Class	Index Number	Name
20S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2021
Preliminary Examination

PHYSICS, Higher 2

9749/02

Paper 2 Structured Questions

13th September 2021
2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, 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	/ 10
3	/ 8
4	/ 6
5	/ 13
6	/ 8
7	/ 6
8	/ 22
Total	/ 80

This document consists of **25** printed pages including this page.

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,	$\phi = -\dfrac{Gm}{r}$
temperature,	$T/\text{K} = T/{}^{\circ}\text{C} + 273.15$
pressure of an ideal gas,	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas 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.,	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{x_0^2 - x^2}$
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,	$\lambda = \dfrac{\ln 2}{t_{1/2}}$

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

1 Experimental measurements of the gravitational constant G in different years are shown in the table.

Year	G / $m^3 kg^{-1} s^{-2}$
2000	$(6.674215 \pm 0.00009) \times 10^{-11}$
2007	$(6.67234 \pm 0.00014) \times 10^{-11}$
2009	$(6.67349 \pm 0.00017) \times 10^{-11}$

(a) State the year in which the measurement of G appears to be the most precise. Explain your answer.

....

.... [1]

(b) The value of G was determined in 2010 at the University of Zurich. The value was consistent with the value obtained in the 2007 experiment but was not consistent with the values from 2000 or 2009. The experimenter who obtained the value for G in 2010 thinks that there is probably a systematic error in each of the other two experiments.

(i) Explain what is meant by a *systematic error*.

....

.... [1]

(ii) Explain why the most precise result may not be the most accurate.

....

....

.... [2]

(c) In year 2009, experimental measurements were made of the mass of Earth, mass of Moon, and the gravitational force between Earth and Moon.

mass of Earth, M	$5.972 \times 10^{24} \pm 1\%$ kg
mass of Moon, m	$7.348 \times 10^{22} \pm 2\%$ kg
gravitational force between Earth and Moon, F	$(1.98 \pm 0.02) \times 10^{20}$ N

The distance between the centres of Earth and moon, R, is estimated to be around 3.844×10^{8} m.

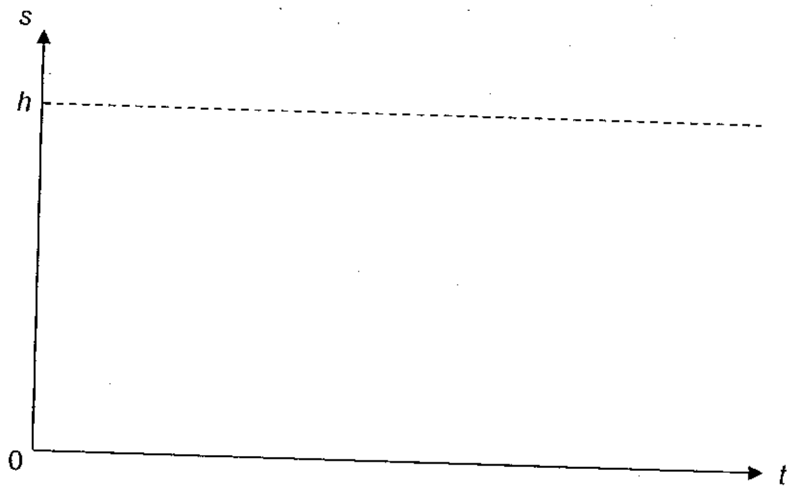
Express R and its actual uncertainty ΔR. Show your working clearly.

$R \pm \Delta R$ = ... ± .... m [3]

2 (a) A ball is released from rest a distance h above a rigid horizontal surface and it rebounds along its original path inelastically.

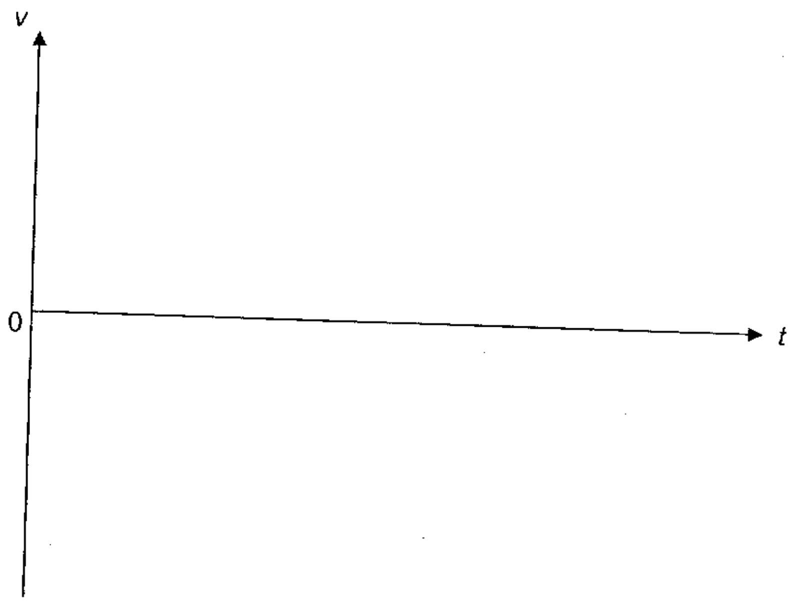
Taking air resistance as negligible and downwards as positive, sketch on the axes provided, for at least 2 bounces, its corresponding graph representing the variation with time t of

(i) its displacement, s



[2]

(ii) its velocity, v



[2]

(b) When the ball is released at height h above the ground, it reaches the ground with speed 3.8 m s^{-1}. The ball is then in contact with the floor for a time of 0.081 s before leaving it with speed 1.7 m s^{-1}. The mass of the ball is 0.062 kg.

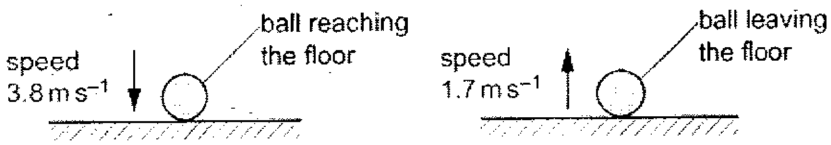


Fig. 2.1

(i) Calculate height h.

h = ... m [1]

(ii) Calculate the magnitude of the average force the ground acts on the ball during the collision.

magnitude of the average force = ... N [2]

(c) Two parallel metal plates, each of length 20.0 cm, are separated by 10.0 cm, as illustrated in Fig. 2.2 below that is not drawn to scale.

