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General Certificate of Education Advanced Level
Higher 2

PHYSICS **9749/03**

Paper 3 Longer Structured Questions **October/November 2022**

2 hours

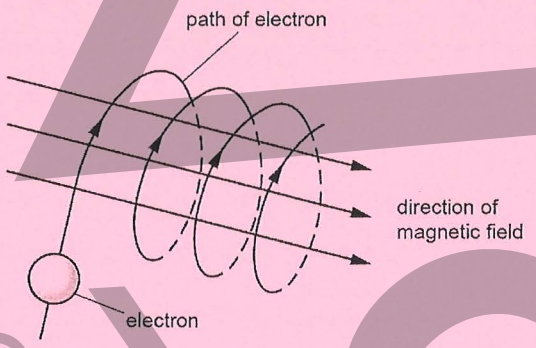
ERRATUM NOTICE
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EACH CANDIDATE TO BE GIVEN ONE COPY OF THIS ERRATUM ONCE THE QUESTION PAPER HAS BEEN DISTRIBUTED AND BEFORE THE EXAMINATION BEGINS

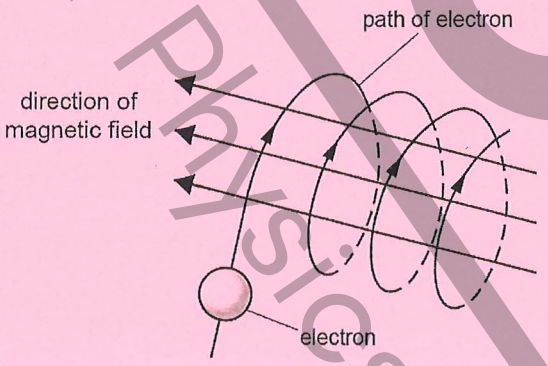
Turn to **page 22** of the Question Paper.

For **Question 8(d).**

The direction of the magnetic field in Fig. 8.6 is shown as:



The direction of the magnetic field in Fig. 8.6 should be shown in the opposite direction as:



Please amend Fig. 8.6 in your copy of the Question Paper.

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PHYSICS

9749/03

Paper 3 Longer Structured Questions

October/November 2022

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name 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.

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Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\text{m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\text{H m}^{-1}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\text{F m}^{-1}$
	$(1/(36\pi)) \times 10^{-9}\,\text{F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\,\text{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\text{J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\text{kg}$
molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\text{mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\text{N m}^2\,\text{kg}^{-2}$
acceleration of free fall	$g = 9.81\,\text{m s}^{-2}$

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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	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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Section A

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

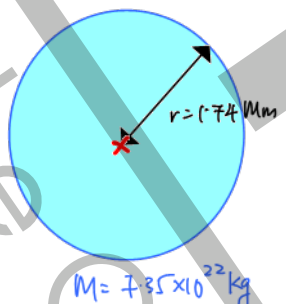
1 **(a)** State what is meant by the *inertia* of a body.

Tendency to resist a change in its motion.

[1]

(b) A planet has a radius of 1.74×10^6 m and may be considered to be a point mass of 7.35×10^{22} kg, situated at its centre. The planet has no atmosphere and is isolated in space.

Show that the gravitational field strength g at the surface of the planet is 1.62 N kg^{-1}.



$g = \frac{GM}{r^2} = \frac{(6.67 \times 10^{-11})(7.35 \times 10^{22})}{(1.74 \times 10^6)^2}$

$= 1.61925$

$= 1.62$ N kg^{-1} * (shown)

[2]

(c) A rocket of initial mass 4000 kg is situated on the surface of the planet in **(b)**.

The rocket fires its engines. The exhaust gases from the engines are all ejected vertically downwards, and the mass of the rocket reduces at a rate of 70.0 kg s^{-1}. A constant thrust of 10.0 kN is generated on the rocket, and it accelerates vertically away from the surface of the planet.

(i) Calculate the speed of the exhaust gases at the instant when the rocket lifts off.

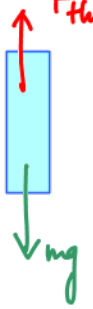
By N2L, $F_{thrust} = v\left(\frac{dm}{dt}\right)$

$\therefore v = \frac{F_{thrust}}{\frac{dm}{dt}} = \frac{10 \times 10^3}{70} = 142.85 = 143$ m/s (3sf) *

speed = 143 m s^{-1} [3]

(ii) Calculate the acceleration of the rocket after the engines have fired for 15.0 s.

You may assume that the gravitational field strength of the planet acting on the rocket is constant.



