Cambridge International AS & A Level

Cambridge Assessment International Education
Cambridge International Advanced Subsidiary and Advanced Level

CANDIDATE NAME: Solved

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4156563837

PHYSICS **9702/21**

Paper 2 AS Level Structured Questions **October/November 2019**

1 hour 15 minutes

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your centre number, candidate number and name 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, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

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.

This document consists of **15** printed pages and **1** blank page.

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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	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{m\,F^{-1}})$
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 unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
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	$W = p\Delta V$
gravitational potential	$\phi = -\frac{Gm}{r}$
hydrostatic pressure	$p = \rho gh$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0{}^2 - x^2)}$
Doppler effect	$f_o = \frac{f_s v}{v \pm v_s}$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy of charged capacitor	$W = \frac{1}{2}QV$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
Hall voltage	$V_H = \frac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

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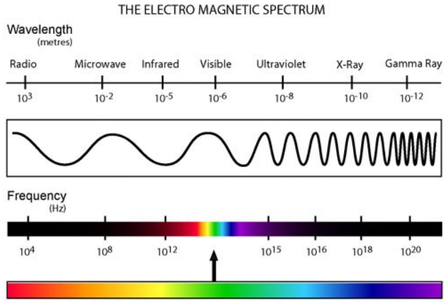


Answer **all** the questions in the spaces provided.

1 **(a)** Make estimates of:

(i) the mass, in g, of a new pencil

mass = ...1...... g [1]

(ii) the wavelength of ultraviolet radiation.

wavelength = ...1×10^{-8}...... m [1]

(b) The period T of the oscillations of a mass m suspended from a spring is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where k is the spring constant of the spring.

The manufacturer of a spring states that it has a spring constant of $25\,\mathrm{N\,m^{-1}} \pm 8\%$. A mass of $200 \times 10^{-3}\,\mathrm{kg} \pm 4 \times 10^{-3}\,\mathrm{kg}$ is suspended from the end of the spring and then made to oscillate.

(i) Calculate the period T of the oscillations.

$2\pi\sqrt{\frac{200\times10^{-3}}{25}} = 0.5619$
≈ 0.56

T = ...0.56...... s [1]

(ii) Determine the value of T, with its absolute uncertainty, to an appropriate number of significant figures.

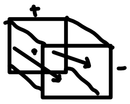
% uncertainty mass = $\frac{4\times10^{-3}}{200\times10^{-3}} \times 100 = 2\%$

% uncertainty T = $\frac{8+2}{2} = 5\%$

Absolute uncertainty = $0.56 \times \frac{5}{100} = 0.028095 \approx 0.03$

T = ...0.56...... ± ......0.03...... s [3]

[Total: 6]



2 A small charged glass bead of weight 5.4×10^{-5} N is initially at rest at point A in a vacuum. The bead then falls through a uniform horizontal electric field as it moves in a straight line to point B, as illustrated in Fig. 2.1.