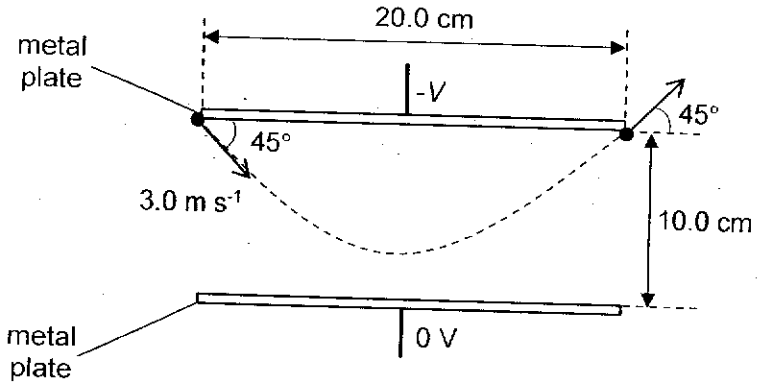


Fig. 2.2

The plates are in a vacuum.

A small ball bearing of charge $+4.4 \times 10^{-7}$ C and mass 1.0×10^{-4} kg with an initial speed 3.0 m s^{-1} enters the plates at an angle of 45° below the horizontal, and just leave the plates at an angle of 45° above the horizontal, as shown in Fig. 2.2.

Calculate the potential V of the plate at the top.

V = ... V [3]

3 **(a)** A photon of wavelength 940.0×10^{-12} m collides with an isolated stationary electron, as illustrated in Fig. 3.1.

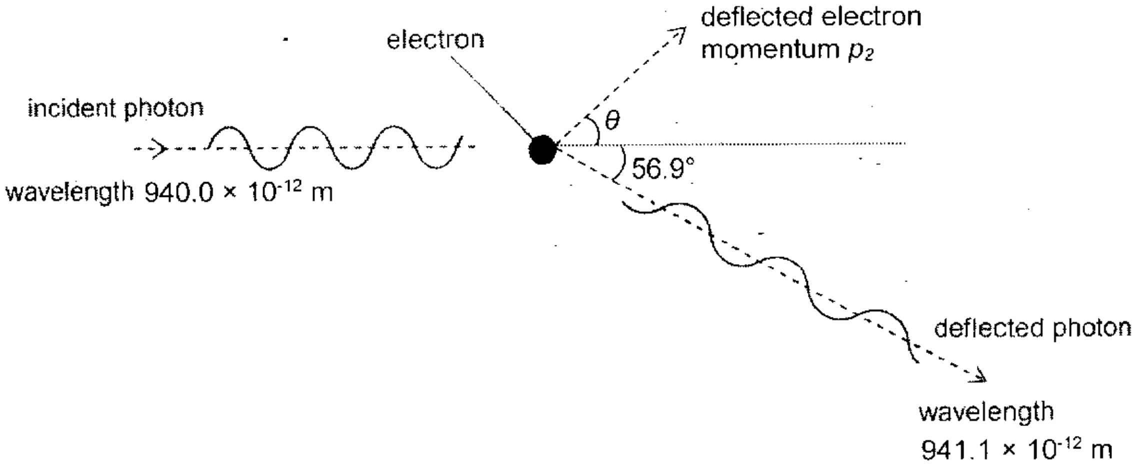


Fig. 3.1

The photon is deflected elastically by the electron.
The wavelength of the deflected photon is 941.1×10^{-12} m.

(i) Without making any calculations, sketch in the space below a vector triangle to show conservation of momentum. Label the triangle with the initial momentum p_1 of incident photon, the final momentum p_2 of electron, and the final momentum p_3 of the deflected photon.

[2]

(ii) Calculate the final momentum p_3 of the deflected photon.

p_3 = ... N s [1]

(iii) Calculate the kinetic energy of the deflected electron.

kinetic energy = ... J [2]

(iv) Using your answer in **(a)(i)**, or otherwise, determine p_2 and θ.

p_2 = ... N s

θ = ... ° [3]

4 **(a)** Define the *moment* of a force about a point.

....

.... [1]

(b) A fishing rod AB is shown in Fig. 4.1.

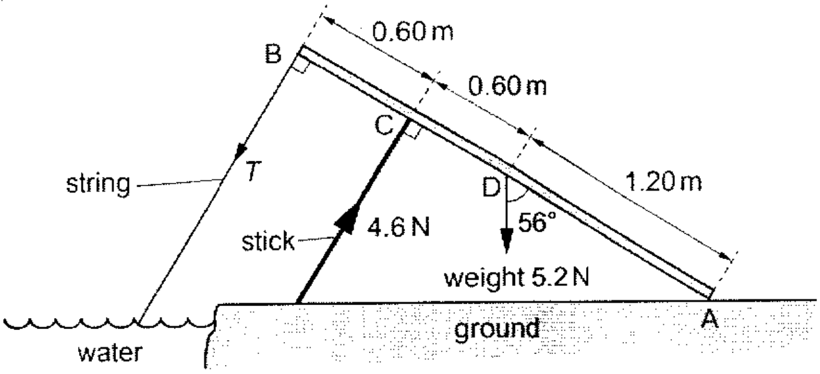


Fig. 4.1

End A of the rod fixed to the ground and a string is attached to the other end B. A support stick exerts a force perpendicular to the rod at point C. The weight of the rod acts at point D.

The tension T in the string is in a direction perpendicular to the rod. The rod is in equilibrium and inclined at an angle of 56° to the vertical.

The forces and the distances along the rod of points A, B, C and D are shown in Fig. 4.1.

(i) Calculate the tension T.

T = ... N [2]

(ii) Calculate the magnitude of the force acting on the rod at point A. State the angle of its direction with respect to the *rod*.

magnitude = ... N

angle = ... ° [3]

5 **(a)** A battery of electromotive force (e.m.f.) 12.0 V and internal resistance *r* is connected to a filament lamp and a resistor, as shown in Fig. 5.1.

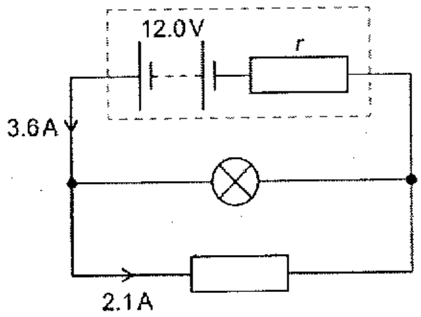


Fig. 5.1

The current in the battery is 3.6 A and the current in the resistor is 2.1 A. The *I*-*V* characteristic for the lamp is shown in Fig. 5.2.

