VICTORIA JUNIOR COLLEGE
2024 JC2 PRELIMINARY EXAMINATION
Higher 2

Name : ____________________ CT group : ____________

PHYSICS

9749/03

Paper 3 Longer Structured Questions

17 September 2024
TUESDAY

Candidates answer on the Question Paper.
No Additional Materials are required.

8 am to 10 am (2 hours)

READ THESE INSTRUCTIONS FIRST

Write your name and Civics Group in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE ON ANY BARCODES.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's use	
Question	**Mark**
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
g	
Units	
sf	
Total	/ 80

This document consists of **27** printed pages and **1** blank page

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_o = 8.85 \times 10^{-12}$ 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 mol^{-1} K^{-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	$s = ut + (½)\,at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\dfrac{GM}{r}$
temperature	$T\,/\,\mathrm{K} = T\,/\,^{\circ}\mathrm{C} + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal 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.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0{}^2 - x^2}$
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	$V = \dfrac{Q}{4\pi\epsilon_0 r}$
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	$\lambda = \dfrac{\ln 2}{t_{1/2}}$

Section A

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

1. A sphere is projected horizontally. The sphere is photographed onto the same film negative at intervals of 0.100 s with an uncertainty of ±0.001 s. The 7 images of the sphere are shown against a grid in Fig. 1.1. The actual uncertainty for the distances measured is 0.1 cm. Air resistance is negligible.

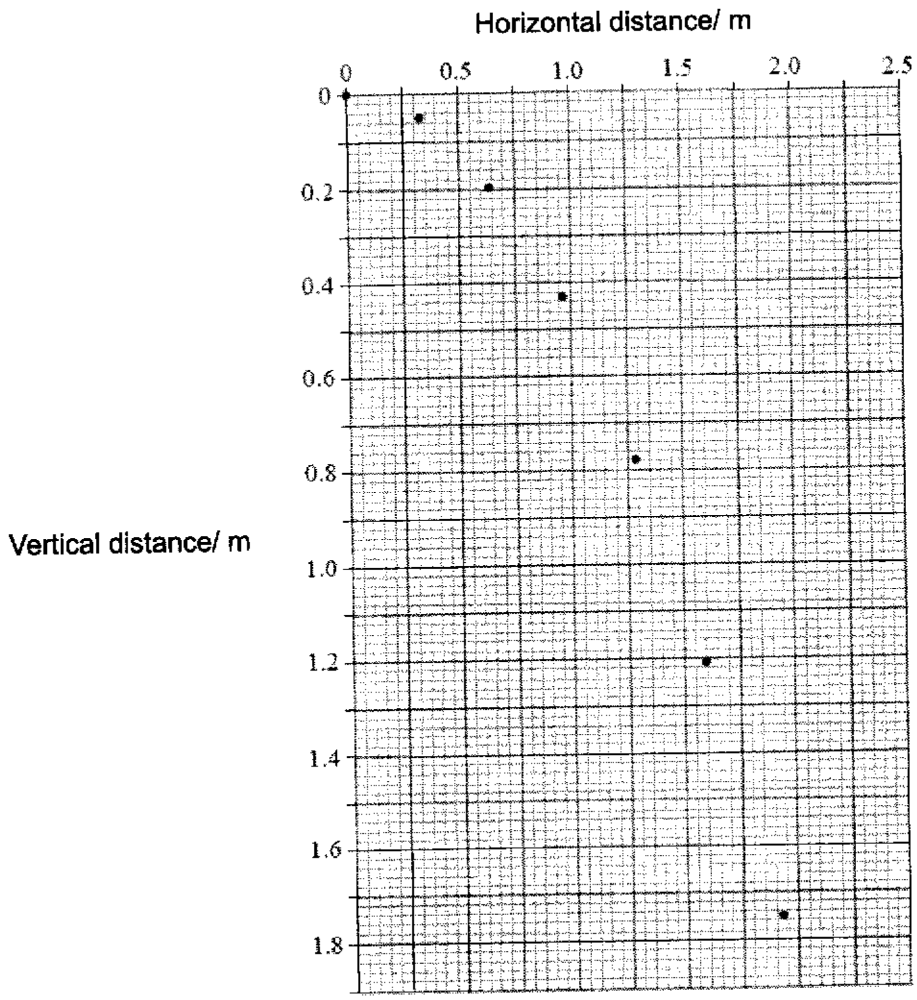

Fig. 1.1

(a) Use Fig.1.1 to determine the acceleration g of the sphere. [2]

g = ...

(b) Explain how your choice of the data point from Fig 1.1 helps to improve the reliability of your calculation in (a). [1]

....

....

(c) Use your answer in (a) to determine the actual uncertainty in the value of g. Hence give a statement of g, with its uncertainty, to an appropriate number of significant figures. [4]

g = ... ± ....

(d) Using existing data, explain how you can improve the accuracy of g obtained by plotting a different graph. Explain why this new method is more accurate. [2]

....

....

....

....

2(a) Student A claims, "When a ball hits and rebounds off a wall, there is impulse on the ball, but not on the wall because the wall does not move."

Discuss whether Student A is correct. [2]

....

....

(b) A ball B of mass 1.2 kg travelling at constant velocity collides head-on with a stationary ball S of mass 3.6 kg, as shown in Fig. 2.1.

Fig. 2.1

Frictional forces are negligible. The variation with time t of the velocity v of ball B before, during and after colliding with ball S is shown in Fig. 2.2.

