Geylang Methodist School (Secondary)
Preliminary Examination 2024

Candidate Name	ANSWERS		
Class		Index Number	

PHYSICS

6091/02

Paper 2 Physics

Sec 4 Express

Additional materials : NIL

1 hour 45 minutes

13 August 2024

READ THESE INSTRUCTIONS FIRST

Write your name, index number and class on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **all** questions. Question 12 has a choice of parts to answer.

Candidates are reminded that **all** quantitative answers should include appropriate units.
You are advised to show all your working in a clear and orderly manner.

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.

Acceleration due to gravity, ***g***, is assumed to be 10 m/s^2 unless otherwise specified.

For Examiner's Use	
Section A	/70
Section B	/10
Total	/80

Section A
Answer **all** questions.

1 Fig. 1.1 shows the velocity-time graph for the first 80 s after an object is dropped from rest at a height of 2000 m above the ground.

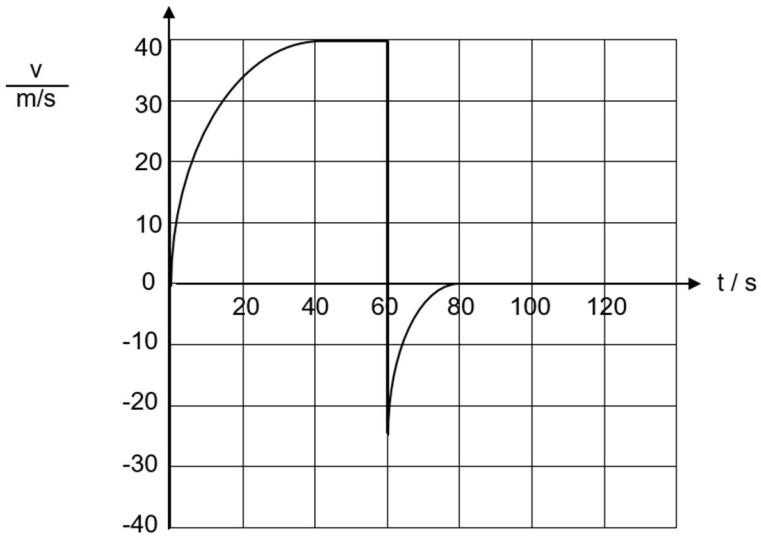


Fig. 1.1

The object has a mass of 9.0 kg.

(a) State the acceleration of the object at 0 s.

acceleration = ……10 m/s^2…… [1]

(b) Describe the motion from 0 to 80 s.

From 0 to 40 s, object is moving downwards with a decreasing acceleration. [1]
From 40 to 60 s, object is moving downwards with a constant velocity of 40 m/s. [1]
From 60 to 80 s, object is moving upwards [1] with a decreasing deceleration [1]

(c) Describe the energy transfer when the object is travelling at terminal velocity.

Energy is transferred from the gravitational potential store of the object [1] to the internal stores of the surrounding and the object. [1]

(d) Calculate the maximum possible air resistance acting on the object when the object is falling at terminal velocity.

Max air resistance = weight = 9.0 x 10 = 90 N [1]

Maximum air resistance = ……[1]

2 A 7.0 kg picture frame is being suspended from a nail by a string. The string forms two segments L_1 and L_2, as shown in the Fig. 2.1. L_1 and L_2 make an angle of 35° and 60° with the vertical respectively.

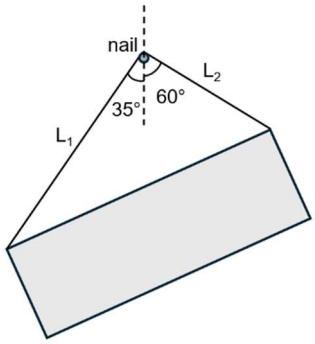


Fig. 2.1

(a) In the space below, draw a vector diagram to determine the tension forces in segments L_1 and L_2. Specify the scale used.

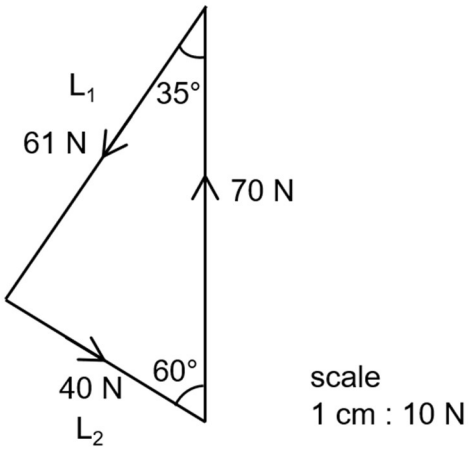


diagram [1], scale [1]

scale = ……

force in L_1 = 61 N [1]…, force in L_2 = 40 N [1]

(b) State the magnitude and direction of the force by the nail, on the string.

70 N [1]
Vertically up [1]

(c) The picture frame was adjusted such that both segments of the string make an angle of 44.5° with the vertical. State the changes to the tensions in segment L_1 and L_2 and how their magnitudes compare.

Tension in L1 decreases and tension in L2 increases. [1]
Their magnitudes are equal. [1]

3 Fig. 3.1 shows a man holding a 0.20 N object in his hand with his forearm in a horizontal position. He can support the object in this position because the flexor muscle exerts a force, F_M vertically upward on the forearm. The man's forearm weighs 22 N and its centre of gravity (C.G.) is indicated in the diagram. The forearm can rotate about the elbow joint.