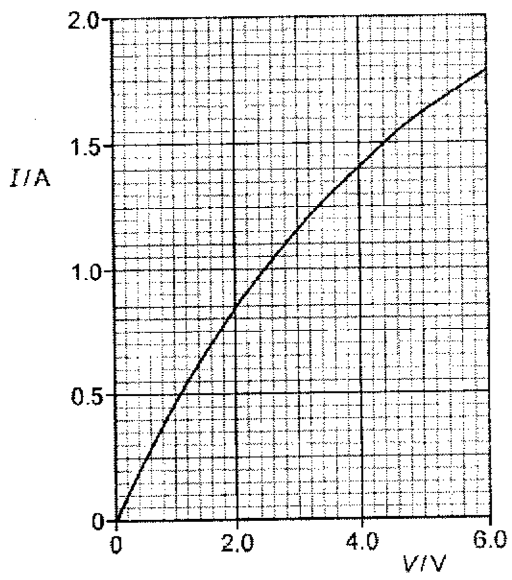


Fig. 5.2

(i) Explain, with reference to the graph, whether the resistance of filament lamp increases or decreases with increasing potential difference.

....

....

....

.... [2]

(ii) Determine the internal resistance r of the cell in Fig. 5.1.

internal resistance = ... Ω [3]

(iii) The filament wire of the lamp is connected in series with the adjacent copper connecting wire of the circuit, as illustrated in Fig. 5.3.

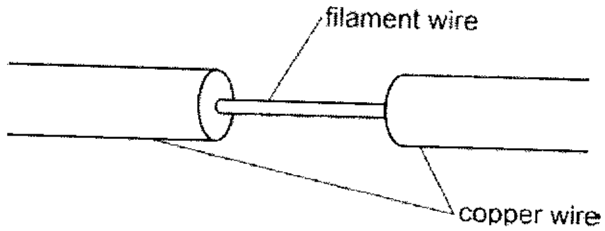


Fig. 5.3

Some data for the filament wire and the adjacent copper connecting wire are given in the table below.

	filament wire	copper wire
cross-sectional area	A	$360A$
number density of free electrons	n	$2.5n$

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire}}{\text{average drift speed of free electrons in copper wire}}.$$

ratio = ... [1]

(b) Two identical filament lamps are connected first in series, and then in parallel, to a 12 V power supply that has negligible internal resistance.

The circuits are shown in Fig. 5.4 & Fig. 5.5 respectively.

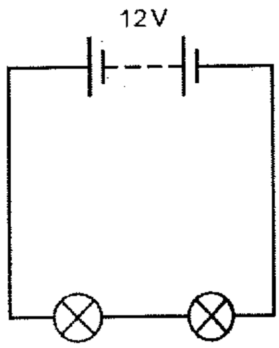


Fig. 5.4

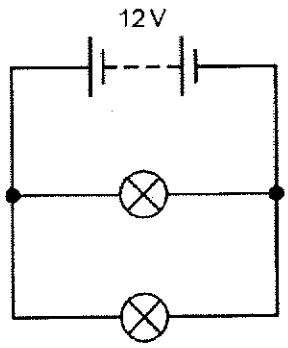


Fig. 5.5

Explain why, after some time, the resistance of each lamp when they are connected in series is different from the resistance of each lamp when they are connected in parallel.

....

....

....

....

....

.... [3]

(c) A potentiometer is setup as shown in Fig. 5.5. A resistive wire of 1.0 m is connected between point B and point D.

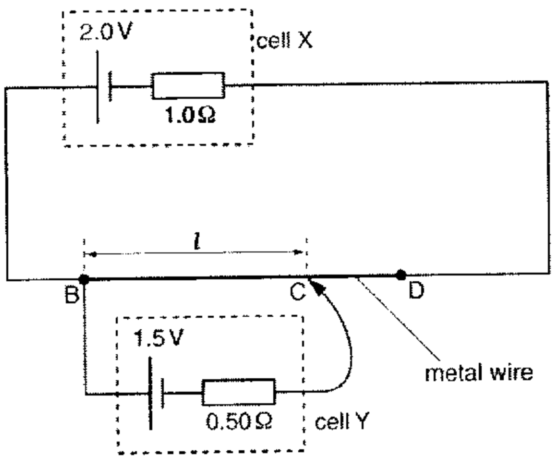


Fig. 5.5

When the length l is set at 93.75 cm, the current in cell Y is zero.

Two resistors are added to the potentiometer circuit, as shown in Fig. 5.6.

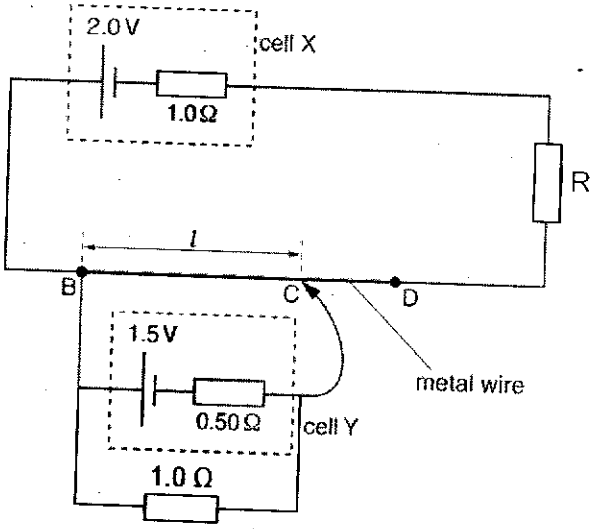


Fig. 5.6

Calculate the value of R such that the balance point of the circuit will be at point D.

R = ... Ω [4]

6 (a) Sound waves travel from a source S to a point X along two paths SX and SPX, as shown in Fig. 6.1.

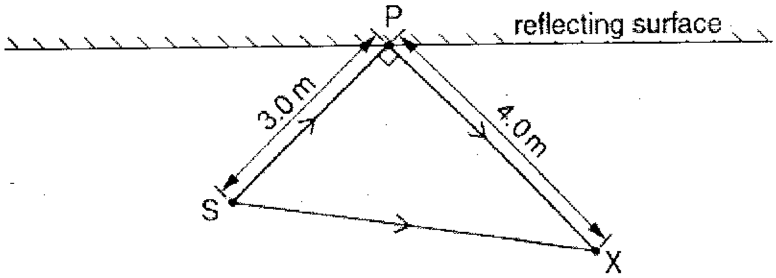


Fig. 6.1

(i) The frequency of the sound from S is 400 Hz and the speed of sound in air is 320 m s^{-1}. Calculate the wavelength of the sound waves.

wavelength = ... m [1]

(ii) The distance SP is 3.0 m and the distance PX is 4.0 m. The angle SPX is 90°.