After 15 s, total mass depleted = (70)(15) = 1050 kg

∴ Mass of rocket at t = 15s = 4000 − 1050 = 2950 kg

At t = 15s, $F_{net} = ma$ from N2L.

$\therefore a = \frac{F_{net}}{m} = \frac{F_{thrust} - mg}{m} = \frac{10{,}000 - (2950)(1.62)}{2950} = 1.769 = 1.77$ m/s^2 (3sf) *

acceleration = 1.77 m s^{-2} [3]

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(iii) The actual acceleration of the rocket after the engines have fired for 15.0 s is different from the value calculated in **(c)(ii)**.

State and explain whether the actual acceleration is greater than or less than the value calculated in **(c)(ii)**.

The actual acceleration is larger. Gravitational field strength, g, of the planet is inversely proportional to the distance from its centre squared. At 15 s, the rocket is further from planet and hence the g is smaller than 1.62 N kg^{-1}. From Newton's 2nd law, the net force and hence the acceleration is larger. [2]

[Total: 11]

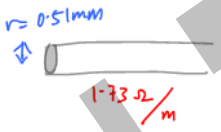
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2 At room temperature, a metal wire has a diameter of 1.02mm and a resistance per unit length of 1.73 Ω m^{-1}.

The wire is connected to a d.c. power supply. When the power supply is first switched on, the wire heats up from room temperature to a higher constant temperature in a time of 60 s.

(a) Calculate the resistivity of the wire at room temperature.



$R = \frac{\rho l}{A}, \therefore \rho = \frac{RA}{l} = \frac{R}{l} \cdot \pi r^2$

$= (1.73)(\pi)(0.51 \times 10^{-3})^2$

$= 1.413 \times 10^{-6}$

$= 1.41 \mu \Omega m$

resistivity = ... 1.41 μ ..... Ω m [3]

(b) (i) The first law of thermodynamics, when applied to a system, can be expressed as:

$$\Delta U = q + w$$

where ΔU is the increase in internal energy of the system,
q is the heat supplied to the system and
w is the work done on the system.

Use the words **positive**, **negative** and **zero** to complete Table 2.1 for the three terms in the equation for the wire at the times shown. You may use each word once, more than once or not at all.

Table 2.1

time after being switched on / s	ΔU	q	w
0–59	positive	negative	positive
60–100	zero	negative	positive

[2]

① $\Delta U \propto \Delta T$

② $W_{on} = qV$

③ When $T > T_{rtp}$, heat loss.

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(ii) At its higher constant temperature, the current in the wire is 12A and the potential difference across it is 230V.

Complete Table 2.2 to show the values of ΔU, q and w for a time of 40s at this higher constant temperature.

① $W_{on} = qV = ItV = (12)(40)(230) = 110400\ J$

$= 0.110\ MJ$

② $\Delta U = 0$, as $\Delta T = 0$

Table 2.2

ΔU/J	q/J	w/J
0	-0.110 MJ	0.110 MJ

[3]

[Total: 8]

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3 Fig. 3.1 shows the drum of a front-loading washing machine. The drum has a radius of 0.230 m and spins at 1200 revolutions per minute when drying clothes. There are small holes in the drum to let the water escape.

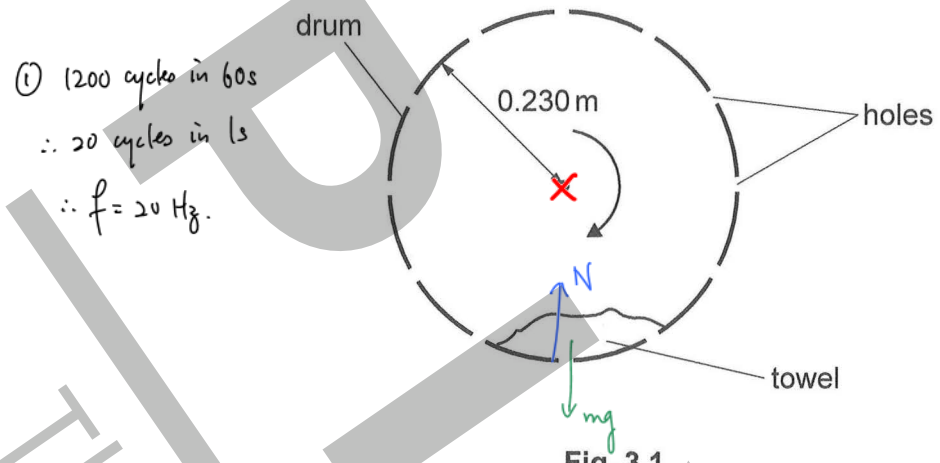


Fig. 3.1

(a) (i) Calculate the angular speed ω of the drum.