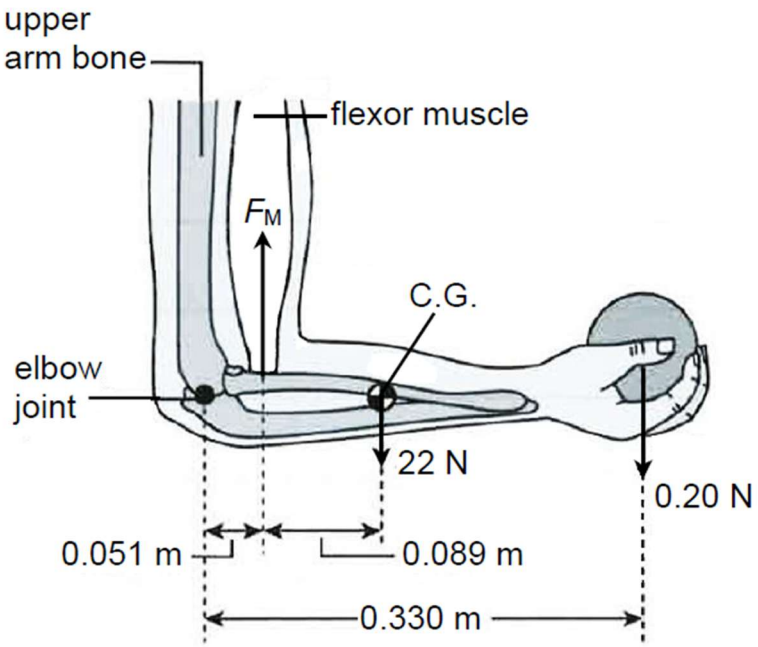


Fig. 3.1

(a) Calculate the value of F_M.

Taking moment about the elbow joint,
Sum of anti-clockwise moment = sum of clockwise moment
F_M x 0.051 = 22 x (0.089 + 0.051) + 0.2 x 0.330 [1]
F_M = 61.6863 N ≈ 61.7 N (3sf) [1]

F_M = ... [2]

(b) To keep the forearm in the horizontal equilibrium position, the upper arm bone exerts a force at the elbow joint. Determine the magnitude and direction of this force.

Sum of upward forces = sum of downward forces
61.6863 = 22 + 0.2 + F [1]
F = 39.5 N (3sf) [1]

direction is downwards [1]

magnitude = ...

direction = ...[3]

(c) Explain why the force in **(b)** is not considered in the calculation in **(a)**.

The line of action of this force passes through the pivot so its perpendicular distance from pivot is zero / its moment about the pivot is zero.

……..…[1]

4 Fig. 4.1 shows two vertical tubes P and Q, each closed at the upper end. The pressure in the space above the mercury meniscus in tube P is 16800 Pa. The pressure in the space above the mercury meniscus in tube Q is unknown.

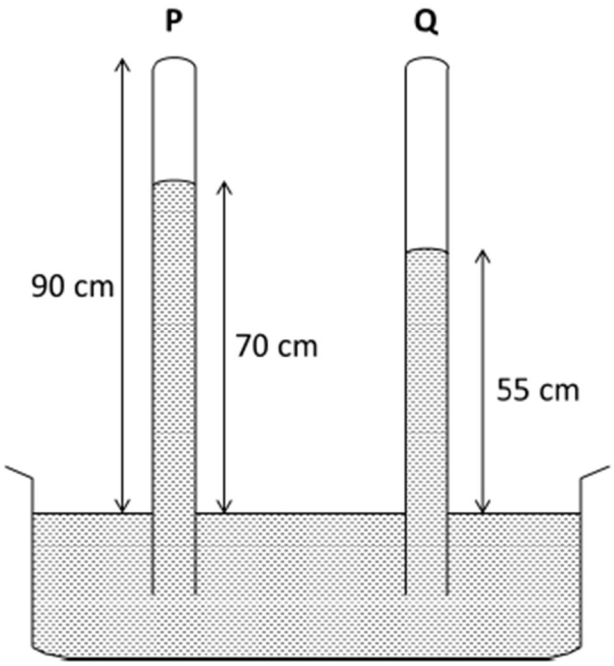


Fig. 4.1

Take the density of mercury to be 13600 kg/m^3.

(a) Using the information provided, calculate

(i) the atmospheric pressure;

$P_{atm} = h\rho g + P_P = (0.70\ m)(13600\ kg\ m^{-3})(10\ N\ kg^{-1}) + 16800\ Pa$ [1]

$= 112000\ Pa$ [1]

atmospheric pressure = …… [2]

(ii) the pressure in the space above the mercury meniscus in tube Q.

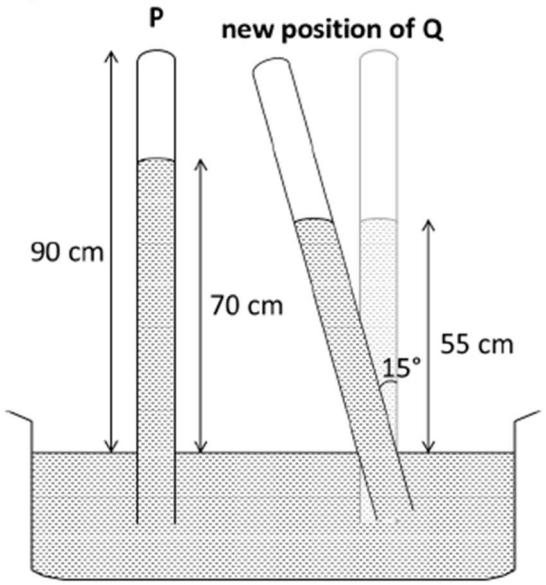
$P_{atm} = h\rho g + P_Q$

$112000\ Pa = (0.55\ m)(13600\ kg\ m^{-3})(10\ N\ kg^{-1}) + P_Q$ [1]

$P_Q = 37200\ Pa$ [1]

pressure = ... [2]

(b) Due to a small knock, tube Q is slightly shifted and ends up at an angle 15° to the vertical, as shown in Fig. 4.2.



