape after being deformed.

He then conducted an experiment and measured the sags of shelves made from six different types of wood, for the same force F applied. The dimensions of each shelf are

length L	= 1.000 m
width w	= 0.500 m
thickness t	= 0.015 m

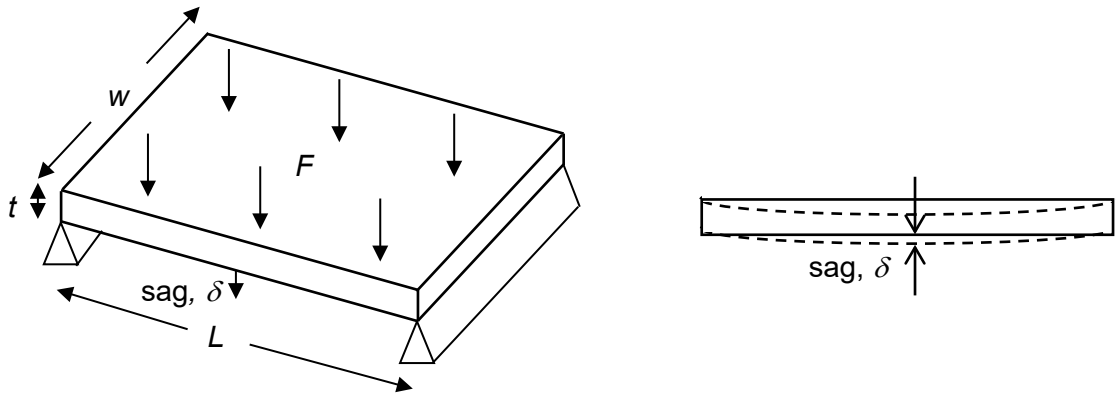

Fig. 21.2

Fig. 21.3 shows the relevant data for the six types of wood used in the experiment.

Type of wood	Unit cost / $	E / 10^9 Pa	δ / 10^{-3} m
Ash	62	9.92	3.50
Beech	73	9.48	3.71
Cherry	65	9.05	3.85
Pine	52	8.57	4.07
Alder	48	7.93	4.41
Redwood	75	7.60	4.61

Fig. 21.3

Fig. 21.4 shows the variation of lg (δ / m) with lg (E / Pa).