(1) 1200 cycles in 60s

∴ 20 cycles in 1s

∴ $f = 20$ Hz.

$\omega = 2\pi f = 2\pi(20) = 125.66$

$= 126$ rad s^{-1} (3sf) *

$\omega =$ 126 rad s^{-1} [2]

(ii) A towel has a mass of 1.20 kg and may be considered to be a point mass at the edge of the drum.

The drum is spinning at the angular speed calculated in **(a)(i)**.

Calculate the force F exerted by the drum on the towel when the towel is at the bottom of the drum, as shown in Fig. 3.1.

$N - mg = F_c$

∴ $N = F_c + mg = mr\omega^2 + mg = m(r\omega^2 + g)$

$= (1.2)[(0.23)(125.66)^2 + 9.81]$

$= 4370.1$

$= 4.37$ kN * (3sf)

$F =$ 4.37 k N [3]

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(iii) With reference to vibrations, and to your answer in **(a)(ii)**, suggest why washing machines have very large masses placed at their base.

The large masses help to lower the centre of gravity of the washing machines thereby increasing its stability to prevent any toppling (washing machines vibrate vigorously while spinning). From Newton's 3rd law, an equally large force (4370 N) is exerted onto the base. The masses help to prevent this large force from breaking the base. The masses also act as a damper by reducing the machines' vibrational amplitudes by lowering its resonant frequency. [3]

(b) Explain, in terms of forces, why the water leaves the drum through the holes when the machine is spinning.

At the holes, there is no normal contact forces acting on the water droplets by drum. So, only force acting on droplets is downward pointing weight (not pointing to centre of circular motion). Hence, water droplets are unable to maintain circular motion, and leave the drum through holes.

[2]

[Total: 10]

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4 Two charged, solid metal spheres, A and B, are situated in a vacuum. The charge on each sphere may be considered to be a point charge at its centre.

Their centres are separated by a distance of 0.90 m, as shown in Fig. 4.1.

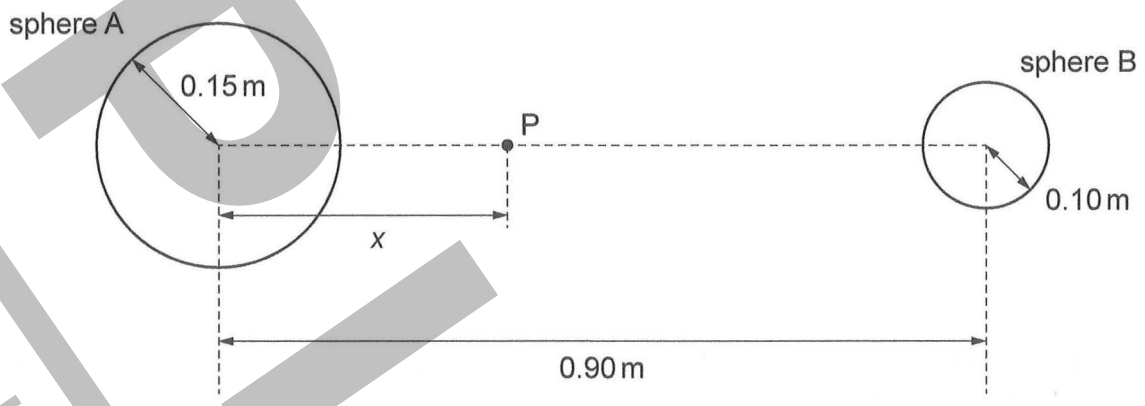
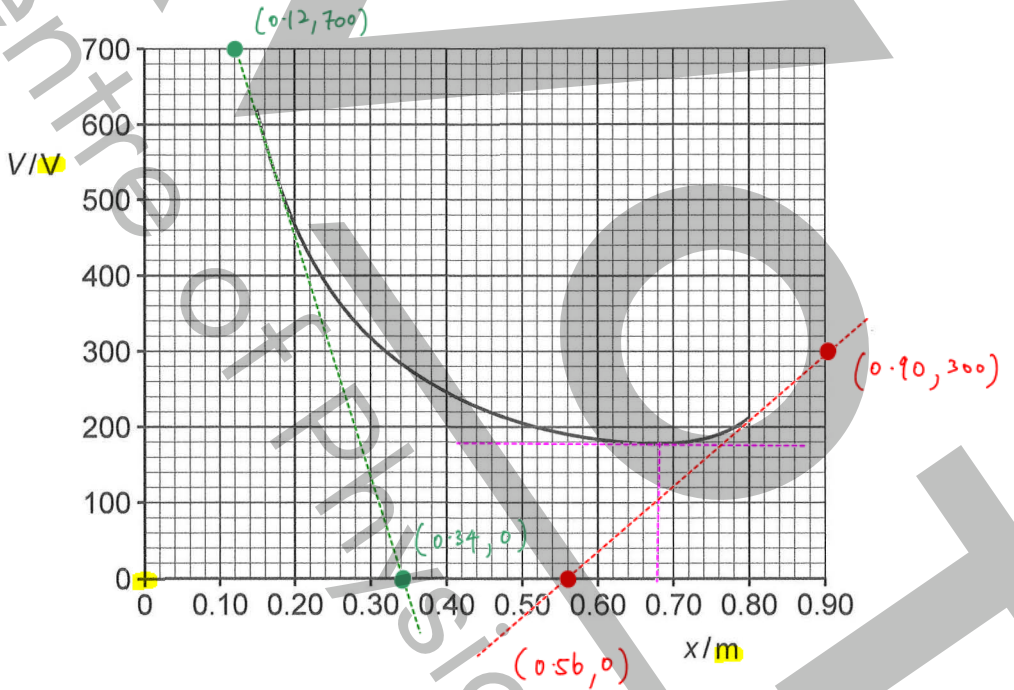