[1]

Fig. 4.2

On Fig. 4.2, draw the new level of the mercury meniscus in tube Q, and explain your answer.

Liquid pressure depends only on the vertical height of the liquid column above it and not the geometry of the liquid column. [1]

.....

.....

.....[2]

5 Fig. 5.1 shows the structure of a water cooler that supplies cold water.

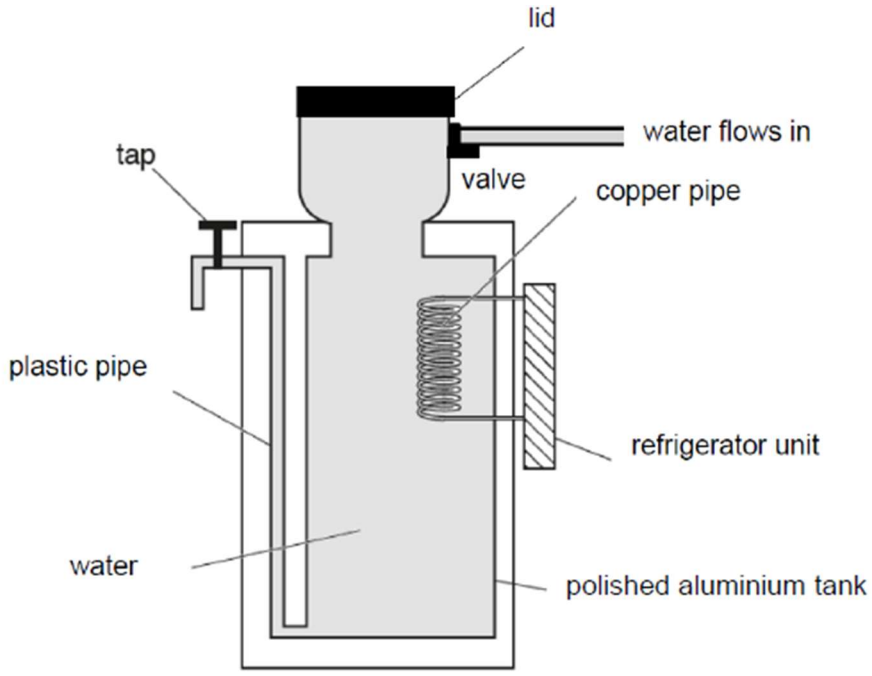


Fig. 5.1

(a) In the refrigerator unit, a coolant is pumped through the copper pipe. Explain how energy is transferred from the water to the coolant in the pipe.

Energy is transferred from the water internal store to the copper pipe internal store by conduction [1] and then from the copper pipe internal store to the coolant internal store by conduction. [1]

(b) Describe how the entire tank of water is cooled.

The water near the copper pipe is cooled, it contracts, becomes denser and sinks to the bottom of the tank. [1]
The warmer water at the bottom, being less dense rises to top to be cooled by the refrigerator unit. This sets up a convection current in the tank. [1]

(c) Explain how the polished aluminium tank helps to keep the water cold.

The polished aluminum tank is good reflector / poor absorber of infra-red radiation. It reduces energy gain from the surrounding by infra-red radiation. [1]

6 Fig. 6.1 shows the equilibrium positions of some particles in a medium at time t = 0 s. When a longitudinal wave travels through this medium, the displacements of these particles at time t = 1 s are shown in the displacement - position graph (Fig. 6.2).