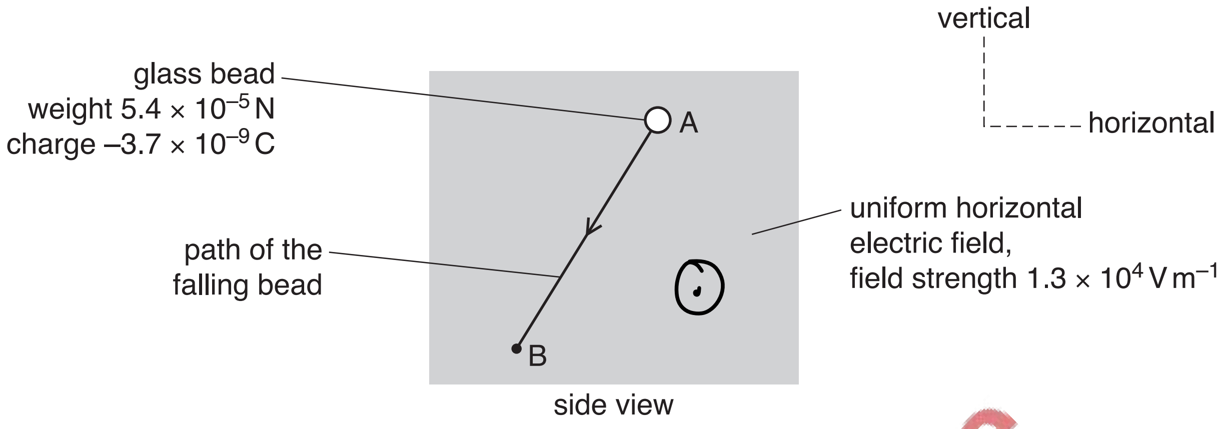
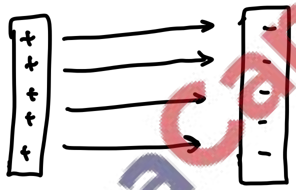


Fig. 2.1 (not to scale)

The electric field strength is 1.3×10^{4} V m^{-1}. The charge on the bead is -3.7×10^{-9} C.

(a) Describe how two metal plates could be used to produce the electric field. Numerical values are not required.



To produce the electric two metallic plates must be setup verticaly with seperation, the left plate must be positively charged & the right plate negetively charged. [2]

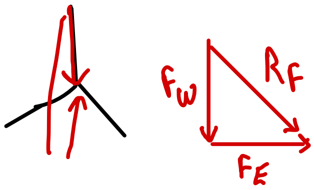
(b) Determine the magnitude of the electric force acting on the bead.

$E = \frac{F}{q}$ $\quad F = 1.3 \times 10^{4} \times -3.7 \times 10^{-9}$

$F = 4.81 \times 10^{-5}$

electric force = 4.8×10^{-5} N [2]

(c) Use your answer in **(b)** and the weight of the bead to show that the resultant force acting on it is 7.2×10^{-5} N.



$R_F^2 = F_W^2 + F_E^2$

$R_F = \sqrt{(5.4 \times 10^{-5})^2 + (4.81 \times 10^{-5})^2}$

$= 7.23 \times 10^{-5}$ N

$\approx 7.2 \times 10^{-5}$ N

[1]

(d) Explain why the resultant force on the bead of 7.2×10^{-5} N is constant as the bead moves along path AB.

Since the electric field is uniform the force due to the electric force will be constant, since the weight also does not change, the resultant force will be constant.

[2]

(e) **(i)** Calculate the magnitude of the acceleration of the bead along the path AB.

$F = ma$ $\qquad m = \frac{W}{g}$

$7.2 \times 10^{-5} = \frac{5.4 \times 10^{-5}}{9.81} \times a$

$a = 13.08$

$\approx 13\ ms^{-2}$ (2sf)

acceleration = 13 ms^{-2} [2]

(ii) The path AB has length 0.58 m.

Use your answer in **(i)** to determine the speed of the bead at point B.

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

$v^2 = 2 \times 13.08 \times 0.58$

$v = 3.895\ ms^{-1}$

$\approx 3.9\ ms^{-1}$

speed = 3.9 ms^{-1} [2]

[Total: 11]

3 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm.
Fig. 3.1 is a side view of the aircraft when hovering.