Fig. 4.1 (not to scale)

Sphere A has a radius of 0.15 m and sphere B has a radius of 0.10 m.

Point P is a point on the line joining the centres of the two spheres. Point P is a distance x from the centre of sphere A.

The variation with distance x of the electric potential V at point P is shown in Fig. 4.2.



(i) $E = -\frac{dV}{dr}$

Fig. 4.2

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(a) Use Fig. 4.2 to explain whether the spheres have charges of the same, or opposite, sign.

State the sign of the charge on sphere A.

Same signs. Electrical potential is a scalar. The net potential is obtained by the algebraic addition of the individual potentials produced by each of the charged spheres. Since the net potential graph is always positive, the individual potential graphs must also be positive. Sphere A is hence positive. [3]

(b) On Fig. 4.3, show the variation with distance x of the electric field strength E for values of x from $x = 0.15\,\text{m}$ to $x = 0.80\,\text{m}$. Use the space above Fig. 4.3 for any working.

① $E_A = -\frac{dV_A}{dr} = -\frac{(700-0)}{(0.12-0.34)} = 3181 = 3180\ \text{NC}^{-1}$ *

② $E_B = -\frac{dV_B}{dr} = -\frac{(300-0)}{(0.90-0.56)} = -882.35 = -882\ \text{NC}^{-1}$

③ Null pt. is @ $x = 0.68\,\text{m}$

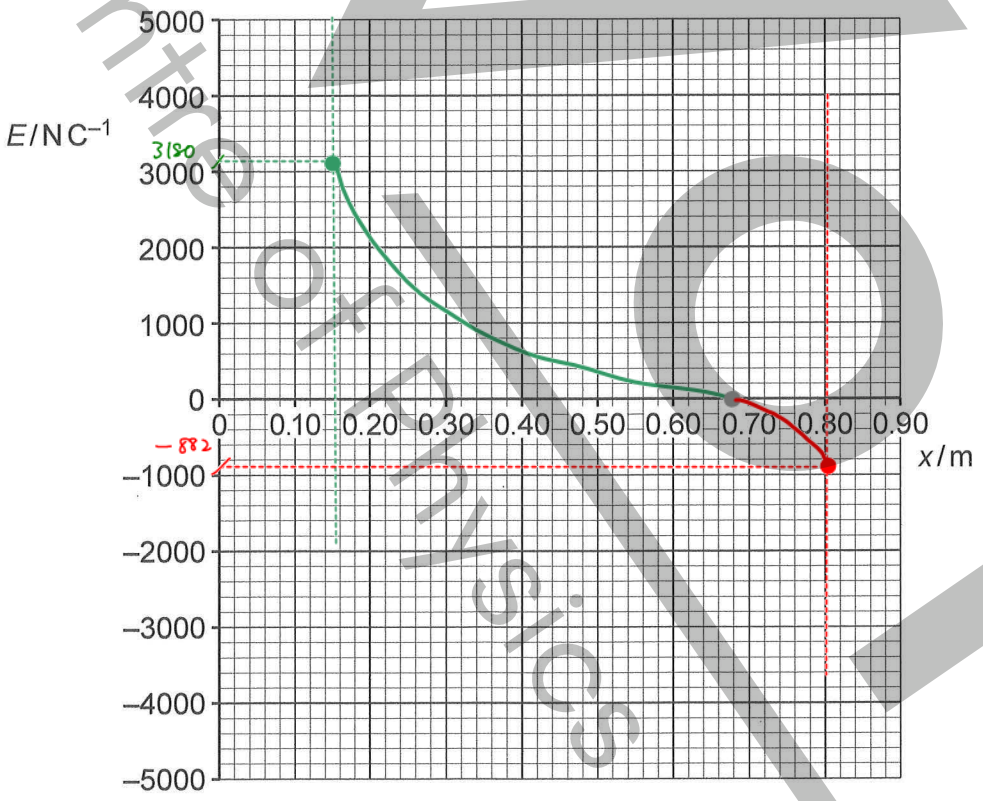


Fig. 4.3

[5]

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(c) The magnitude of the charge on sphere A is 1.0×10^{-8} C.