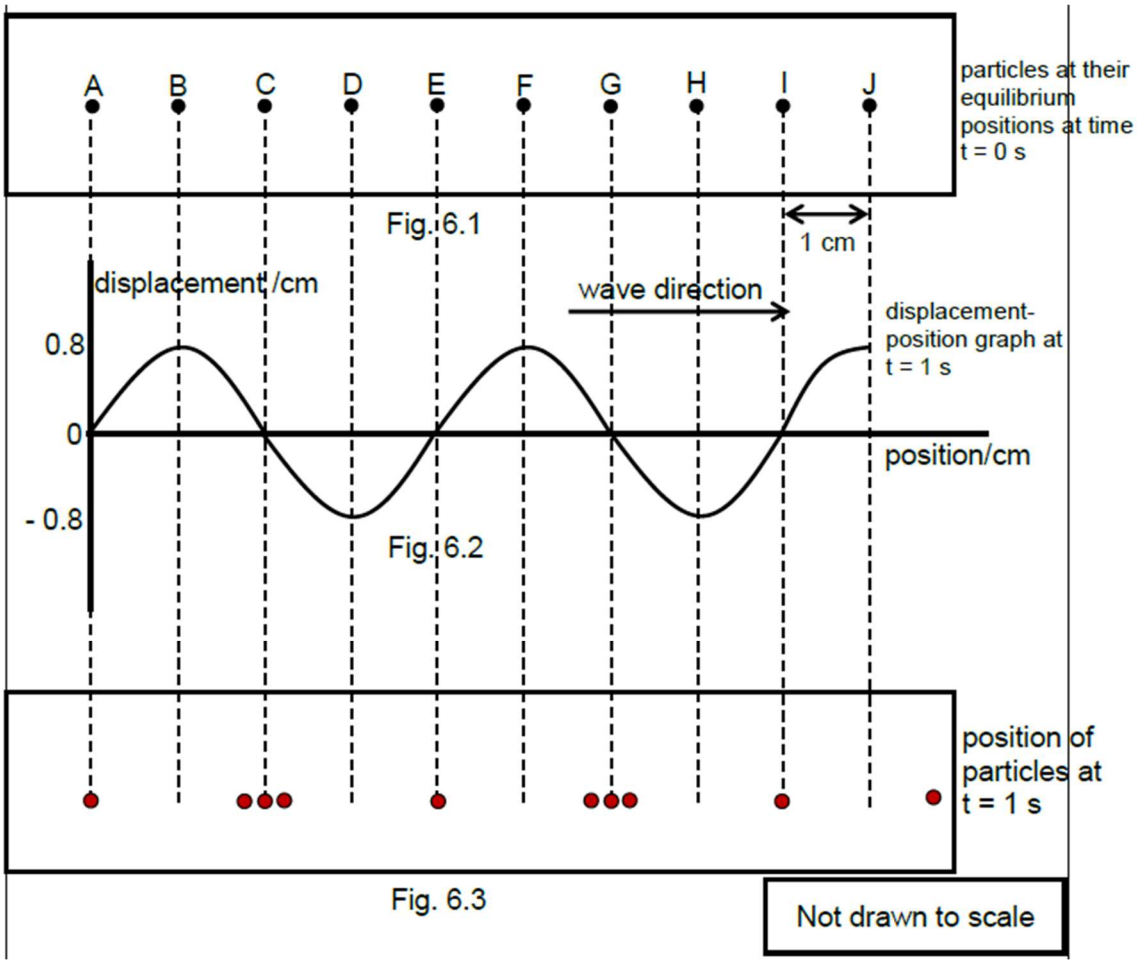


Fig. 6.1

Fig. 6.2

Fig. 6.3

[1]

(a) Mark the positions of the particles A – J at the time t = 1 s in the space provided in Fig. 6.3 with reference to the displacement - position graph shown in Fig. 6.2. [1]

(b) With reference to your answer to (a) which particle(s) is/are at the

(i) centre of compression,

particle(s) C and G [1]

(ii) centre of rarefaction.

particle(s) A, E and I [1]

(c) If the speed of the wave is 340 m s-1, find the period.

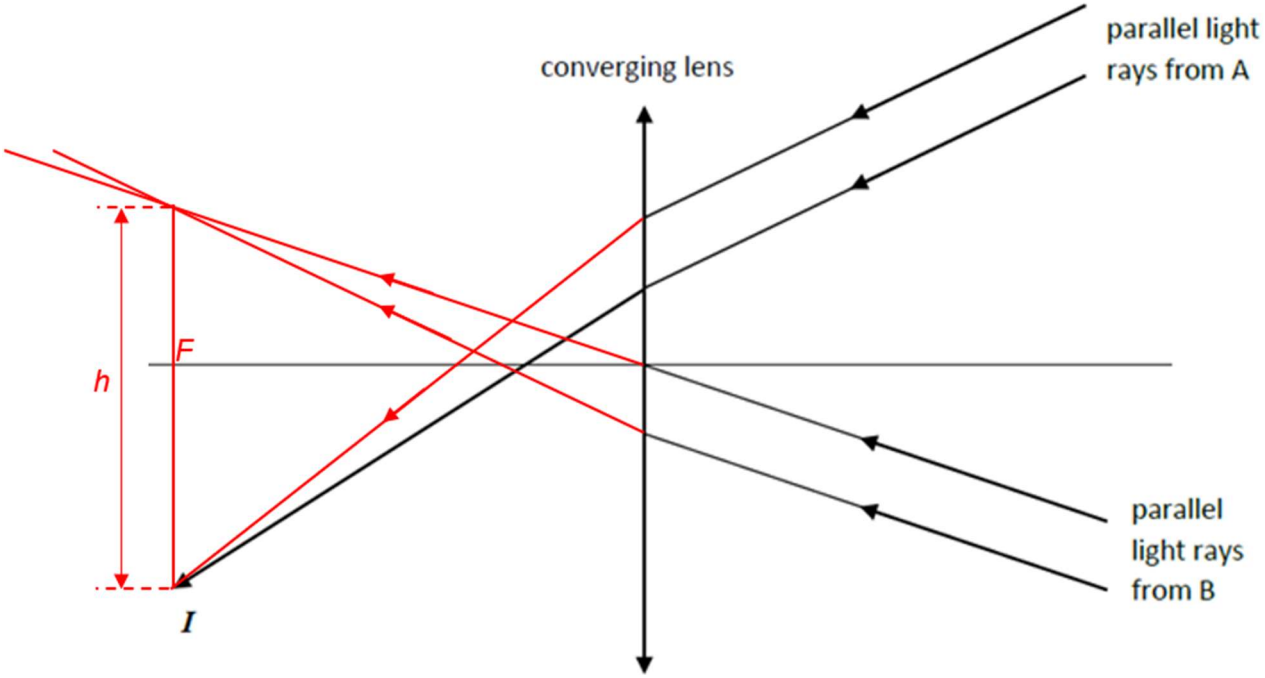
$T = \lambda / v$

$= (4/100) / 340$ [1]

$= 1.18 \times 10^{-4}$ s [1]

OR use $v = f \lambda$ and $T = 1/f$

7 Fig. 7.1 shows a converging lens. Parallel rays of light from point A which is from the top of a distant building is brought to a focus at *I*. Parallel rays of light from another point B which is from the bottom of the same building is incident on the lens as shown. One of the ray from A is refracted as shown.