Suggest whether a maximum or a minimum is detected at point X if there is a phase change of π of the sound wave upon reflection on the surface. Explain your answer.

....

....

.... [2]

(b) A laser produces a narrow beam of coherent light of wavelength 632 nm. The beam is incident normally on a diffraction grating, as shown in Fig. 6.2.

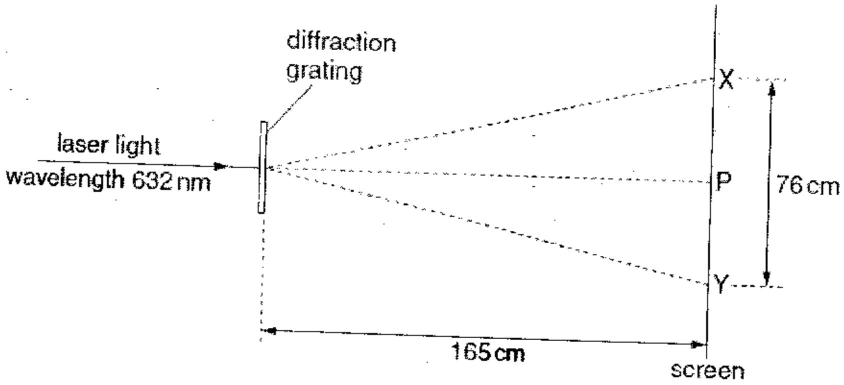


Fig. 6.2

Spots of light are observed on a screen placed parallel to the grating. The distance between the grating and the screen is 165 cm.

The brightest spot is P. The spots formed closest to P and on each side of P are X and Y. X and Y are separated by a distance of 76 cm.

(i) Calculate the number of lines per metre on the grating.

number per metre = ... [2]

(ii) The grating is now rotated about an axis parallel to the incident laser beam, as shown in Fig. 6.3.

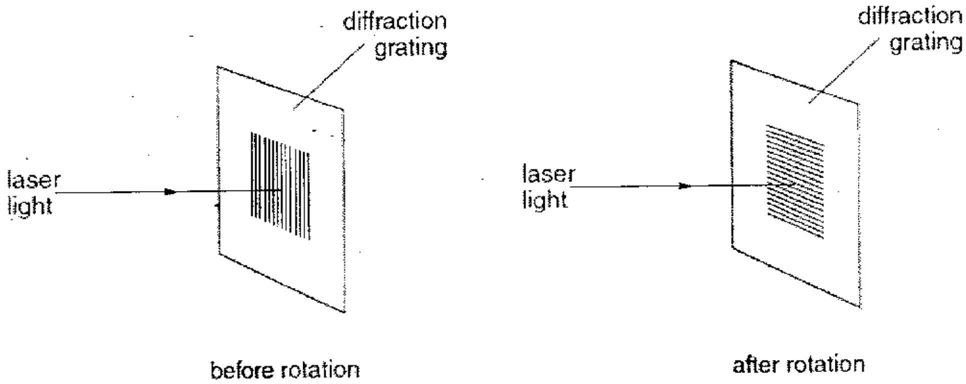


Fig. 6.3

State what effect, if any, this rotation will have on the positions of the spots P, X and Y.

....

....

.... [2]

(c) In another experiment using the apparatus in **(b)**, a student notices that the distances XP and PY, as shown in Fig. 6.1, are not equal.

Suggest a reason for this difference.

....

.... [1]

7 A helium-neon laser produces light of wavelength 633nm. The laser is placed behind a glass microscope slide that has been painted black. A single vertical slit of width 0.0800mm has been produced by scratching through the paint with a razor blade.

Light from the laser passes through the slit and hits a white wall at a distance of 5.12m from the slit. A patch of red light is formed on the screen. On both sides of this central patch there are smaller, less intense patches.

A light sensor connected to a data logger is moved across the screen and the distance moved by the light sensor and the intensity of the light is recorded. Fig. 7.1 is the intensity-distance graph generated.

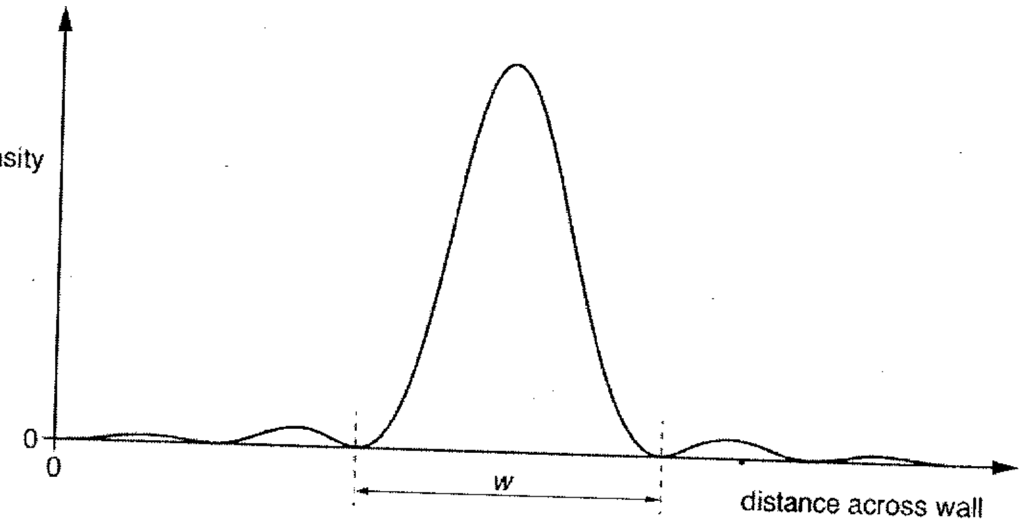


Fig. 7.1

The width w of the central patch is equal to the distance between the two minimum points on either side of the central patch where the intensity of red light is equal to zero.

(a) Show that w is 0.0810 m wide.

[2]

(b) A second vertical slit of width 0.0800mm is scratched across the slide. The second slit is parallel to the first and its centre is a horizontal distance of 0.240mm away from the centre of the first slit.

The microscope slide now acts as a double slit. At the centre of the double-slit interference pattern on the wall, there are bright and dark fringes which are uniformly spaced.

(i) Some parts of the screen that were brightly lit when only the first slit was present are now dark, even though light is still passing through the first slit in the same way.

Explain what causes this to happen.

....

....