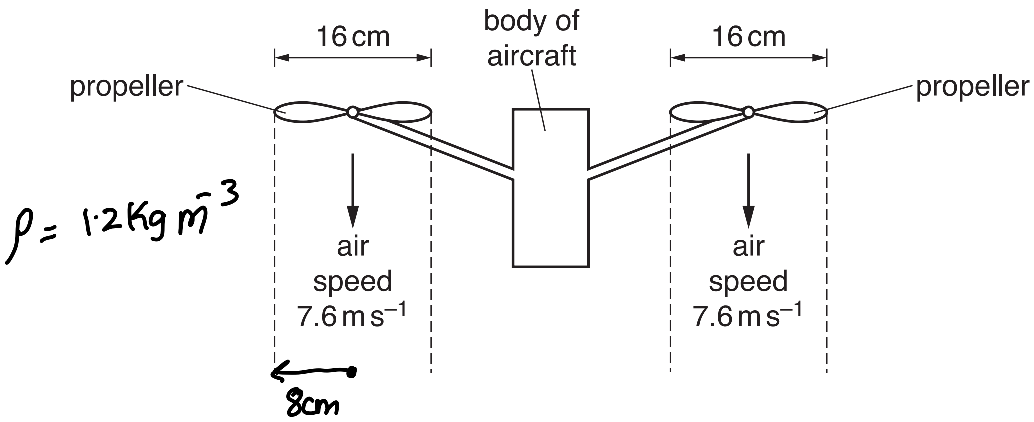


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,kg\,m^{-3}$. Assume that the air from each propeller moves with a constant speed of $7.6\,m\,s^{-1}$ in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

(a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

length of cylinder (air column) in 3sec = $7.6 \times 3 = 22.8$ m

volume of cylinder = $\pi r^2 \times L$

$= \pi (8 \times 10^{-2})^2 \times 22.8$

$\approx 0.4584\ m^3$

Density = $\dfrac{mass}{volume}$

mass = $1.2 \times 0.4584 \approx 0.55$ Kg

[3]

(b) Calculate:

(i) the increase in momentum of the mass of air in **(a)**

momentum = m x v

$0.55 \times 7.6 = 4.18$

increase in momentum = ...4.2.......... Ns [1]

(ii) the downward force exerted on this mass of air by the propeller.

$F = \dfrac{\text{change in mometum}}{\text{time}} = \dfrac{4.18}{3} = 1.393 \approx 1.4\,N$

force = ...1.4 N.......... N [1]

(c) State:

(i) the upward force acting on **one** propeller

force = 1.4 N [1]

(ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

Newtons third law of motion [1]

(d) Determine the mass of the aircraft.

Upward force by 2 propelers = 1.2 × 2 = 2.8 N

Hovering ∴ upward force = Downward force
∴ 2.8 N = weight

$$\text{mass} = \frac{2.8}{9.81} = 0.285$$

mass = 0.29 kg [1]

(e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

Density of air is less at higher altitudes.

[1]

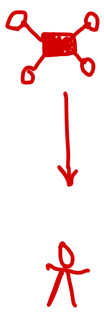
(f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of 22 m s^{-1}, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is 340 m s^{-1}.

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

$$f_o = \frac{3000 \times 340}{340 - 22} = 3207.54$$

$$\approx 3200 \text{ Hz}$$

$$f_o = \frac{f_s v}{v \pm v_s}$$



Drone approaching source,

waves more dense
∴ F ↑ so denominator lower
hence " – " sign

frequency = 3200 Hz [2]

[Total: 11]