(a) Complete the rays from A and B on Fig. 7.1 to show how the image is formed. [2]

(b) Indicate on Fig 7.1 the height of the image with letter *h* and principal focal point with the letter *F*. [2]

8 LASER is the acronym for Light Amplification by Simulated Emission of Radiation.

Table 8.1 shows different brands of laser guns for industrial use and their specific wavelengths. All laser guns emit electromagnetic waves.

An enthusiastic laser user sorts out the different brands of laser guns into Types I, II and III. He also discovers that the Red Beam laser gun emits a bright, red light.

Table . 8.1

Type	brand of laser gun	wavelength / x 10^{-7} m
I	Trace	3.2
II	Eagle Eye	4.9
	Fire Fly	5.5
	Red Beam	6.3
III	Sparrow Beak	9.8

(a) State the type of electromagnetic waves emitted by Type I, Type II and Type III laser guns in the electromagnetic spectrum respectively.

Type I : ultraviolet radiation
Type II : visible light
Type III : infrared radiation

2 correct [1], all correct [2]

(b) State and explain which brand(s) of the laser guns listed in Table 8.1 can be used in a vacuum environment?

All the brands can be used in vacuum [1]
as all electromagnetic waves can travel in vacuum. [1]

9 Fig. 9.1 shows a coil of wire wound on a soft iron core. A current is passed through the coil in the direction indicated by the arrows.

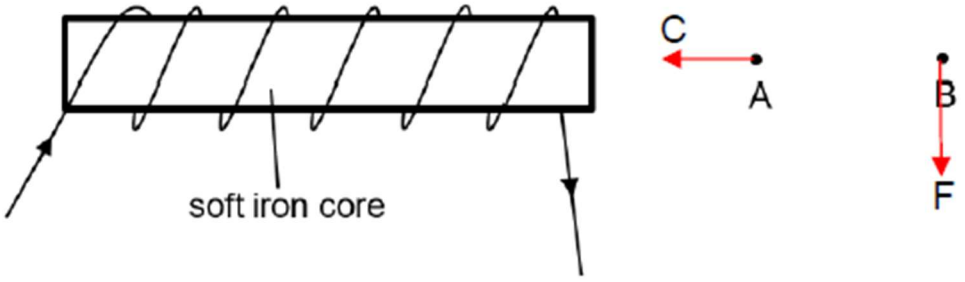


Fig. 9.1

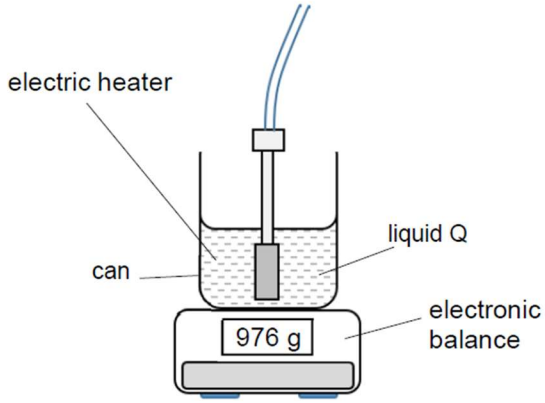
(a) Show by drawing an arrow, the direction in which the north end of a compass needle would point when placed at position A in Fig. 9.1. Label the arrow C. [1]

(b) A beam of electrons flows through the point B in a direction that is perpendicularly downwards into the paper.

Show clearly by an arrow labelled F, the direction of the force exerted by the magnetic field on the electron beam. [1]

(c) Explain how you determine the direction indicated in **(b).**
Using Fleming's Left-Hand rule, the fore finger which indicates magnetic field, points to the left. [1]
The middle finger which indicates conventional current (flow of positive charges), points perpendicularly out of the plane of the paper and the thumb which indicates the force, points down. [1]

10 Fig. 10.1 shows an experimental set up that can be used to calculate the specific heat capacity and specific latent heat of vaporisation of a liquid Q. Energy is continuously provided by a 100 W electric heater to liquid Q. The temperature and electronic balance readings are recorded at regular intervals of time.



power of electric heater = 100 W

mass of empty can = 100 g

mass of liquid Q and can = 976 g

specific latent heat of vaporisation of liquid Q = 330 kJ/kg

Fig. 10.1

Fig. 10.2 shows how the total mass (mass of can + mass of liquid Q) changes with time.
Fig. 10.3 shows how temperature of liquid Q changes with time.