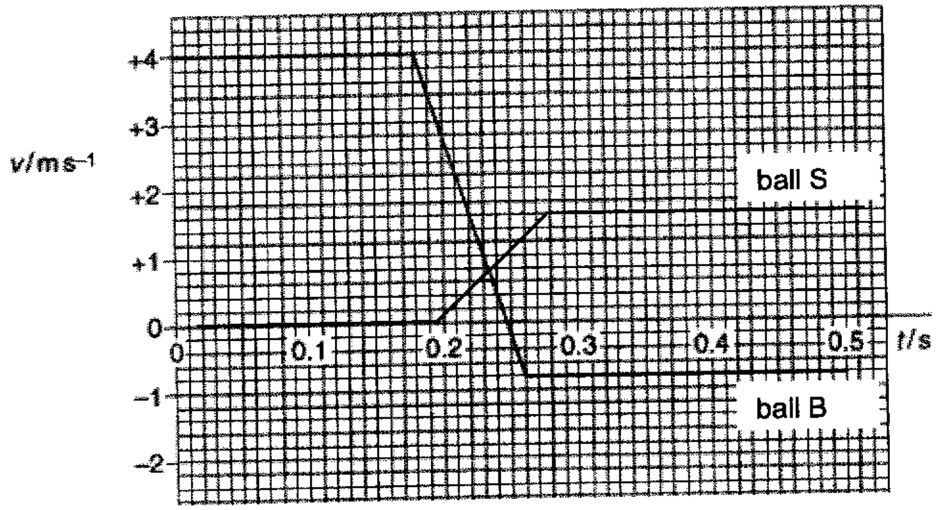

Fig. 2.2

(i) Using Fig. 2.2, explain whether momentum is conserved in this collision. [3]

(ii) Determine quantitatively whether the collision is elastic or inelastic. [2]

3(a) A beam of vertically polarized light is incident normally on a polarizing filter, as shown in Fig 3.1

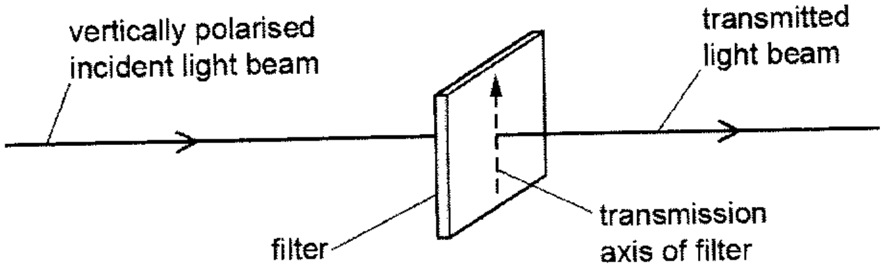

Fig 3.1

(i) The transmission axis of the filter is initially vertical. The filter is then rotated through an angle of 360° while the plane of the filter remains perpendicular to the beam.

On Fig 3.2, sketch a graph to show the variation of the intensity of the light in the transmitted beam with the angle through which the transmission axis is rotated. [1]

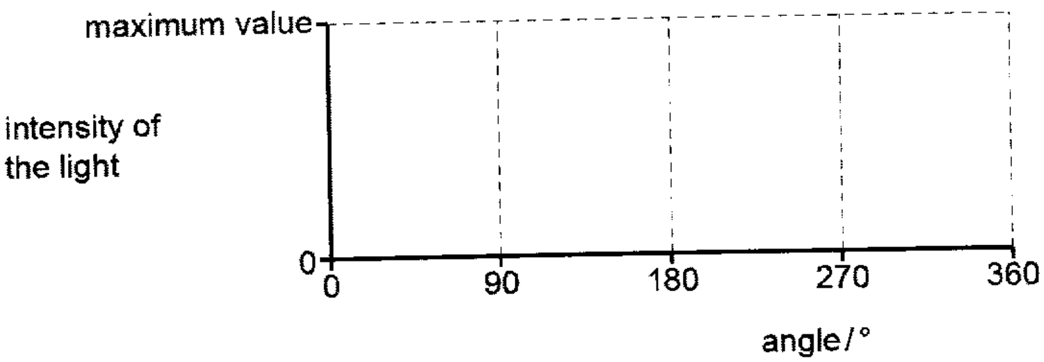

Fig 3.2

(ii) The intensity of the light in the incident beam is 7.6 W m^{-2}. When the transmission axis of the filter is at angle θ to the vertical, the light intensity of the transmitted beam is 4.2 W m^{-2}. Calculate the angle θ. [2]

θ = ...

(b) State what is meant by the diffraction of a wave. [2]

....

....

....

....

(c) A beam of light wavelength 4.3×10^{-7} m is incident normally on a diffraction grating in air, as shown in Fig 3.3.

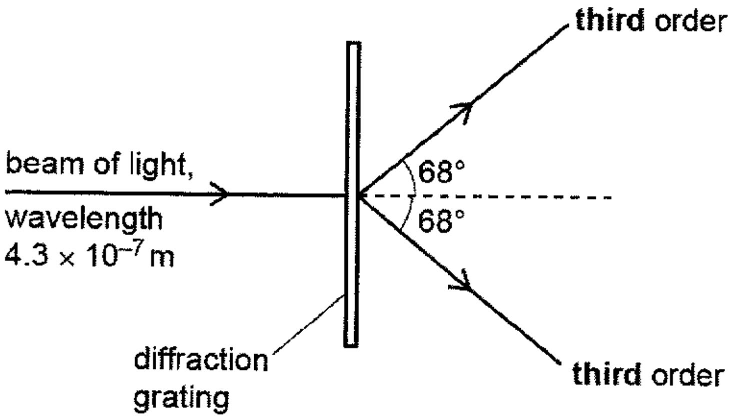

Fig 3.3

The **third-order** diffraction maximum of the light is at an angle of 68° to the direction of the incident light beam.

(i) Calculate the line spacing *a* of the diffraction grating. [2]

a = ...

(ii) Determine a different wavelength of **visible** light that will also produce a diffraction maximum at an angle of 68°. [2]

Wavelength = ...

4(a) State what is meant by the electric field strength at a point [1]

....

....

(b) A potential difference is applied between two horizontal plates, each 1.0 m long and separated by 2.5 cm. A beam of α-particles enters the field horizontally mid-way between the plates at a speed of 1.5×10^7 m s^{-1}. The electric field strength between the two plates is 7.5×10^4 N C^{-1} as shown in Fig. 4.1 which is not drawn to scale.