4 The variation with extension x of the force F applied to a spring is shown in Fig. 4.1.

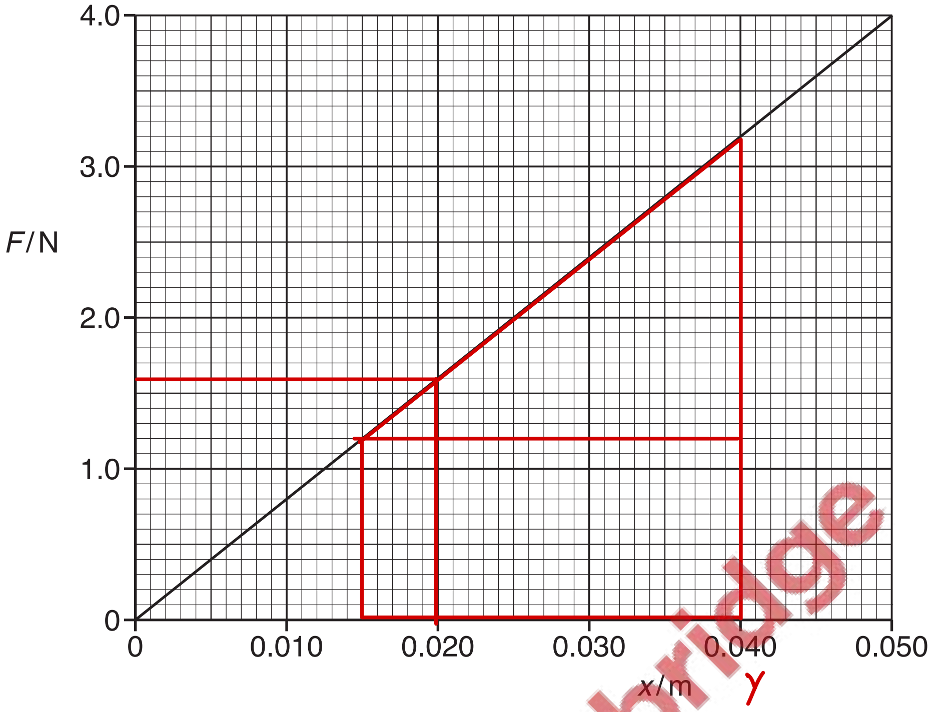


Fig. 4.1

The spring has an unstretched length of 0.080 m and is suspended vertically from a fixed point, as shown in Fig. 4.2.

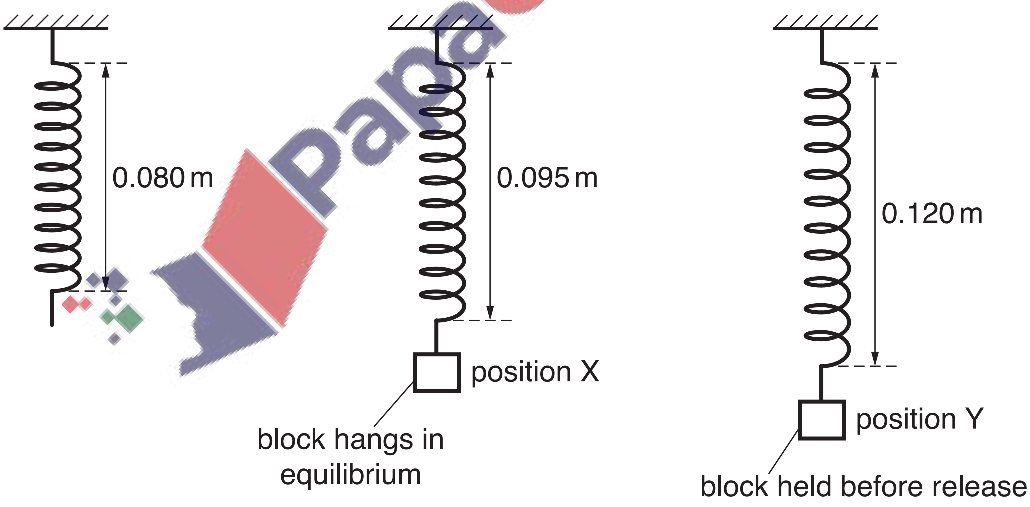


Fig. 4.2 **Fig. 4.3** **Fig. 4.4**

A block is attached to the lower end of the spring. The block hangs in equilibrium at position X when the length of the spring is 0.095 m, as shown in Fig. 4.3.

The block is then pulled vertically downwards and held at position Y so that the length of the spring is 0.120 m, as shown in Fig. 4.4. The block is then released and moves vertically upwards from position Y back towards position X.

(a) Use Fig. 4.1 to determine the spring constant of the spring.