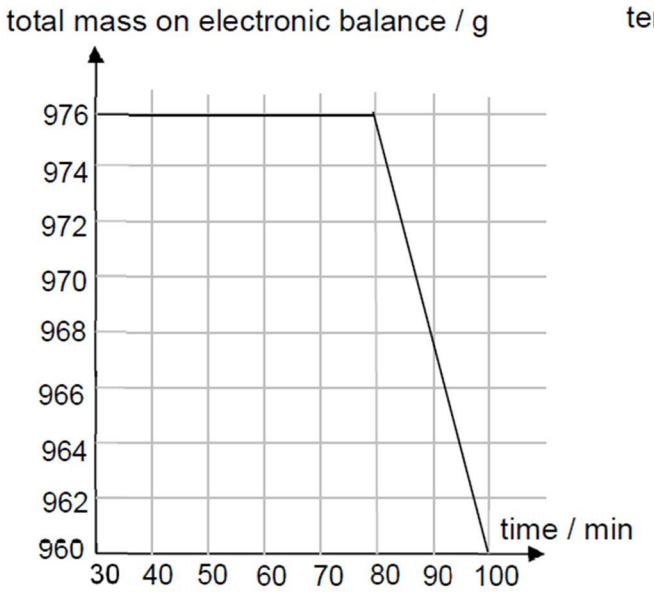


Fig. 10.2

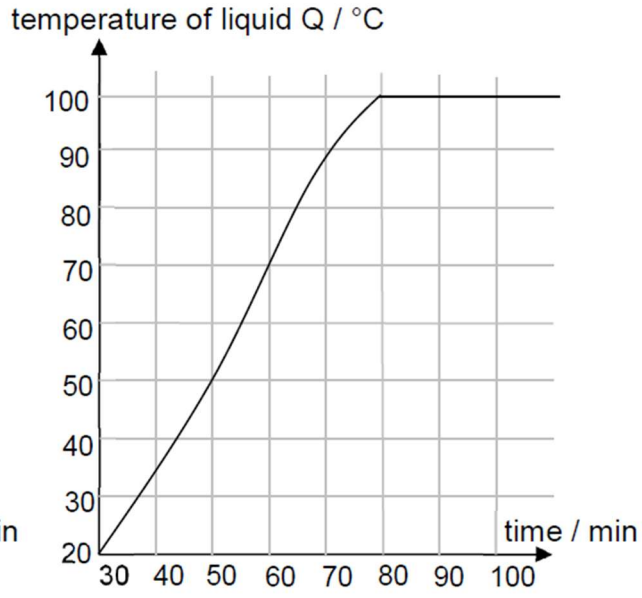


Fig. 10.3

(a) Define *specific latent heat of vaporisation*.

The energy needed to change unit mass of substance from liquid to gas (or vice versa) without a change in temperature. [1]

(b) **(i)** Calculate the amount of energy supplied by the heater from 30 minutes to 80 minutes.

energy supplied = Pt
= 100 x (80-30) (60) [1]
= 3.0×10^5 J [1]

energy supplied = ... [2]

(ii) Given that 60 000 J of energy is transferred from the experimental set up to the surroundings from 30 minutes to 80 minutes, calculate the specific heat capacity of the liquid Q. Assume the can has negligible specific heat capacity.

Energy supplied by heater = energy gained by liquid Q + energy transferred to surrounding

$3.0 \times 10^5 = mc\Delta\theta + Pt$ [1]

$3.0 \times 10^5 = \frac{976-100}{1000}$ (c)(100-20) + 60 000 [1]

C = 3424.66 J/ (kg ºC)
= 3420 J/ (kg ºC) 93sf) [1]

specific heat capacity of liquid Q = ... [3]

(iii) With reference to your calculation in (b)(ii), explain whether the value of the specific heat capacity of liquid Q calculated is higher or lower than the actual specific heat capacity of the liquid if specific heat capacity of the can is not negligible.
The calculated value is higher than the actual value. [1]
Part of the energy from the heater is transferred to the container, thus less energy is transferred to the liquid. The actual value of c for Q is lower than the above calculated value. [1]

(c) **(i)** Calculate the amount of thermal energy needed to boil off liquid Q from 80 minutes to 100 minutes.

energy needed to boil = ml_V

$= \frac{976-960}{1000}$ $(330 \times 10^3) = 5.28 \times 10^3$ J [1]

energy = ... [1]

(ii) The mass of the liquid remains relatively constant from 0 minutes to 80 minutes. The rate of evaporation is hence insignificant. Suggest why the rate of evaporation is insignificant.
- The humidity in the room is high
- Liquid Q has low volatility
- Small exposed surface area
- Lack of air flow/wind (Any one)

11 Fig. 11.1 shows a radioactive source used to measure and control the thickness of cardboard during manufacture.

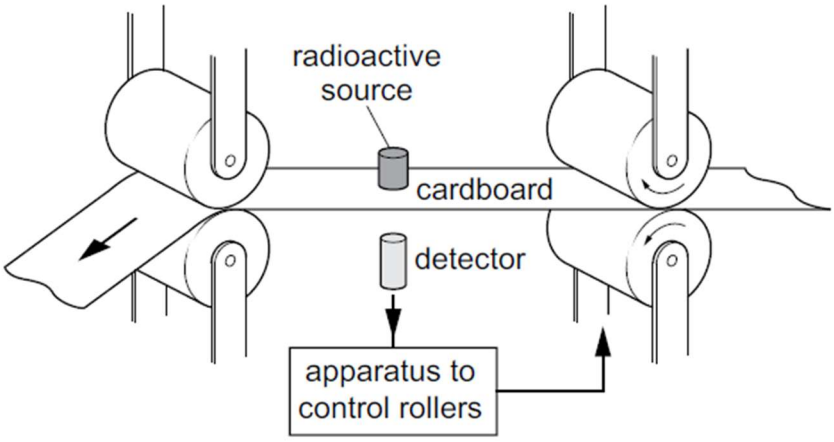


Fig. 11.1

(a) Some radioactive sources emit alpha-particles, some beta-particles and some gamma radiation.

Explain why emission count of alpha-particles and gamma radiation are not suitable for the application shown in Fig. 11.1.

Alpha-particles cannot penetrate through the cardboard and the detector will not measure any count. [1]

Gamma radiation penetrates through the cardboard easily, so the detector will not measure any difference in counts regardless of the cardboard thickness. [1]

(b) Strontium-90 is an isotope used in the radioactive source in Fig. 11.1.

A nucleus of strontium-90 emits a beta-particle as it decays.

(i) The radioactive decay of a nucleus is a random and spontaneous process.

Explain what is meant by a random decay.

time between emissions is unpredictable
or emission can occur at any time / in any direction [1]

(ii) In nuclide notation, strontium-90 is written as $^{90}_{38}Sr$.
When a nucleus of strontium-90 emits a beta-particle (β), it decays to an isotope of yttrium (Y).