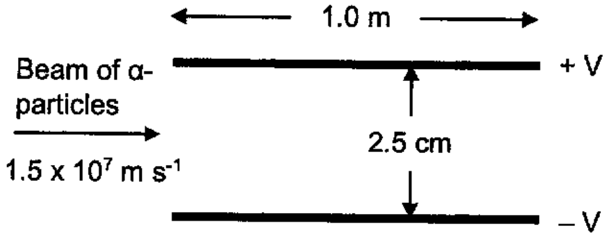

Fig. 4.1

(i) Calculate the force on each α-particle due to the electric field. [2]

Force = ...

(ii) Determine the time that each α-particle spends inside the field. [1]

Time = ...

(iii) Show that the α-particles will not hit the plates. [2]

(iv) Sketch on Fig 4.1, the path of the α-particles between and beyond the plates. [1]

5(a) Define magnetic flux density. [2]

....

....

....

(b) Electrons are moving in a vacuum with speed 1.7×10^7 m s^{-1}. The electrons enter a uniform magnetic field of flux density 4.8 mT. The figure below shows the path of the electrons.

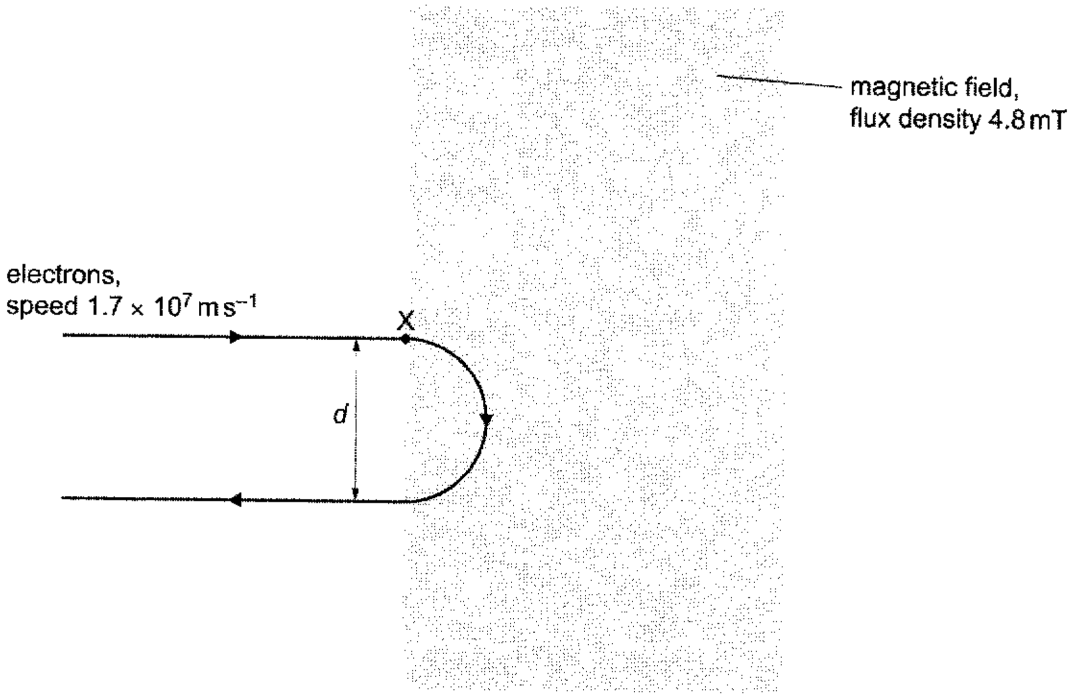

Fig 5.1

The path of the electrons remains in the plane of the page.

(i) State the direction of the magnetic flux density. [1]

....

(ii) Calculate the magnitude of the force exerted on each electron by the magnetic field. [2]

Magnitude of the force = ...

(iii) Use the information in (ii) to calculate the distance *d* between the path of the electrons entering the magnetic field and the path of the electrons leaving the magnetic field. [3]

d = ...

6(a) The variation of an alternating voltage V_P in volts with time t in seconds is given by

$$V_P = 170 \sin(314t)$$

Determine

(i) the r.m.s. potential difference $V_{r.m.s}$ [1]

$V_{r.m.s}$ = ...

(ii) the period, T of the voltage supply. [2]

T = ...

(b) The alternating voltage V_P is connected to the primary coil of a transformer as shown in Fig. 6.1.

An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

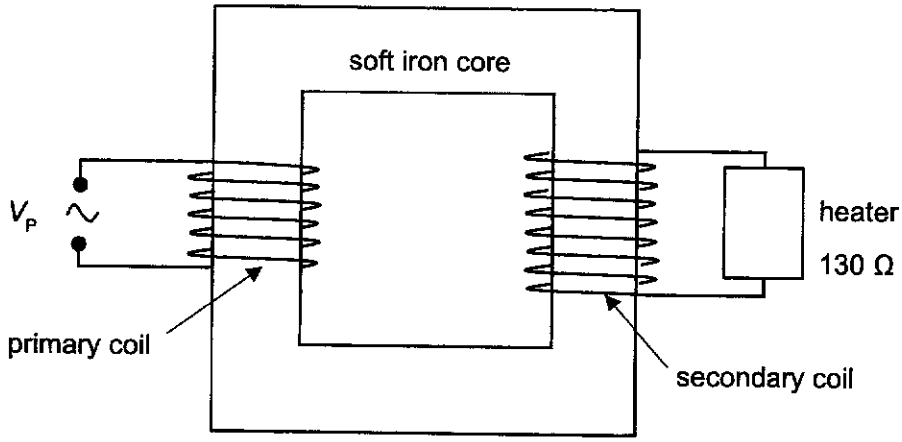

Fig 6.1

The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

(i) Determine the peak potential difference, V_S of the secondary coil. [2]

V_s = ...

(ii) Determine the peak current, I_P in the primary coil. [3]

I_p = ...

(c) A diode and another identical heater are connected to the secondary coil as shown in Fig. 6.2.