(i) Calculate the magnitude of the electric potential at the surface of sphere A due to its charge.

$V_A = \frac{Q}{4\pi\varepsilon_0 r} = \frac{(8.99 \times 10^9)(1 \times 10^{-8})}{(0.15)} = 599.33$

$= 599$ V (3 s.f.)

electric potential = 599 V [2]

(ii) Explain why this value is different from the electric potential at the surface of sphere A as shown in Fig. 4.2.

The potential on surface A in Fig. 4.2 (620 V) is the net potential (includes the sum of individual potentials of charges A and B). The value calculated in (c)(i) is the individual potential of charge A only. [2]

[Total: 12]

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5 A cell and a switch are connected to the primary coil of a transformer. A digital voltmeter is connected to the secondary coil, as shown in Fig. 5.1.

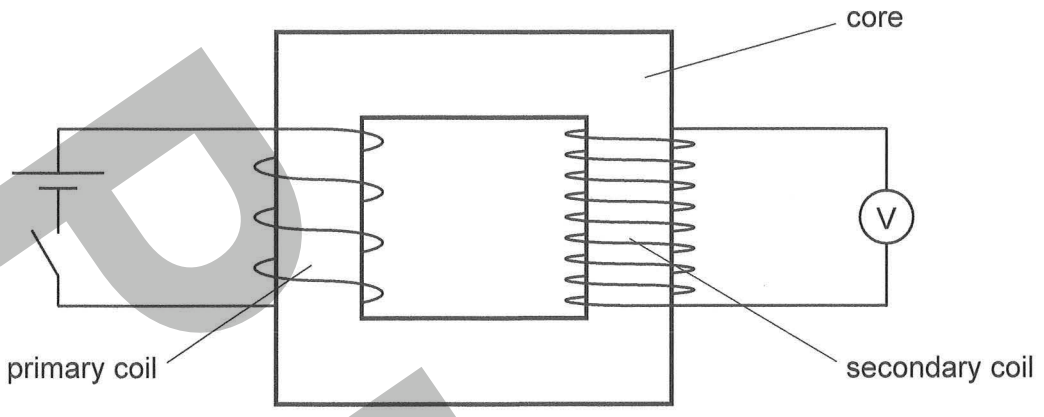


Fig. 5.1 (not to scale)

Initially, the switch is open. The switch is then closed for a short time and then re-opened.

(a) Describe what happens to the reading on the voltmeter.

When the switch is open, the reading is 0.

When the switch is closed, the reading increases to a non-zero value from 0.

When the switch is re-opened, the reading changes sign to a negative non-zero value and becomes 0 again. [3]

(b) Use Faraday's law of electromagnetic induction to explain these observations.

When the switch was initially open, there was no change in magnetic flux linkage. From Faradays laws of electromagnetic induction, there is no induced emf and hence the voltmeter reads 0.

When the switch is closed, current flows through the primary coil, producing an increasing flux. This increasing flux is channeled through the soft iron core to the secondary coil, resulting in an increasing flux linkage in the secondary coil. From Faradays law, there is an induced emf, resulting in the voltmeter registering a non-zero voltage.

When the switch is re-opened, current no longer flows through the primary coil, producing a decreasing flux. This decreasing flux is channeled through the soft iron core to the secondary coil, resulting in a decreasing flux linkage in the secondary coil. Again, from Faradays Law, there is now an induced emf, in the opposite polarity, registering a negative non-zero voltage. Once the rate of change of flux linkage in the secondary coil (and primary coil) becomes 0, the voltmeter reads 0. [5]

[Total: 8]

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6 A thermistor of resistance R, a fixed resistor and a cell are connected in series in a circuit. A voltmeter is connected in parallel across the resistor, as shown in Fig. 6.1.