.... [1]

(ii) Determine the separation x of the bright fringes.

x = ... m [1]

(iii) Most of the bright fringes are separated from adjacent bright fringes by a distance x. In a few places, away from the centre, however, there is no light in a position where a bright fringe is expected.

Using the results from **(a)** and **(b)(ii)**, explain why there is no light at such places.

....

....

....

.... [2]

8 The magnitude of the rate of flow of heat $\frac{dQ}{dt}$ through a length d of material from a higher temperature T_1 to a lower temperature T_2 can be modelled by the following equation:

$$\frac{dQ}{dt} = kA\frac{T_1 - T_2}{d}$$

where k is a constant called the thermal conductivity of the material, and A is the cross-sectional area of the material. A simple experimental setup shown in Fig. 8.1 can be used to verify the model, using a cylindrical metal bar as the material under test.

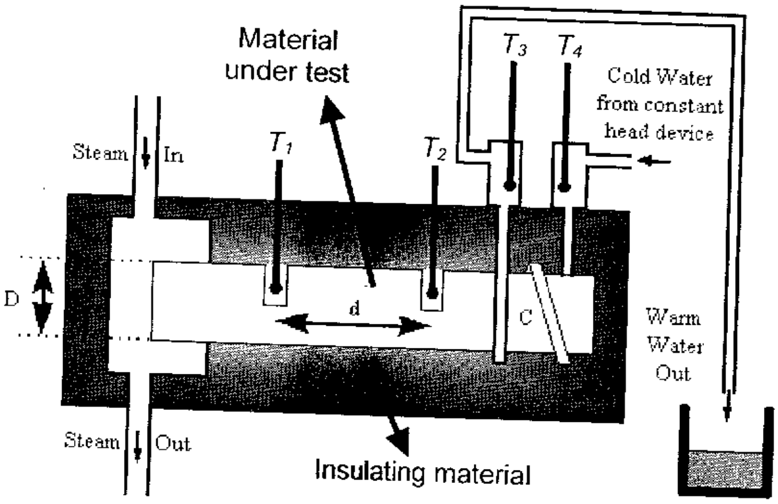


Fig. 8.1

Heat flows from the left end of the material at 100 °C, through the material and out from the right end, carried away by the flowing water. Cold water flows in at a temperature T_4 = 30.0 °C and flows out at a temperature T_3 = 32.5 °C at a rate of 0.186 kg min^{-1}. The specific heat capacity of water is 4200 J K^{-1} kg^{-1}.

When the temperatures have stabilized, the variation of temperature with distance from the hot end is shown in Fig. 8.2.

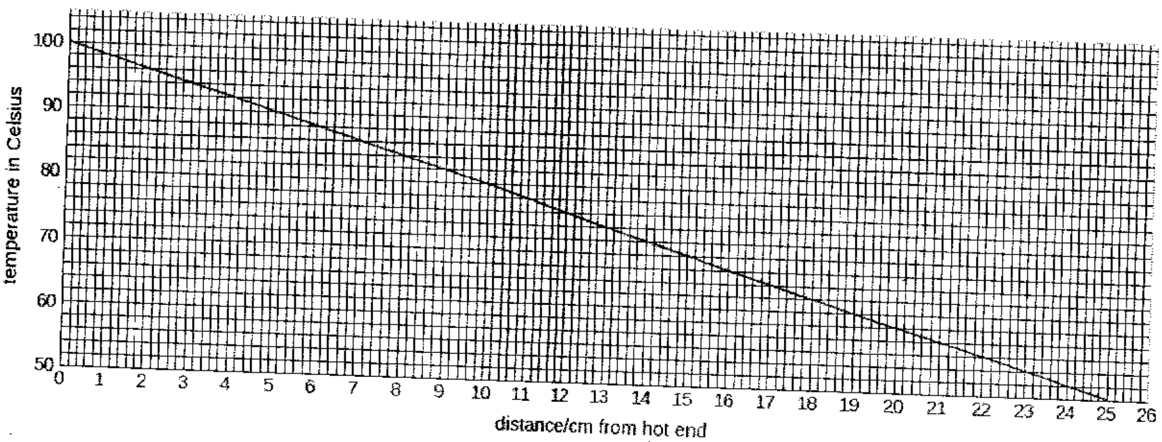


Fig. 8.2

(a) State the SI unit for k.

unit = ... [1]

(b) Calculate the rate of heat flow through the metal bar.

rate of heat flow = ... J s^{-1} [2]

(c) Given that the diameter of the cylindrical metal bar is 3.00 cm, calculate the thermal conductivity of the metal bar. Express your numerical answer in standard SI unit.

thermal conductivity = ... SI unit [3]

(d) **(i)** Draw on Fig. 8.2 another graph if the cross-sectional area of the metal bar decreases with distance from the hot end to the cold end, as shown in Fig. 8.3.

Label this line (i). [1]

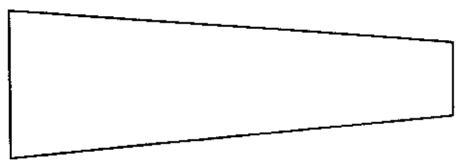


Fig. 8.3

(ii) The insulating material is now removed from the uniform metal bar in Fig. 8.1.

Draw another graph on Fig. 8.2 to show how the temperature varies with distance from the hot end to the cold end.

Label this line (ii). Explain the shape of your graph.

....

....

.... [2]

(iii) The same experimental setup cannot be used for an insulating material by directly substituting the metal bar with a wooden bar.

Explain why and suggest an improvement to allow the thermal conductivity of a piece of wood to be measured.

....

....

....

.... [2]

(e) Ice at 0 °C fills up the entire volume of a cylindrical container as shown in Fig. 8.4. The container is suspended from a support using insulating material.

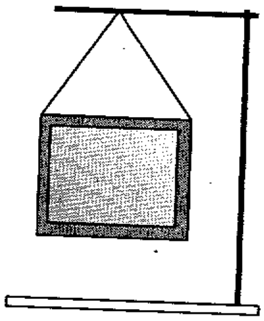


Fig. 8.4

Temperature of the room	= 30 °C
Internal diameter of container	= 20.0 cm
Height of ice in container	= 16.0 cm
Thickness of wall of container	= 2.00 cm
Density of ice	= 917 kg m^{-3}
Specific latent heat of ice	= 3.35×10^5 J kg^{-1}
Thermal conductivity of container wall	= 2.50 in standard SI unit

(i) Calculate the quantity of ice that has melted in the container in 120 s. State the assumption you have made in your calculations.

mass of ice melted = ... kg [4]

(ii) Heat energy can also be absorbed by radiation from surrounding objects that are at higher temperatures.