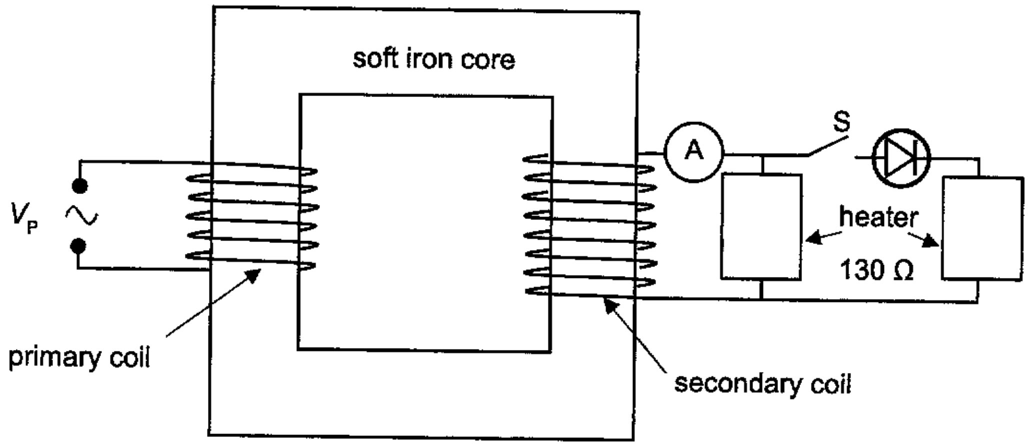

Fig 6.2

Sketch on the axes of Fig 6.3, the variation with time of the current I in the secondary coil when switch S is closed. Label the axes with appropriate values, Include on your graph a time equal to two periods of the alternating potential difference. [3]

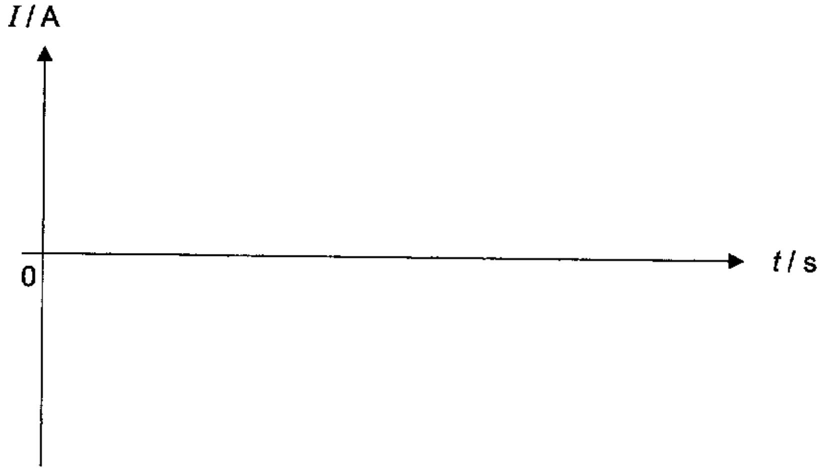

Fig 6.3

7 VJC students are designing a space probe to explore the outer reaches of the Solar System. Because the space probe will travel very far away from the Sun, it cannot be powered using solar panels. Instead, a 'nuclear battery' called a radioisotope thermoelectric generator (RTG) that converts the heat produced from the nuclear fuel directly into electric energy.

The nuclear fuel to be used is strontium-90 ($^{90}_{38}Sr$), with a half-life of 29 years. It decays by beta emission to form yttrium-90 (symbol: Y).

(a) Write an equation to represent the decay of strontium-90 to yttrium-90. [1]

(b) The masses of a strontium-90 nucleus and a yttrium-90 nucleus are shown below:

Strontium-90: 89.907738*u*
Yttrium-90: 89.907151*u*

Show that the energy released in one reaction is 5.71×10^{-15} J. [2]

(c) The RTG is required to supply a power of 155 W at the beginning of the space mission. The efficiency of the conversion process from nuclear power to electrical power is 7.0%.

(i) Show that the activity needed from the strontium-90 fuel at the beginning of the mission is 3.88×10^{17} Bq. [2]

(ii) Calculate the number of nuclei of strontium-90 needed at the start of the mission. [2]

Number of nuclei = ...

(iii) Hence calculate the mass of pure strontium-90 needed at the start of the mission. [2]

Mass = ...

Section B

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

8(a) There are approximately about 600 geostationary satellites orbiting around the Earth. The mass of the Earth is 5.9×10^{24} kg and its radius is 6.4×10^{6} m.

(i) Determine the angular velocity of a geostationary satellite. [2]

(ii) Calculate the radius of the geostationary orbit. [3]

(iii) State one application of geostationary satellites. [1]

....

(iv) State one advantage and one disadvantage of using a geostationary orbit for the application stated in (a)(iii). [2]

....

....

....

(b) Fig. 8.1 shows a binary star system consists of two stars S_1 and S_2 with masses M_1 and M_2 respectively rotating about a common centre. The centres of the two stars are separated by a distance $R = 1.2 \times 10^{10}$ m.

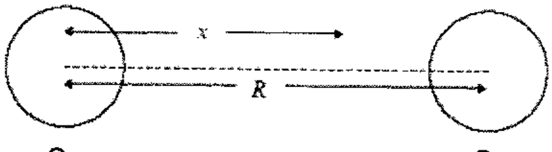

Fig. 8.1

The total gravitational potential due to the stars at any point along a line joining their centres is ϕ. Fig. 8.2 shows how ϕ varies with the distance x from the centre of star S_1. (Values of the potential inside each star are not known.)