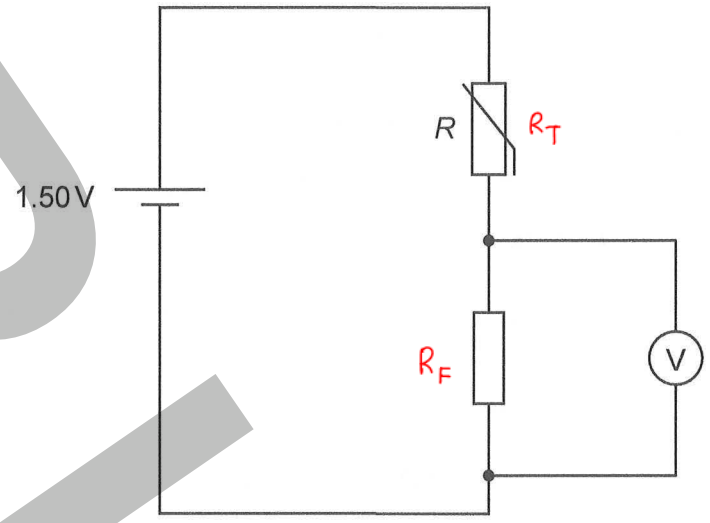


Fig. 6.1

The cell has an e.m.f. of 1.50 V and negligible internal resistance.

The variation with temperature θ of the resistance R of the thermistor is shown in Fig. 6.2.

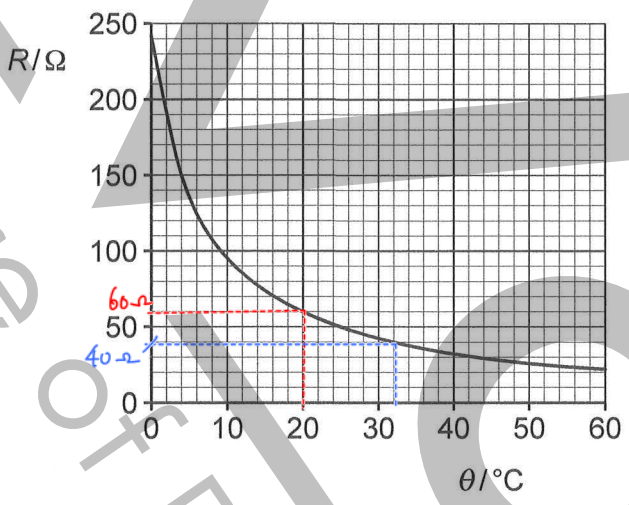


Fig. 6.2

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(a) When the thermistor is at a temperature of 20 °C, the reading on the voltmeter is 0.43 V.

Show that the resistance of the fixed resistor is 24 Ω.

① $R_T = 60\,\Omega$

② $\mathcal{E} = IR_T + IR_F$

$\therefore 1.5 = I(60) + 0.43$

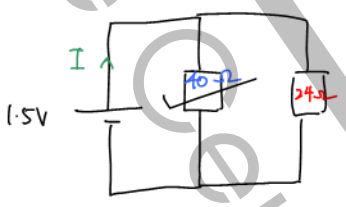
Hence $I = 0.0178333$

③ From ohm's law, $R = \frac{V}{I} = \frac{0.43}{0.0178333} = 24.112 = 24\,\Omega$ shown

[3]

(b) The thermistor and resistor are then connected in parallel with the 1.50 V cell. The temperature of the thermistor is changed to 32 °C.

Determine the current in the cell.



① $R_{eff} = 40 \parallel 24 = 15\,\Omega$

② From ohm's law, $I = \frac{\mathcal{E}}{R_{eff}} = \frac{1.5}{15} = 0.100\,A$ (3sf)

current = ... 0.100 ..... A [3]

[Total: 6]

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7 (a) Explain what is meant by *coherent* light waves.

The waves have the same period, frequency, speed and wavelength. They also have a constant phase difference. [1]

(b) Coherent light of wavelength 640 nm is incident normally on a diffraction grating having 300 lines per millimetre, as shown in Fig. 7.1.