Complete the decay equation below for this decay.

$$^{90}_{38}Sr \longrightarrow {}^{90}_{39}Y + {}^{0}_{-1}\beta$$

(iii) Beta decay can be considered as the decay of a neutron to a proton and an electron.

Explain how the composition of the nuclei of the strontium and yttrium isotopes illustrates this statement.

beta-particle is an electron [1]
Sr nucleus contains 52 neutrons and 38 protons and Y 51 neutrons and 39 protons [1]

(c) The half-life of strontium-90 is 29 years.

(i) Suggest why a radioactive source with a half-life of millions of years is unsuitable for use in the apparatus shown in Fig. 11.1.

source dangerous for a long time / after the apparatus is scrapped / out of use or the activity of this source would be low [1]

(ii) A pure source of strontium-90 emits 1.6×10^5 beta-particles per second.

Calculate the number of beta-particles emitted per second by the source after 87 years.

any attempt at halving e.g. 160 000 → 80 000 or 3 half-lives seen [1]

20 000 [1]

number of particles per second = ……[2]

End of Section A

Section B

Answer **one** question from this section.

12 Two light bulbs (A and B) are at their normal brightness when each is connected to a 3 V battery. The graph in Fig. 12.1 shows how the current varies with the applied voltage (potential difference) for each bulb.

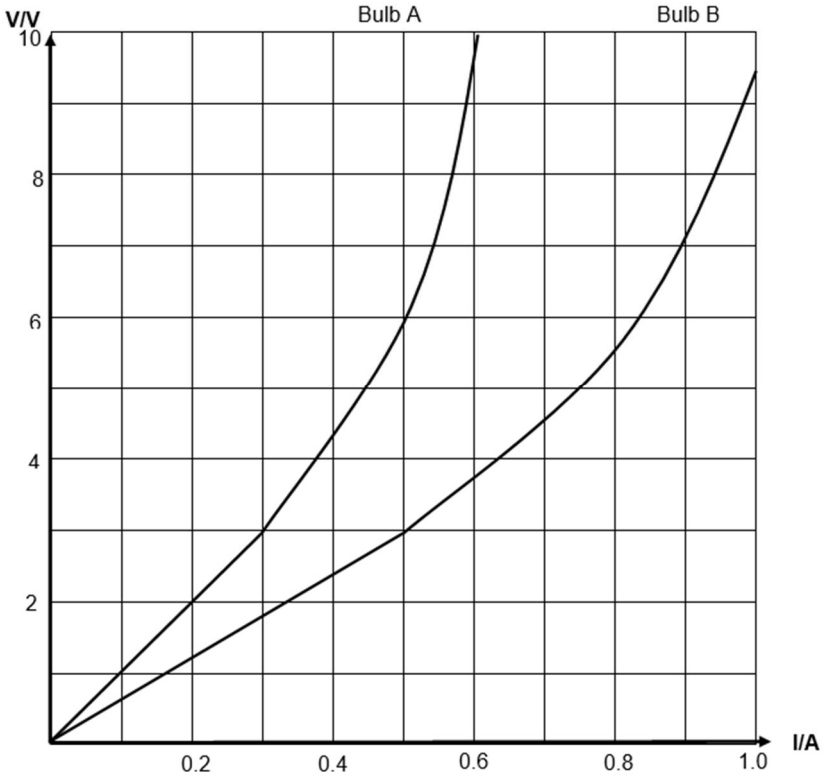


Fig. 12.1

(a) **(i)** Explain the shape of the V-I graph of bulb A.

The graph is linear at low voltages as the bulbs have constant resistance. [1]
As the potential difference increases, the temperature of the bulb increases causing the resistance to increase, thus the V-I becomes a curve with increasing gradient. [1]

(ii) Determine the resistance of each bulb when they are operating at normal brightness.

Resistance of A = 3 / 0.3 = 10 ohm [1]
Resistance of B = 3 / 0.5 = 6 ohm [1]

resistance of bulb A = …… , resistance of bulb B = ……..…[2]

(b) A pupil studying potential dividers sets up the circuit as shown in Fig. 12.2 using bulb A.

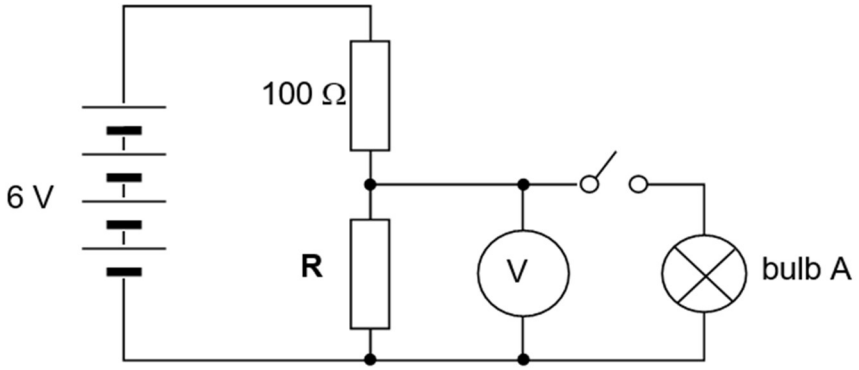


Fig. 12.2

When the switch is open the voltmeter shows a reading of 3.5 V.

(i) Calculate the value of R.

$$\frac{R}{R+100}(6)=3.5 \quad [1]$$

R = 140 Ω [1]

R = ... [2]

(ii) Explain why the reading shown on the voltmeter decreases.