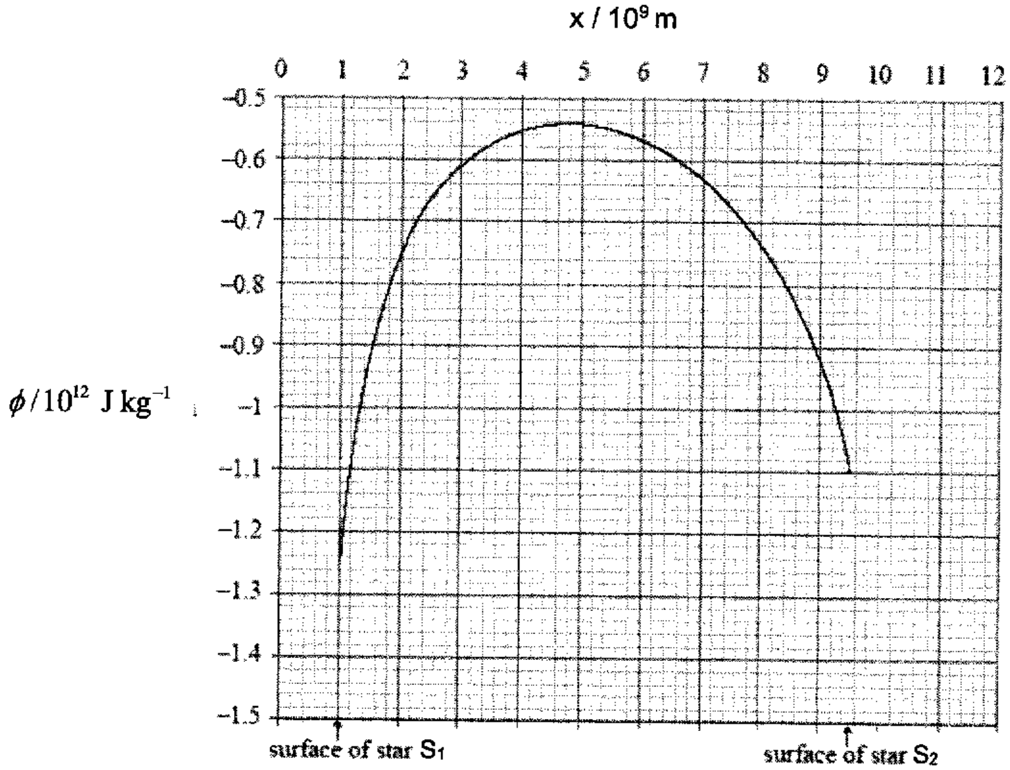

Fig. 8.2

(i) State the relationship between gravitational potential ϕ and gravitational field strength g. [2]

....

....

(ii) Explain, using Fig. 8.2, whether the gravitational field strength at the surface of star S_1 is greater or less than the gravitational field strength at the surface of star S_2. [2]

....

....

....

(iii) A particle is launched with kinetic energy E_k from the surface of star S_2. The particle arrives at the surface of star S_1. Use Fig. 8.2 to explain whether the kinetic energy of the particle at the surface of star S_1 is less than, equal to, or larger than E_k. [2]

....

....

....

(iv) Explain the significance of the maximum point on Fig. 8.2. [1]

....

(v) Determine the ratio $\frac{M_1}{M_2}$. [3]

$\frac{M_1}{M_2}$ = ...

(vi) Sketch the variation with x of the gravitational field strength g between the surfaces of the two stars. No numerical values are required. [2]

9(a) A metal wire X of length 6.0 cm and diameter 0.30 mm is made of a material with resistivity $1.50 \times 10^{-6}\ \Omega$ m at room temperature.

(i) Show that the resistance of X at room temperature is 1.3 Ω. [2]

(ii) The metal wire X is placed in a circuit in series with an ideal cell of e.m.f. of 1.2 V and a variable resistor. An ideal voltmeter is connected across X to measure its p.d. V, and an ideal ammeter is connected in series with X to measure its current I, as shown in Fig. 9.1:

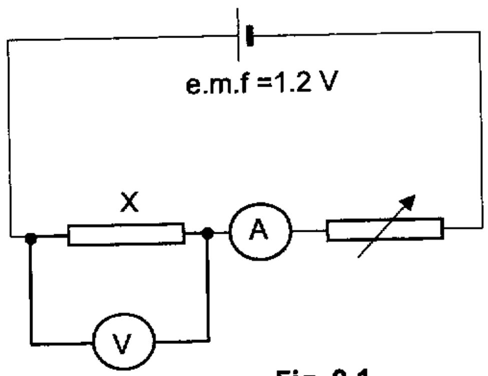

Fig. 9.1

1. Distinguish between e.m.f. and p.d. [2]

....

....

....

2. As the current through X is increased, its temperature rises. Sketch an $I - V$ characteristic graph for X. [1]

3. Explain how the graph in (ii)2. can be used to determine the resistance of X for a given value of V. [1]

....

....

4. The variable resistor is set to 0.50 Ω. Using the value of the resistance of X that you found in (i), calculate the fraction of the power delivered by the cell that is dissipated through X. [2]

Fraction = ...

(b) A light bulb is placed in a circuit with a rheostat and an ideal voltmeter connected across it. The resistance of the rheostat can be varied from 0 Ω to 10 Ω. The combination is placed in series with an ideal cell of e.m.f. 3.0 V and a resistor S of 0.60 Ω, as shown in Fig. 9.2:

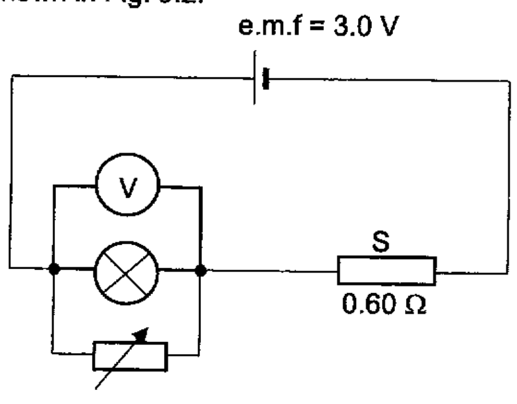

Fig. 9.2

(i) Explain how the reading on the voltmeter will change as resistance of the rheostat is varied from minimum to maximum value. [3]

....

....

....

....

....

(ii) Explain the purpose of resistor S. [2]

....

(iii) When the rheostat is set to the maximum setting of 10 Ω, the voltmeter reads 1.2 V.

1. Calculate the current delivered by the cell. [2]

Current = ...