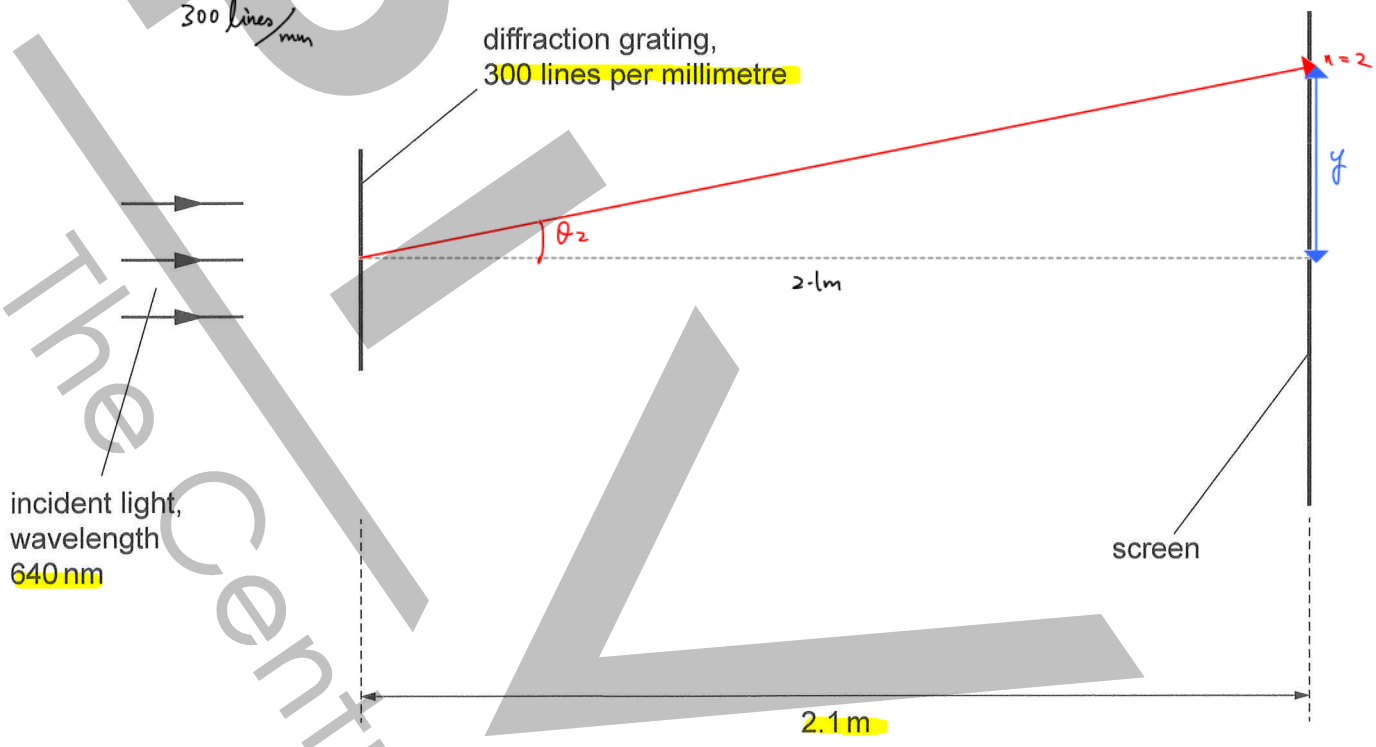


Fig. 7.1 (not to scale)

The planes of the grating and the screen are parallel.

The perpendicular distance between the grating and the screen is 2.1 m.

A diffraction pattern is observed on the screen.

Calculate the distance in cm on the screen from the central (zeroth order) maximum to the second order maximum for this light.

$d\sin\theta = n\lambda$

$\frac{L}{N} \cdot \sin\left[\tan^{-1}\frac{y}{D}\right] = 2\lambda$

$\therefore \frac{1\times10^{-3}}{300} \cdot \sin\left[\tan^{-1}\left(\frac{y}{2.1}\right)\right] = 2(640\times10^{-9})$

$\therefore y = 0.8733\,m$

$= 87.3\,cm$ (3sf)

distance = 87.3 cm [4]

[Total: 5]