The magnitude of the rate of heat absorbed by radiation is given by the formula

$$\frac{dQ}{dt} = (5.7 \times 10^{-8})(A)(T_{room}^4 - T_{ice}^4),$$

where A is the total area of the container and T_{room} and T_{ice} are the thermodynamic temperatures of the room and ice.

Calculate the rate of radiation energy absorption. Comment on your answer.

....

.... [3]

(iii) In order to reduce rate of heat lost to the surrounding, a double-glazed wall is used. The wall consists of 2 material layers with a layer of air in between. The thermal conductivity of air is 0.024 in standard SI unit.

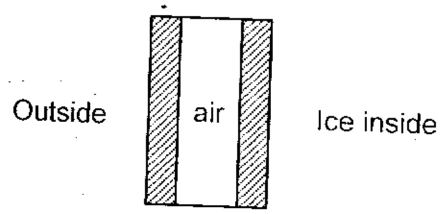
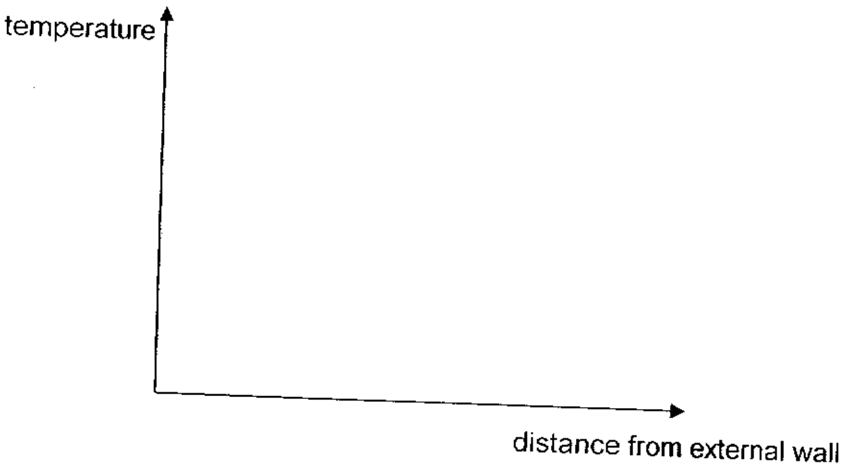


Fig. 8.5

Sketch a graph of temperature variation across the double-glazed wall. [2]



(iv) Increasing the thickness of the air layer can enhance the heat insulation up to a point. Suggest why this is the case.

....

....

.... [2]

End of paper

Solution for 2021 SAJC Prelim Paper 2

1 **(a)** The result from the 2000 experiment. It has the smallest range of uncertainty. (accept smallest uncertainty / error) [1]

(b) **(i)** An error which results in values being always higher or always lower than expected / true value. [1]

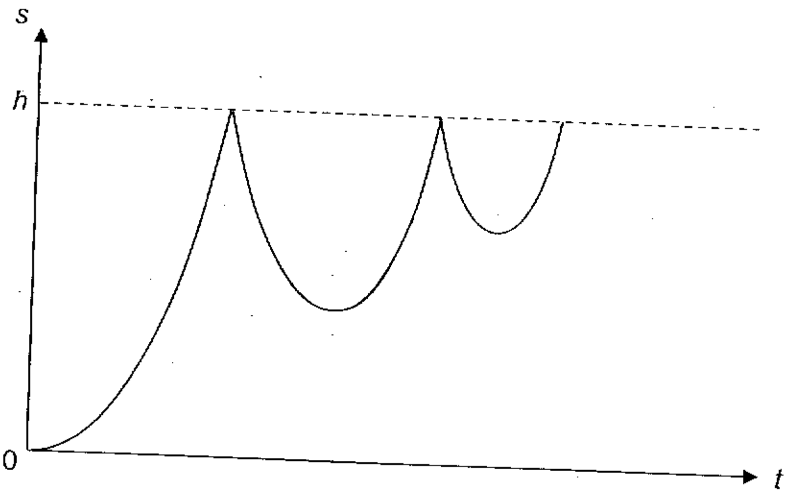
(ii) There might be systematic errors in this experiment [1]
which would shift the result away from the true value (without affecting the precision of the measurement.) [1]

(c) $F = GMm / R^2$
Making R the subject, $R = (GMm / F)^{½}$

Using 2009 results for G & fractional uncertainty method,
$\Delta R / R = ½ (0.00017 / 6.67349 + \Delta M / M + \Delta m / m + \Delta F / F)$ [1]
$\Delta R / (3.844 \times 10^8) = ½ (0.00017 / 6.67349 + 0.01 + 0.02 + 0.02 / 1.98)$

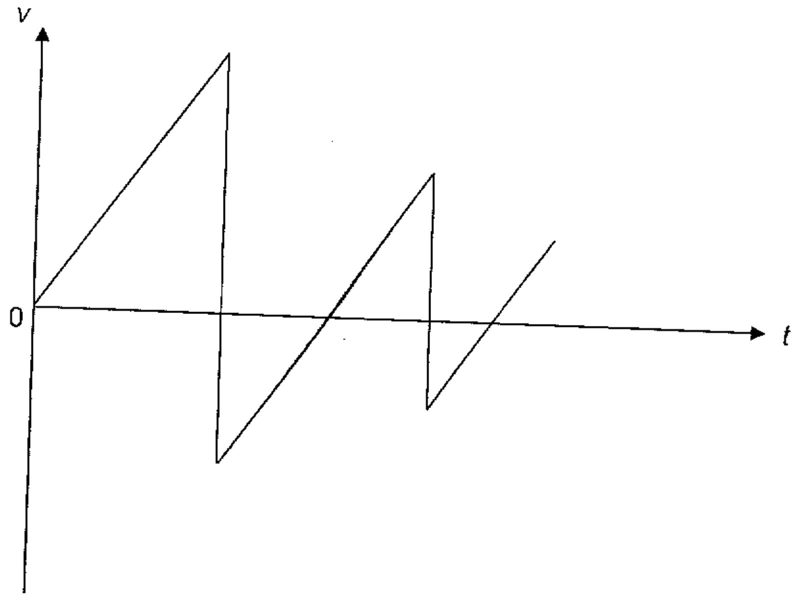
$\Delta R = 0.08 \times 10^8$ m (1 sf) [1]
$R \pm \Delta R = (3.84 \pm 0.08) \times 10^8$ (correct dp for R) [1]

2 (a) (i)



Shape (including the duration interval is decreasing) and start from 0 [2]

(ii)



Shape [1]
Decreasing peak [1]