2. Calculate the current flowing through the light bulb. [3]

Current = ...

3. A student suggests that the rheostat can act as a switch for the light bulb, since setting the resistance of the rheostat to 0 Ω will cause the current in the light bulb to drop to 0 A. Explain why it is not practical to use the rheostat as a switch. [2]

....

....

....

End of paper

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2024 Physics Prelim Exam H2 Paper 3 suggested solutions

1(a)

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

From Fig. 1.1, $s_y = 1.75$ m and $t = 0.600$ s [1]

$$\therefore g = \frac{2s_y}{t^2} = \frac{2(1.75)}{(0.600)^2}$$

$$= 9.722 \text{ m s}^{-2}$$

$$= 9.72 \text{ m s}^{-2} \quad [1]$$

(b) % uncertainty = actual uncertainty/ data point. [1]

Hence the larger the data point, the smaller the % uncertainty since the absolute uncertainty is fixed. Hence more reliable. [1]

(c)

$$\frac{\Delta g}{g} = \frac{\Delta s_y}{s_y} + 2\frac{\Delta t}{t} \quad [1]$$

$$\Delta g = [\frac{0.001}{1.75} + 2(\frac{0.006}{0.600})](9.722)$$

$$= 0.2 \text{ m s}^{-2} \quad [1]$$

$$g = 9.7 \pm 0.2 \text{ m s}^{-2} \quad [1]$$

(d) Since $s_y = ½gt^2$, plot a graph of s_y against t^2, where, s_y = vertical distance travelled by the sphere, t = time taken to travel s_y. The gradient = $½g$. [1]

Random error is reduced when a best fit line is drawn using all the data points. [1]

2(a) By the principle of conservation of momentum, since there is no external force acting, the total change in momentum of the of ball and wall = 0. [1]

Therefore the change in momentum (impulse) of the wall is equal and opposite to the change in momentum of the ball . [1]

Therefore, Student A is wrong.

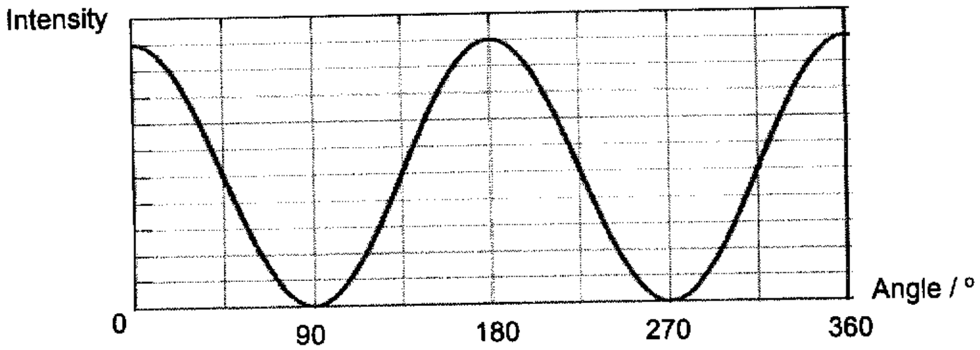
(b) Taking values from Fig 2.2,
Total momentum before collision = (1.2 x 4) + 0 = 4.8 kg m s^{-1} [1]
Total momentum after collision = (1.6 x 3.6) + (-0.8 x 1.2) = 4.8 kg m s^{-1} [1]

Since total momentum before collision is equal to the total momentum after collision, momentum is conserved in this collision. [1]

(c) Relative speed of approach = 4.0 – 0 = 4.0 m s^{-1}
Relative speed of separation = 1.6 – (-0.8) = 2.4 m s^{-1} [1]

Since relative speed of approach is not equal to relative speed of separation, the collision is inelastic. [1]

3 (a) (i)



Sinusoidally shaped graph [1]
Maximum intensity value at 0°, 180° and 360° and zero intensity at 90° and 270°. [1]

(ii) Using Malus's Law, intensity of transmitted beam, $I_t = I_o \cos^2\theta$ [1]

Therefore angle, $\theta = \cos^{-1}\left(\sqrt{\frac{I_t}{I_o}}\right) = \cos^{-1}\left(\sqrt{\frac{4.2}{7.6}}\right) = 42°$ [1]

(b) Diffraction refers to the spreading or bending of plane waves when they encounter an aperture or obstacle, [1]
whose linear dimension is comparable to the wavelength of the waves. [1]

(c)(i) For diffraction grating, $d\sin\theta = n\lambda$ [1]

Therefore, line spacing, $d = \frac{n\lambda}{\sin\theta} = \frac{3(4.3\times10^{-7})}{\sin 68°} = 1.4\times10^{-6}\,\text{m}$ [1]

(c)(ii) For diffraction grating, $d\sin\theta = n\lambda$

Different visible wavelength, $\lambda = \frac{d\sin\theta}{n} = \frac{(1.4\times10^{-6})(\sin 68°)}{2} = 6.5\times10^{-7}\,\text{m}$

[1 for n = 2; 1 for answer]

4(a) Electric field strength at a point is electric force per unit positive charge at that point. [1]

(b)(i) $F = (2e)E$ [1]

$= 2\times(1.6\times10^{-19})(7.5\times10^{4})$

$= 2.4\times10^{-14}$ N [1]

(b)(ii) Time taken for alpha particles to travel 1 m in the horizontal direction,

$t = \frac{s_x}{u_x} = \frac{1.0}{1.50\times10^{7}}$

$= 6.67\times10^{-8}\ s$ [1]

(b)(iii) Acceleration in the vertical direction,

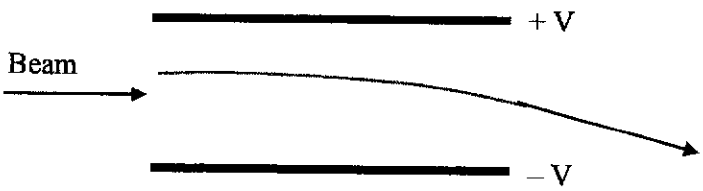
$a = \frac{F}{m} = \frac{F}{4u} = \frac{2.4\times10^{-14}}{4\times1.66\times10^{-27}} = 0.3614\times10^{13}\ ms^{-2}$ [1]

Displacement in vertical-direction during time t,

$s = \frac{1}{2}at^2 = \frac{1}{2}(0.3614\times10^{13})(6.67\times10^{-8})^2 = 0.008039 \approx 0.0080\ m$ [1]

The particles will not hit any of the plates as the vertical displacement of the electron is less than 0.0125 m when it is travellling between the two parallel plates.