$F = Kx$

$K = \frac{F}{x} = \frac{1.6}{0.020} = 80$

spring constant = ...80.......... $N m^{-1}$ [2]

(b) Use Fig. 4.1 to show that the decrease in elastic potential energy of the spring is 0.055 J when the block moves from position Y to position X.

extension at position Y = 0.120 - 0.080 = 0.04

extension at position X = 0.095 - 0.080 = 0.015

Energy change = area under graph = $(1.2 \times (0.04 - 0.015)) + (\frac{1}{2} \times (0.04 - 0.015) \times 2)$

= 0.055 J

[2]

(c) The block has a mass of 0.122 kg. Calculate the increase in gravitational potential energy of the block for its movement from position Y to position X.

$\Delta P_E = mg\Delta h$

$= 0.122 \times 9.81 \times (0.04 - 0.015)$

$= 0.0299 \approx 0.030$

increase in gravitational potential energy = ...0.030.......... J [2]

(d) Use the decrease in elastic potential energy stated in **(b)** and your answer in **(c)** to determine, for the block, as it moves through position X:

↑ Elastic PE

↓ gravitational PE

(i) its kinetic energy

KE = 0.055 − 0.030

kinetic energy = ...0.025.......... J [1]

(ii) its speed.

$0.025 = \frac{1}{2} \times 0.122 \times V^2$

$V = 0.64 \ ms^{-1}$

speed = ...0.64.......... $m s^{-1}$ [2]

[Total: 9]

5 A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 5.1.

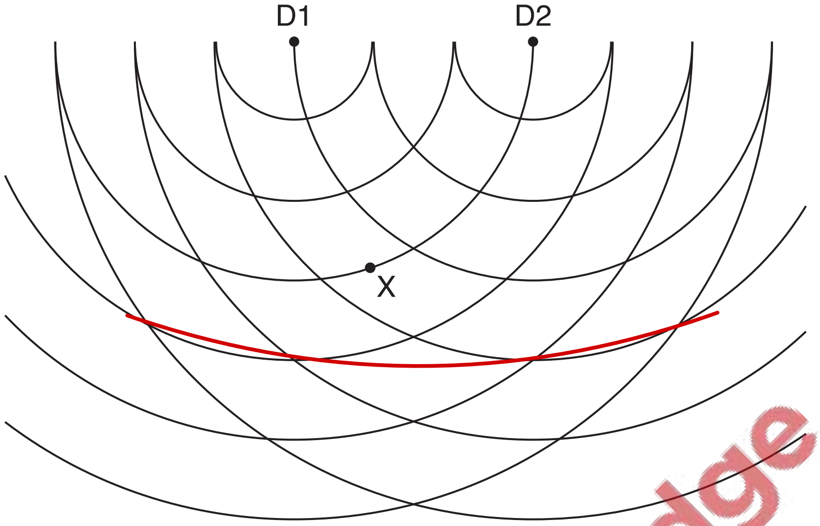


Fig. 5.1

The lines in the diagram represent crests. The waves have a wavelength of 6.0 cm.

(a) One condition that is required for an observable interference pattern is that the waves must be coherent.

(i) Describe how the apparatus is arranged to ensure that the waves from the dippers are coherent.

dippers connected to the same motor

.... [1]

(ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

they have simillar amplitudes

.... [1]

(b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

Use a stroboscope

.... [1]

(c) The speed of the waves is 0.40 m s^{-1}. Calculate the period of the waves.

$V = f\lambda$

$f = \frac{0.40}{6 \times 10^{-2}} = \frac{20}{3}$

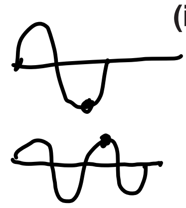
$f = \frac{1}{T} \quad \therefore T = \frac{3}{20} = 0.15$

period = ...0.15...... s [2]

(d) Fig. 5.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X, state:

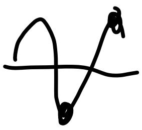
(i) the path difference, in cm



Π (½ Wave) $= \frac{\lambda}{2} = \frac{6}{2} = 3$

path difference = ...3.0...... cm [1]

(ii) the phase difference.