(b) (i) $mgh = \frac{1}{2} mv^2$

$h = (\frac{1}{2})(3.8^2) / (9.81) = 0.736$ m [1]

(ii) Using Newton's 2nd Law, average *net* force $= \Delta p / \Delta t$

$= (0.062)(1.7 + 3.8) / 0.081$

$= 4.2$ N [1]

Average force ground acts on ball $= 4.2 + mg$

$= 4.8$ N [1]

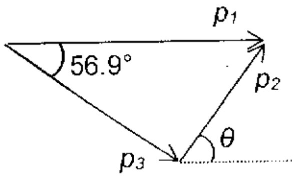
(c) Horizontally, $(3.0 \cos 45°)(t) = 0.20$
$t = (0.20) / (3.0 \cos 45°)$ [1]

Vertically, $(3.0 \sin 45°) = (-3.0 \sin 45°) + (a)[(0.20) / (3.0 \cos 45°)]$ [1]
$a = 45 \text{ m s}^{-2}$

$q(V / d) - mg = ma$
$(4.4 \times 10^{-7})(V / 0.10) - (1.0 \times 10^{-4})(9.81) = (1.0 \times 10^{-4})(45)$

Solving, $V = -1250 \text{ V}$ [1]

3 (a) (i)



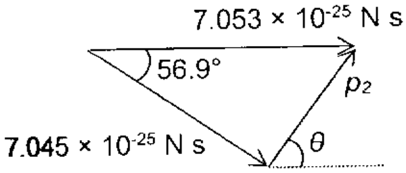
Correct triangle with label and directions [1]
At least 1 angle indicated if correct triangle [1]

(ii) $p_3 = h / \lambda = (6.63 \times 10^{-34}) / (941.1 \times 10^{-12}) = 7.04 \times 10^{-25}$ [1]

(iii) Energy of photon = hc / λ [1]

KE of electron = $hc / (940.0 \times 10^{-12}) - hc / (941.1 \times 10^{-12}) = 2.47 \times 10^{-19}$ [1]

(iv)



Calculating p_1 correctly (i.e. $p_1 = 7.053 \times 10^{-25}$ N s) [1]
Using cosine rule, $p_2 = 6.72 \times 10^{-25}$ N s [1]
Using sine rule, $\sin \theta / (7.045 \times 10^{-25}) = \sin 56.9 / (6.71 \times 10^{-25})$
$\theta = 61.5°$ [1]

4 (a) The product of the force and the perpendicular distance of its line of action from the pivot. [1]

(b) (i) Component of the weight perpendicular to rod = 5.2 sin 56°

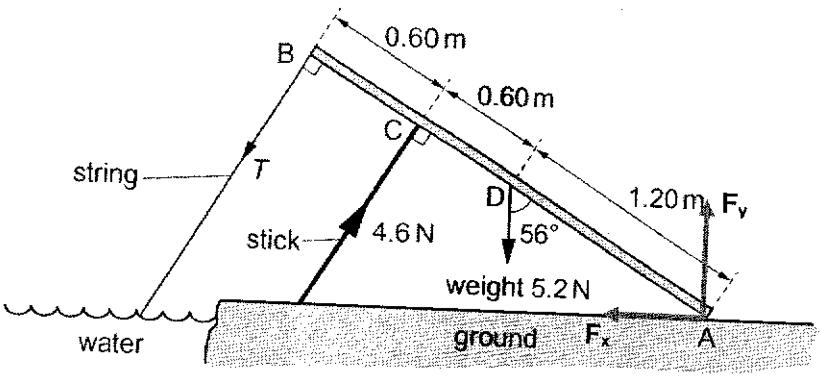
Taking moments about A,

$(T)(2.40) + (5.2 \sin 56°)(1.20) = (4.6)(1.80)$

$T = 1.29$ N [1]

[1]

(ii)



Horizontally, $F_x + T \cos 56° = 4.6 \cos 56°$

$F_x = 1.85$ N

Vertically, $F_y + 4.6 \sin 56° = T \sin 56° + 5.2$

$F_y = 2.46$ N

[1 for both F_x and F_y. ECF from (b)(i)]

Magnitude of F = 3.1 N

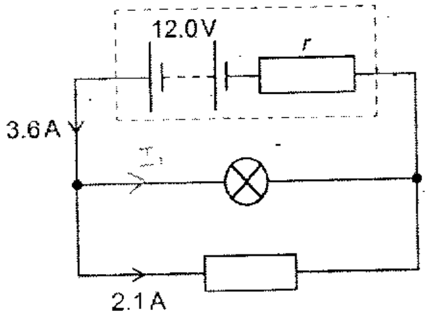
[1]

Angle with respect to rod = $\tan^{-1}(2.460 / 1.848) - 34° = 19°$ [1]

5 (a) (i) Since resistance is the ratio of potential difference to current, and from the graph, [M1]

From graph, this ratio is increasing and thus resistance increases. [A1]

(ii)



Current across filament lamp, $I_1 = 3.6 - 2.1 = 1.5$ A [1]
Reading off Fig. 4.2, p.d across filament lamp V = 4.4 V [1]

p.d across internal r = 12.0 – 4.4 = 7.6 V
Internal resistance, r = 7.6 / 3.6 = 2.11 Ω [1]

(iii) I = nAvq and current in series connection is constant

$(nAvq)_{filament} = (nAvq)_{copper}$
$nAv_{filament}e = (2.5n)(360A)(v_{copper})(e)$

ratio = (2.5)(360) = 900 [1]

(b) Potential difference across each lamp in series is 6 V, while potential difference across each lamp in parallel is 12 V. [1]

Since power = V^2 / R, each lamp in parallel receives more power than each lamp in series. Hence, temperature increases more for each lamp in parallel. [1]

Since resistance of filament lamp increases with temperature, resistance of each lamp in parallel will be greater. [1]

(c) From the first circuit, $V_{BC} = 1.5$ V and $V_{BD} = \frac{R_{BD}}{R_{BD} + 1.0} \times 2.0$ [1]

At balance length, $0.9375 \times V_{BD} = 1.5$

$0.9375 \times \frac{R_{BD}}{R_{BD} + 1.0} \times 2.0 = 1.5$

$R_{BD} = 4.0\ \Omega$ [1]

From the second circuit, to balance at point D, then

$V_{BD} = 1.0 / 1.5 \times 1.5$ [1]

$\frac{4.0}{4.0 + 1.0 + R} \times 2.0 = 1.0$

Solving, R = 3.0 Ω [1]