(b)(iv)



Parabolic path curves downward inside the plates

Straight path outside the plates

5(a) Magnetic flux density is defined to be the magnetic force acting per unit current and per unit length on a conducting wire [1]
placed at right angles to the direction of the magnetic field. [1]

(b)(i) Direction of the magnetic flux density is *into* the plane of the page. [1]

(ii) Magnetic force on a charge particle, $F_B = Bqv\sin\theta$ [1]

$$= \left(4.8\times10^{-3}\right)\left(1.6\times10^{-19}\right)\left(1.7\times10^{7}\right)\left(\sin 90°\right)$$ [1]

$$= 1.3\times10^{-14}\text{ N}$$

(iii) For circular motion, magnetic force provides for the circular motion,

$$\therefore F_B = \frac{mv^2}{r}$$ [1]

Therefore, the electron will move in a circular motion of radius,

$$r = \frac{mv^2}{F_B}$$

$$= \frac{\left(9.11\times10^{-31}\right)\left(1.7\times10^{7}\right)^2}{1.3\times10^{-14}} = 0.020\text{ m}$$ [1]

Required distance, $d = 2r = 2(0.020) = 0.040\text{ m}$ [1]

6(a)(i) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120\text{ V}$ [1]

(ii) $\omega = 2\pi/T = 314$

$T = 0.0200\text{ s}$ [1]

(b)(i)

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{V_S}{170} = \frac{3500}{2000}$$ [1]

$$V_S = 298\text{ V}$$ [1]

(ii) $V_S = I_S R$

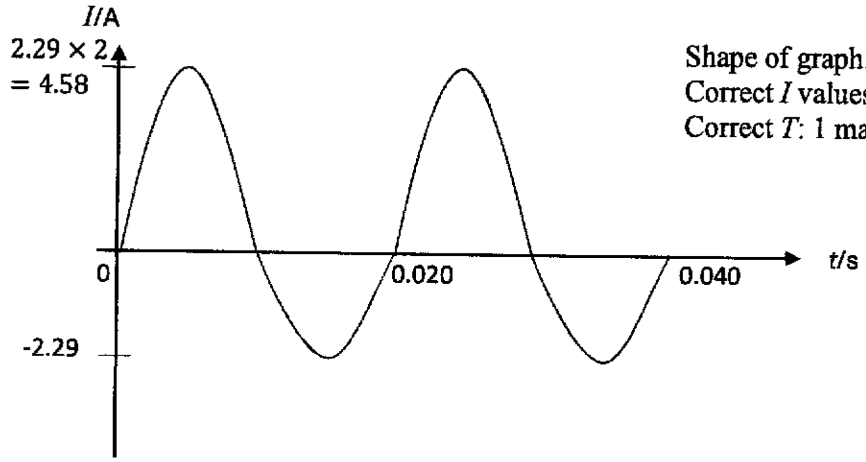
$298 = I_S(130)$

$I_S = 2.288\text{ A}$ [1]

$$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{3500}{2000}$$

$I_P = 4.00\text{ A}$ [1]

(c)



Shape of graph: 1 mark.
Correct I values: 1 mark
Correct T: 1 mark

7(a) $^{90}_{38}Sr \rightarrow ^{90}_{39}Y + ^{0}_{-1}e$ [1; no need neutrino]

(b) Energy released = (mass defect) c^2

$= (m_{Sr} - m_Y - m_e)\,c^2$ [1]

$= [(89.907738 - 89.907151) \times 1.66 \times 10^{-27} - 9.11 \times 10^{-31}] \times (3.00 \times 10^8)^2$

$= 5.7078 \times 10^{-15}$ [1]

$= 5.71 \times 10^{-15}$ J

(c)(i) Total energy that needs to be released per second, $E = \frac{\text{Power to be supplied}}{\text{Efficiency}}$

$= \frac{155}{0.070}$

= 2214.3 J [1]

Activity $= \frac{E}{\text{Energy released in one reaction}}$

$= \frac{2214.3}{5.71 \times 10^{-15}}$

$= 3.8779 \times 10^{17}$ [1]

$= 3.88 \times 10^{17}$ Bq

(ii) $A = \lambda N$

Number of strontium-90 needed $N = \frac{A}{\lambda}$ [1]

$= \frac{A\,\tau_{1/2}}{\ln 2}$

$= \frac{3.8779 \times 10^{17} \times 29 \times 365 \times 24 \times 3600}{\ln 2}$

$= 5.1165 \times 10^{26}$

$= 5.12 \times 10^{26}$ [1]

(iii) Mass of strontium-90 needed = number of nuclei x mass of 1 nuceus [1]
$= 5.1165 \times 10^{26} \times 89.907738 \times 1.66 \times 10^{-27}$
= 76.4 kg [1]

8(a)(i)

$T = 24$ hours [1]

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{(24\times 60\times 60)}$$

$= 7.3\times 10^{-5}$ rad s^{-1} [1]

(ii)

Gravitational force provides centripetal force

$$\frac{GMm}{r^2} = mr\omega^2$$ [1]

$$r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{(6.67\times 10^{-11})(5.9\times 10^{24})}{(7.3\times 10^{-5})^2}}$$ [1]

$= 4.2\times 10^7$ m [1]

(iii) Communication, weather forecasting or navigation (GPS)

(iv)

Application	Advantage	Disadvantage
Communication Weather Navigation	No break in the signal transmissions as it is fixed position in sky.	High altitude so there is a significant lag time in the signal transmissions.