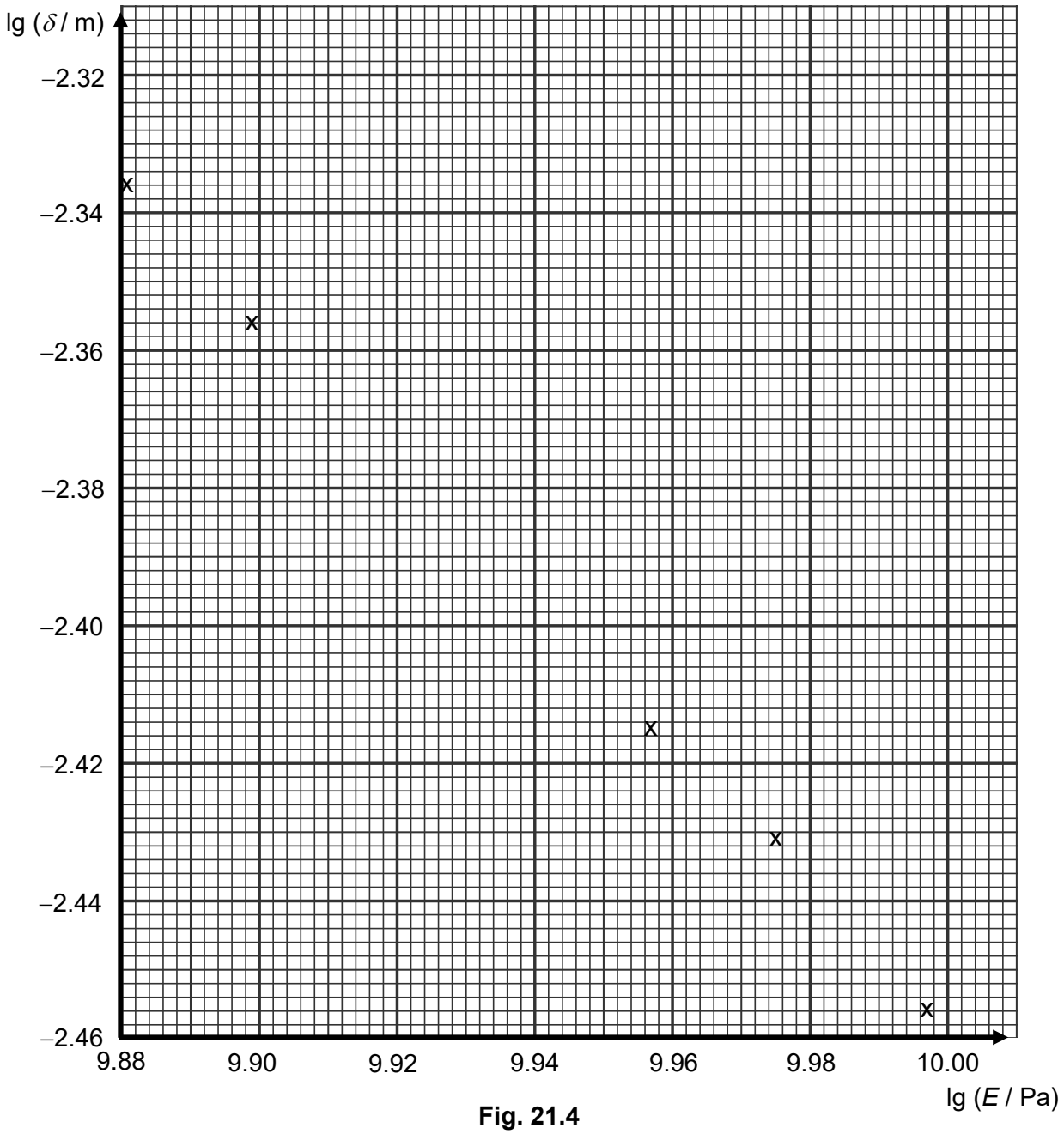

Fig. 21.4

(a) On Fig. 21.4,

(i) plot the point corresponding to $\delta = 4.07 \times 10^{-3}$ m for Pine wood. [2]

(ii) draw the line of best-fit for all the points. [1]

(b) Determine the value of *n* using Fig. 21.4.

n = ... [2]

(c) Using your answer in **(b)**, determine the value of *k*, together with its base units.

value of *k* = ... [2]

base units of *k* = ... [1]

(d) Theory suggests that *k* is given by the expression

$$k = \frac{0.150\,F}{w}\left(\frac{L}{t}\right)^3$$

Calculate the force *F* applied on the shelf in this experiment.

F = ... N [2]

(e) Using Fig. 21.3, explain why Ash wood is a better choice to make the shelves than Beech wood and Cherry wood.

.....

..... [1]

(f) **(i)** The elasticity of stainless steel is 1.8×10^{11} Pa.
Show that δ for a stainless steel shelf of the same dimensions as the wood shelf is less than 10% of that for Ash wood.

[1]

(ii) Explain why a stainless steel shelf of the same dimensions as the wood shelf is not suitable for a book shelf.

.....

..... [1]

(g) Suggest one additional factor that can affect the sagging of a wood shelf, apart from the magnitude of the force applied, its length, width, thickness and elasticity *E*.

.....

..... [1]

22 (a) (i) State *Newton's third law of motion*.

.....

..... [1]

(ii) A plastic cube of mass 1.8 kg rests at equilibrium on a wooden block as shown in Fig 22.1.

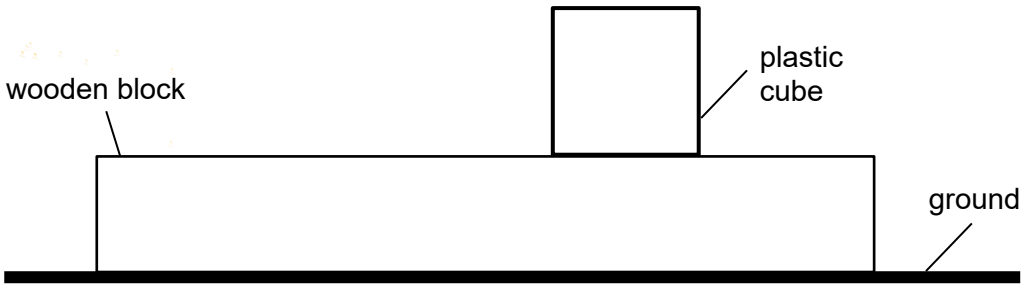

Fig. 22.1

On Fig. 22.1, draw and label a pair of forces that illustrates Newton's third law of motion.

[2]

(iii) The plastic cube is lifted and then dropped onto the wooden block. The plastic cube has a speed of 3.3 m s^{-1} just before impact and it comes to rest in 0.021 s.

Determine the magnitude of the average force exerted by the wooden block on the plastic cube during the impact.

magnitude of average force = ... N [3]

(b) The plastic cube of sides 0.30 m is now placed on the end of a horizontal uniform platform of mass 4.2 kg and length 1.4 m, that is hinged to a wall at H as shown in Fig. 22.2. The platform is supported by a light rigid brace strut of length 0.50 m. The strut exerts a force *F* on the platform at an angle 29° to the horizontal.

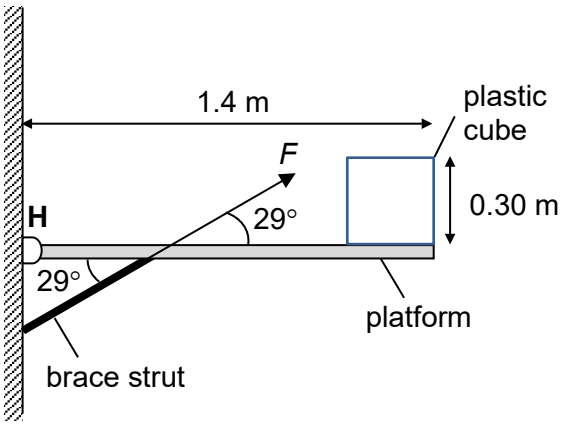

Fig. 22.2

(i) State the two conditions necessary for an object to be in equilibrium.

1. .....

.....

2. .....

..... [2]

(ii) Show that the magnitude of *F* is 240 N.

[3]

(iii) Hence, calculate the magnitude and direction of the reaction force of the hinge on the platform at H.

magnitude = ... N

direction = ... [4]

(iv) State and explain whether the magnitude of *F* increases, decreases or remains the same when the plastic cube is shifted closer to H. The direction of *F* remains the same.

.....

..... [1]

End of paper