6 (a) (i) $v = f\lambda$ => $\lambda = \frac{v}{f} = \frac{320}{400} = 0.80$ m [1]

(ii) path difference = 7 m – 5 m = 2 m = 2.5 λ [1]

As there is a phase change of π during reflection, a path difference of 2.5 λ would suggest a maximum at point X. [1]

(b) (i) $d\sin\theta = n\lambda$ => $d = \frac{n\lambda}{\sin\theta} = \frac{(1)(632 \times 10^{-9})}{\frac{38}{\sqrt{(38^2 + 165^2)}}} = 2.816 \times 10^{-6}$ m [1]

Hence, number of lines per metre = $\frac{1}{2.816 \times 10^{-6}} = 355000$ [1]

(ii) The distances PX and PY remain unchanged and P remains at the same spot. [1]

However, the positions of X & Y will be rotated by 90°. [1]

(c) The laser beam is not pointed perpendicularly to the plane of the grating. [1]

7 (a) $\sin\theta = \lambda / b = (633 \times 10^{-9}) / (8.0 \times 10^{-5})$
$\theta = 0.453°$ [1]

$w = 2 \times 5.12 \times \tan(0.453°)$
$= 0.0810$ m (shown) [1]

(if student use $\lambda D / a$, 0 immediately. Be aware....)

(b) (i) crests / light from <u>second slit</u> cancel troughs / light from first slit or destructive interference and <u>reference to second slit</u> or *owtte* [1]

(ii) $x = \lambda D/a = (633 \times 10^{-9})(5.12) / (2.40 \times 10^{-4}) = 0.0135$ m [1]

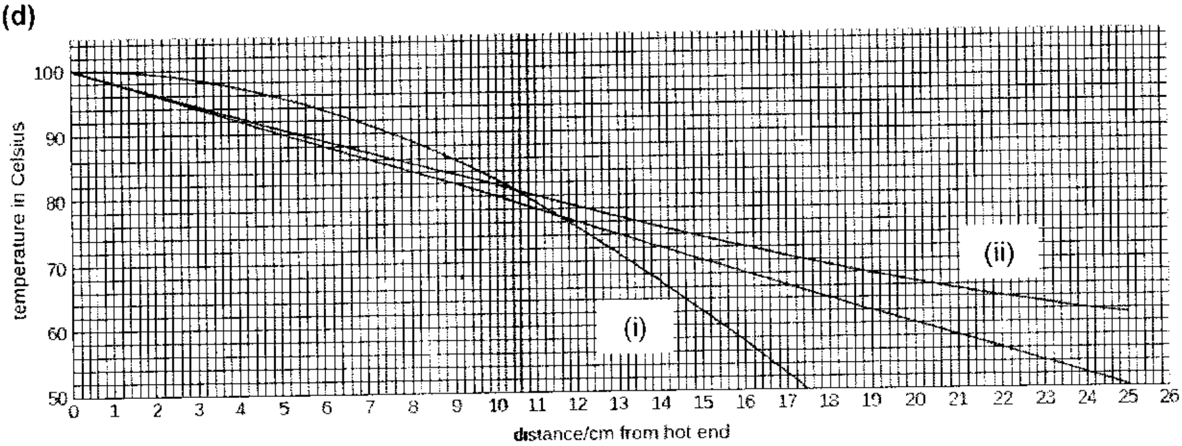
(iii) At these places are single slit diffraction minimums [1]
No light to interfere [1]

8 **(a)** W m^{-1} K^{-1} [1]

(b) Rate of heat flow = power carried by water [1]
= (m / t)(c)(32.5 – 30)
= 32.6 W [1]

(c) 32.6 = (k)(π)(1.5 × 10^{-2})^2(gradient) [1, ecf]
32.6 = (k)(π)(1.5 × 10^{-2})^2 [(100 – 50) / 0.25] [1]
k = 230 [1]

(d)



(i) *A* decrease with distance, so (magnitude of) *T*-*x* gradient increases with distance.
[correct line, 1]

(ii) Without insulation, dQ/dt decreases along the length, therefore gradient decreases with distance.
[explanation, 1]
[correct line, 1]

(iii) There will be a sharp drop in temperature over a small distance. All the temperature values will be the same beyond a small distance [1]

Use a short length (or small **d**) of material instead (or large A) [1]

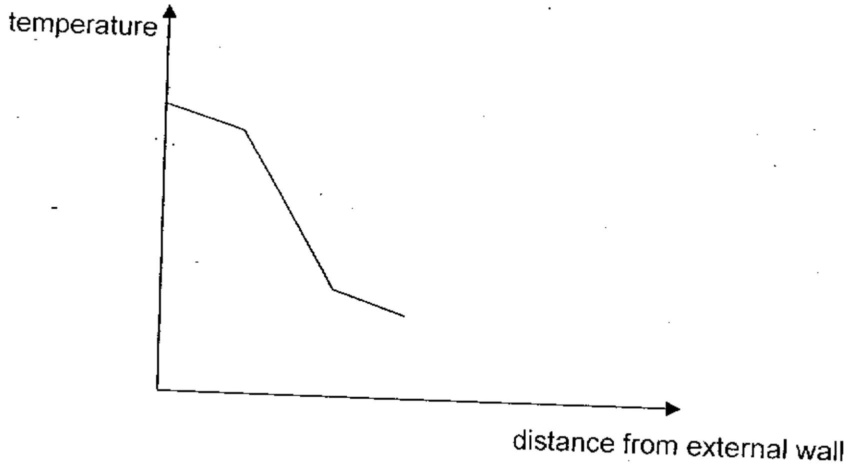
(e) (i) Total area of container = $2\pi(10\times10^{-2})^2+2\pi(10\times10^{-2})(16\times10^{-2}) = 0.163\ m^2$ [1]
Heat conducted into container 120 s = $(2.50)(0.163)(\frac{30}{2\times10^{-2}})(120)$ = 73476 J
[1,ecf]

Mass melted away = $\frac{73476}{3.35\times10^5}$ = 0.219 kg [1,ecf]
Assumption: heat conducted through wall of container only. [1]

(ii) Rate of heat absorbed by radiation
= $(5.7\times10^{-8})(0.1632)(303.15^4 - 273.15^4)$ [1]
= 26.8 J [1]

Compared to conduction, the rate of heat loss by radiation is small (< 5%) [1]

(iii) The gradient is steeper in the air gap [1]
The two insulating layer has the same gradient. [1]



(iv) Thicker layer of air allows air to flow or circulate when it is further away from the wall. [1]

Convection current circulation can happen with a thick layer of air, helping the transfer heat energy. [1]