(b)(i) Gravitational field strength is equal to the negative gravitational potential gradient i.e. $g = -d\phi/dr$

(ii) Potential gradient at surface of star S_1 is steeper than that of S_2. [1]
Using relationship in (b)(i), gravitational field strength at the surface of star S_1 is greater than that of star S_2. [1]

(iii) From the graph, when the particle travels from S_2 to S_1, it loses gravitational pe (since it experiences a drop in gravitational potential). [1]

As the total energy of the particle is constant, it gains ke. So its ke at the surface of S_1 is larger than E_k. [1]

(iv) It is the point in which the resultant gravitational field strength is zero. [1]

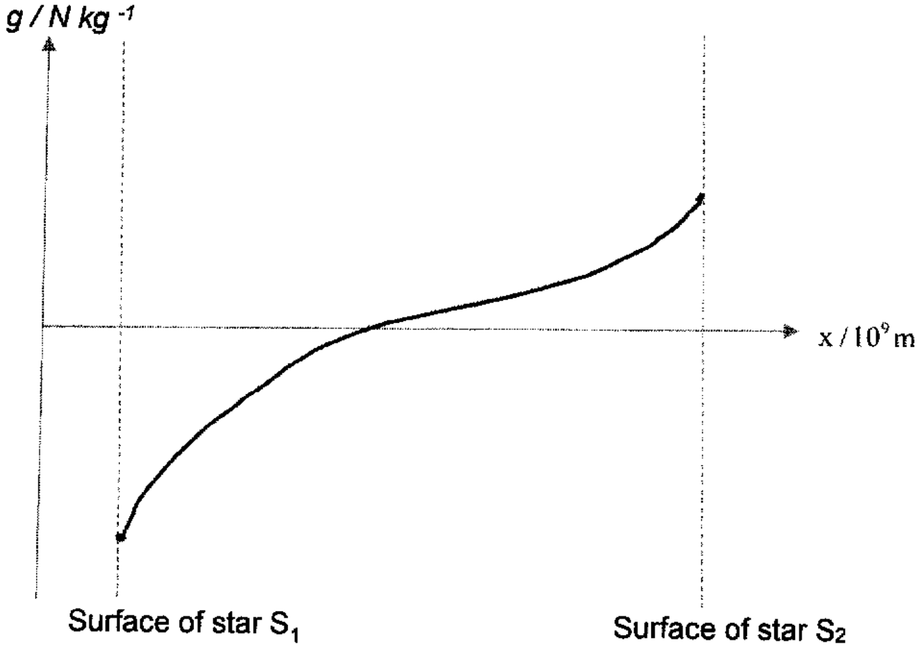
(v)

$$\frac{GM_1}{x^2} = \frac{GM_2}{(1.2\times10^{10} - x)^2} \quad [1]$$

From Fig. 8.2, x = 4.8 x 10^9 m [1]

$$\frac{M_1}{M_2} = [\frac{4.8\times10^9}{(1.2\times10^{10} - 4.8\times10^9)}]^2$$
$$= 0.44 \quad [1]$$

(vi)



Correct shape of curve with gravitational field strength at surface of star S_1 greater than S_2. [1]
Field strength is zero at the point of maximum potential. [1]

9(a)(i) Resistance = $\frac{\rho L}{A}$ [1]

$= \frac{\rho L}{\left(\frac{\pi d^2}{4}\right)}$ Cross sectional area of wire, $A = \frac{\pi d^2}{4}$

$= \frac{1.50 \times 10^{-6} \times 6.0 \times 10^{-2}}{\left(\frac{\pi (0.30 \times 10^{-3})^2}{4}\right)}$

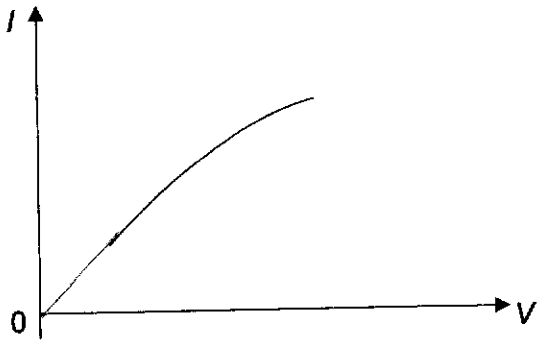
= 1.273 [1]

= 1.3 Ω

(ii)1. e.m.f. is the amount of other forms of energy converted to electrical energy per unit charge delivered by a source of e.m.f. [1]

p.d. is the amount of electrical energy converted to other forms of energy per unit charge flowing through a device. [1]

2.



[1; no need to show negative quadrant]

3. Read off the corresponding value of I.

Resistance = $\frac{V}{I}$ [1; must have both statements]

4. Fraction of power delivered = $\frac{\text{Power dissipated through X}}{\text{Total power dissipated in circuit}}$

$= \frac{I^2 R_X}{I^2 (R_X + R_{variable})}$ (R_X and $R_{variable}$ are in series)

[1]

$= \frac{R_X}{(R_X + R_{variable})}$

$= \frac{1.3}{(1.3 + 0.50)}$

= 0.72 [1]

(b)(i)

- As the resistance of the rheostat is increased, the total resistance across the voltmeter is increased. [1]
- Using the potential divider principle, the p.d. across the voltmeter will take up a bigger fraction of the e.m.f. [1]
- So the voltmeter reading will increase. [1]

(ii) S is to prevent short circuit of the cell [1] when the rheostat is set to 0 Ω. [1]

(iii)1. If voltmeter reads 1.2 V, then p.d. across S = 3.0 -1.2
= 1.8 V [1]

∴ current delivered by cell = current through S
= 1.8 / 0.60
= 3.0 A [1]

2. Current through rheostat = 1.2 / 10
= 0.12 A [1]

Current through bulb = Main current – current through rheostat [1]
= 3.0 – 0.12
= 2.9 A [1]

3.

- When the rheostat is set to 0 Ω, a current will still flow through S. [1]
- So power will be wasted [1], that's why the suggestion is not practical.