$\Pi = 180'$

Ans in degrees

phase difference = ...180'...... ° [1]

(e) On Fig. 5.1, draw **one** line, at least 4 cm long, which joins points where only maxima of the interference pattern are observed. [1]

[Total: 8]

6 **(a)** Define *electric potential difference* (*p.d.*).

The amount of work done per unit positive charge to bring it from infinity to a point. [1]

(b) The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 6.1.

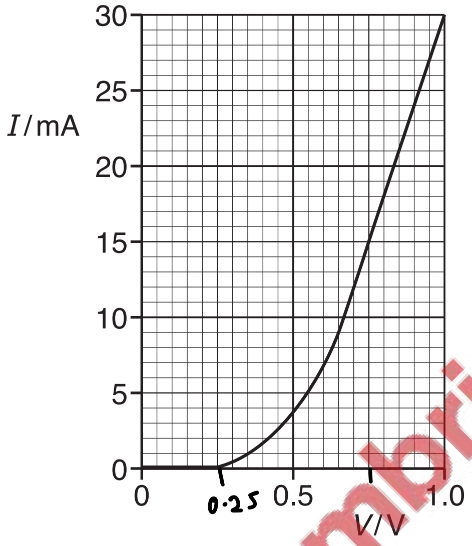


Fig. 6.1

$V = IR$

$R = \frac{V}{I}$

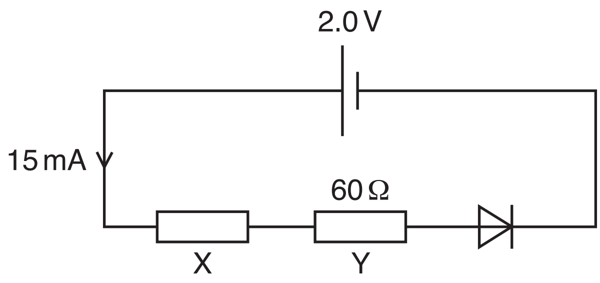
$\frac{0.20}{0} = \infty$

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as V increases from 0 to 1.0 V.

for voltages less than 0.25 V the Resistance is infinite as current is 0. For voltages more than 0.25 V the resistance decreases as I ↑ R ↓

[2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.



$V = IR$

Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

In series current is constant = 15mA

∴ V is diode = 0.75 V (from graph)

$R = \frac{V}{I} = \frac{0.75}{15\times10^{-3}} = 50\ \Omega$

resistance = ...50...... Ω [3]

(ii) Calculate:

1. the resistance of X

$2 = (15\times10^{-3}\times60) + (50\times15\times10^{-3}) + (R\times15\times10^{-3})$

$R = 23.3\ \Omega$

$\approx 23\ \Omega$

$V = IR$

$P = VI$

$P = I^2R$

resistance = ...23...... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

$= \frac{(15\times10^{-3})^2\times60}{2\times(15\times10^{-3})} = 0.45$

ratio = ...0.45...... [2]

[Total: 11]

  [Turn over

7 (a) The decay of a nucleus ${}^{35}_{18}Ar$ by β^+ emission is represented by

$${}^{35}_{18}Ar \rightarrow X + \beta^+ + Y.$$

A nucleus X and two particles, β^+ and Y, are produced by the decay.

State:

(i) the proton number and the nucleon number of nucleus X

proton number = 17

nucleon number = 35
[1]

(ii) the name of the particle represented by the symbol Y.

neutrino [1]

(b) A hadron consists of two down quarks and one strange quark.

Determine, in terms of the elementary charge e, the charge of this hadron.

↓ quark charge = $-1/3$

s quark charge = $-1/3$

$-\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1$

charge = $-1e$ [2]

[Total: 4]