When the switch is closed, the total resistance connected in parallel will be less than the original R value. [1]
The ratio of the effective resistance R and the bulb to the total resistance decreases and thus the voltage reading will drop. [1]

(iii) Suggest and explain how the circuit can be modified so that it can be used in a temperature sensor which lights up when placed in a very hot environment.

The 100 ohm resistor should be replaced by a **NTC thermistor.** [1]
As temperature increase, the thermistor's resistance decreases which increase the potential difference across the bulb leading to its lighting up. [1]

13 Fig 13.1 represents a typical transformer. When a primary voltage V_P is applied across the

primary coil, a secondary voltage V_S occurs in the secondary coil.

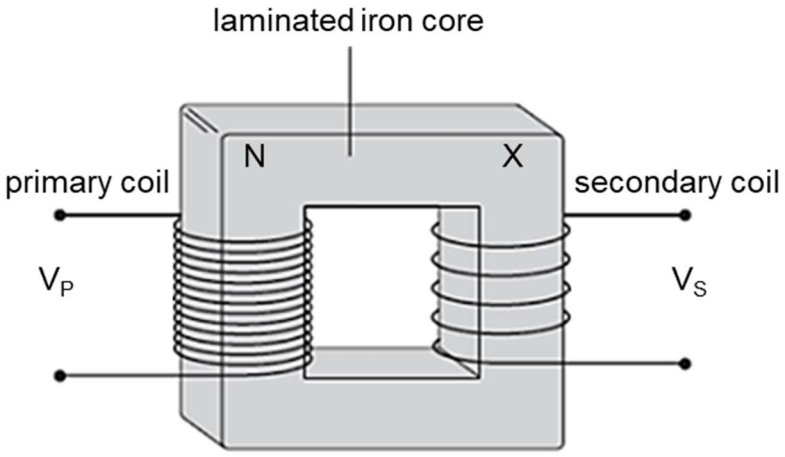


Fig. 13.1

(a) (i) Explain how current can flow in the secondary coil when V_P is applied even though there is no electrical contact between the primary and secondary coil.

The primary coil alternating current causes a changing magnetic flux to cut the secondary coil, which induces an emf in the secondary coil. [1]

(ii) Explain why the secondary voltage V_S is reduced when the number of turns in its secondary coil is reduced.

Faraday's Law states that the magnitude of the emf induced is proportional to the rate of change of magnetic flux. When the number of turns are reduced, the amount of magnetic flux cutting the coil is reduced. [1]

(iii) Fig 13.1 shows an instant when the current in the primary coil produces a N pole above the coil. State the pole that is formed at X above the secondary coil at this instant. Explain how you obtained your answer.

N pole formed at X. [1]
Lenz's Law states that the emf generated in the secondary coil would be in a direction to oppose the magnetic field from the primary coil that is causing the emf induction. [1]

(b) A remote village is supplied with electrical energy from a power station some distance away by power cables as shown in Fig. 13.2 below. At the village, a transformer steps down the potential difference from 10,000 V to 250 V.
R represents the net resistance of the electrical circuits in the village. The mean rate of supply of electrical energy to the village is 400 kW.

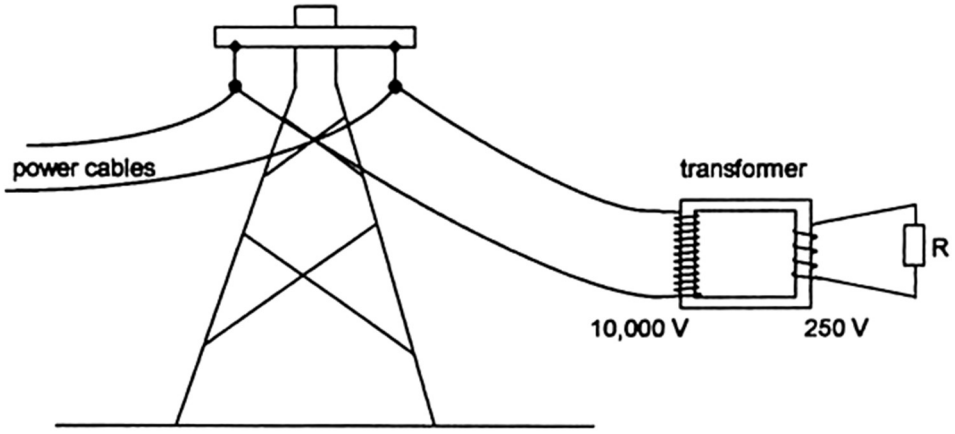


Fig. 13.2

(i) Explain why a high voltage of 10,000 V is used to transmit the electrical power.
The voltage transmitted is high so that the current flowing through the power cables is small [1].
As a result, the energy lost due to the resistance of the cable is reduced. [1]

(ii) Calculate the current flowing in the secondary coil of the transformer. Hence calculate the current in the primary coil assuming that the transformer is 100% efficient.
Current I_s = P/ V
= 400 000/ 250
= 1600 A [1]
Pin = Pout
$V_p I_p$ = 400000
I_p = 400 000 / 10 000 = 40 A [1]
current in secondary coil = ……. , current in primary coil = ……[2]

(iii) If the power cables have a resistance of 25 Ω, calculate the rate at which energy is lost in the power cables. Hence, deduce the power the cables must draw from the power station, in order to deliver 400 kW of electrical power to the village.
Power loss = $I^2 R$ = 40^2 x 25 = 40 000 W
= 40 kW [1]

Power input from station = 400 + 40
= 440 kW [1]
rate = ……. , power = ……[2]