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Section B

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

8 Fig. 8.1 shows apparatus used for deflecting an electron beam into a circular path.

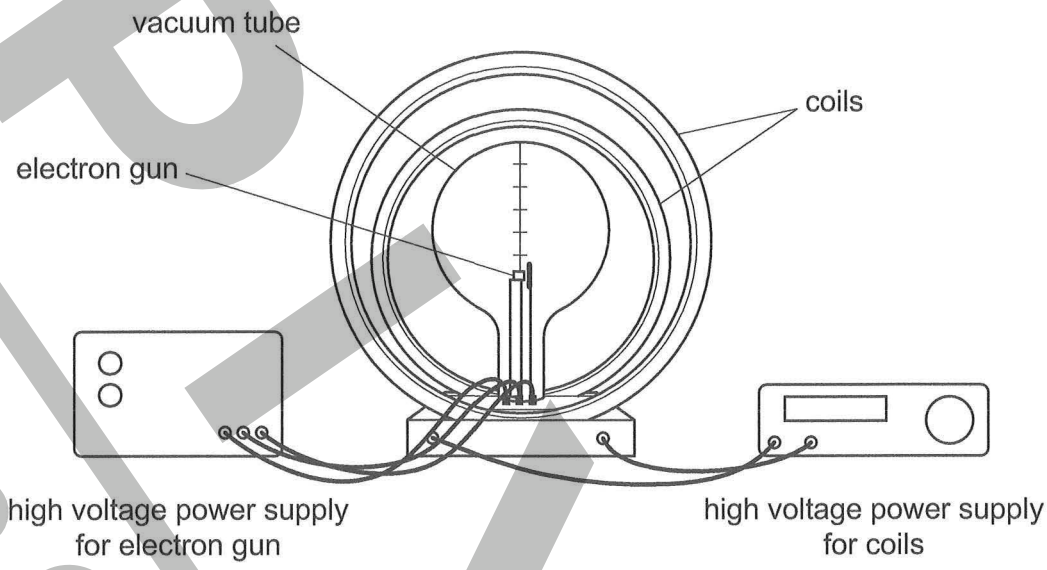


Fig. 8.1

(a) Fig. 8.2 shows a diagram of the electron gun.

Electrons are emitted from a hot cathode. The electric field between the cathode and the anode accelerates the electrons through an accelerating potential difference (p.d.).

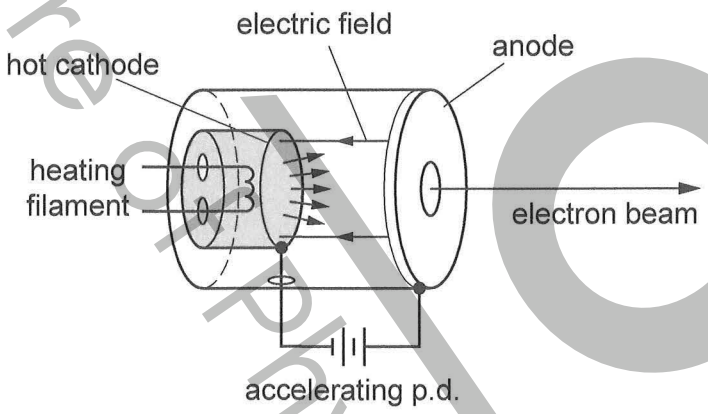


Fig. 8.2

(i) Define *electric field strength* at a point.

Electric force per unit positive test (point) charge placed at a point in an Electric field [1]

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(ii) Explain why the electron gun in Fig. 8.2 must be in a vacuum.

To avoid electrons from colliding with air particles and losing energy. If excess energy is lost, electrons may not even exit the anode.

[2]

(iii) The kinetic energy of the electrons increases by 2.48×10^{-16} J between leaving the cathode and reaching the anode.

Calculate the accelerating p.d.

$W = qV = \Delta KE$

$\therefore V = \frac{\Delta KE}{q} = \frac{2.48 \times 10^{-16}}{1.6 \times 10^{-19}} = 1550 = 1.55\,kV$ (3sf)

accelerating p.d. = 1.55K V [2]

(iv) Explain why the electrons reaching the anode have a range of speeds.

Electrons may collide with other electrons thereby losing kinetic energy. Electrons from the heated cathode may not be ejected horizontally (parallel to the Electric field), but at an angle. Electrons ejected parallel to the Electric field will be the fastest whereas electrons ejected perpendicular to the field will be the slowest. [2]

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(b) Fig. 8.3 shows one of the coils in Fig. 8.1.

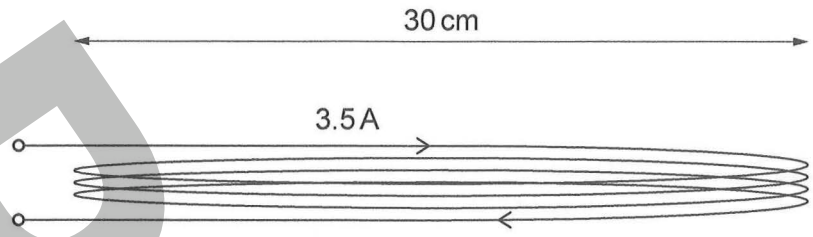


Fig. 8.3 (not to scale)

r = 15cm

The flat circular coil has 120 turns and a diameter of 30 cm. The current in the coil is 3.5A.

(i) Calculate the magnitude of the magnetic flux density B at the centre of the coil in Fig. 8.3 due to the current of 3.5A.

$$B_{centre_coil} = \frac{\mu_0 I}{2r} \cdot N = \frac{(4\pi \times 10^{-7})(3.5)(120)}{0.3} = 1.7592 \times 10^{-3} = 1.76\,m\,T$$

B = 1.76 m T [2]

(ii) Inside the dashed region on Fig. 8.4, sketch the magnetic field pattern due to the current in the flat coil.

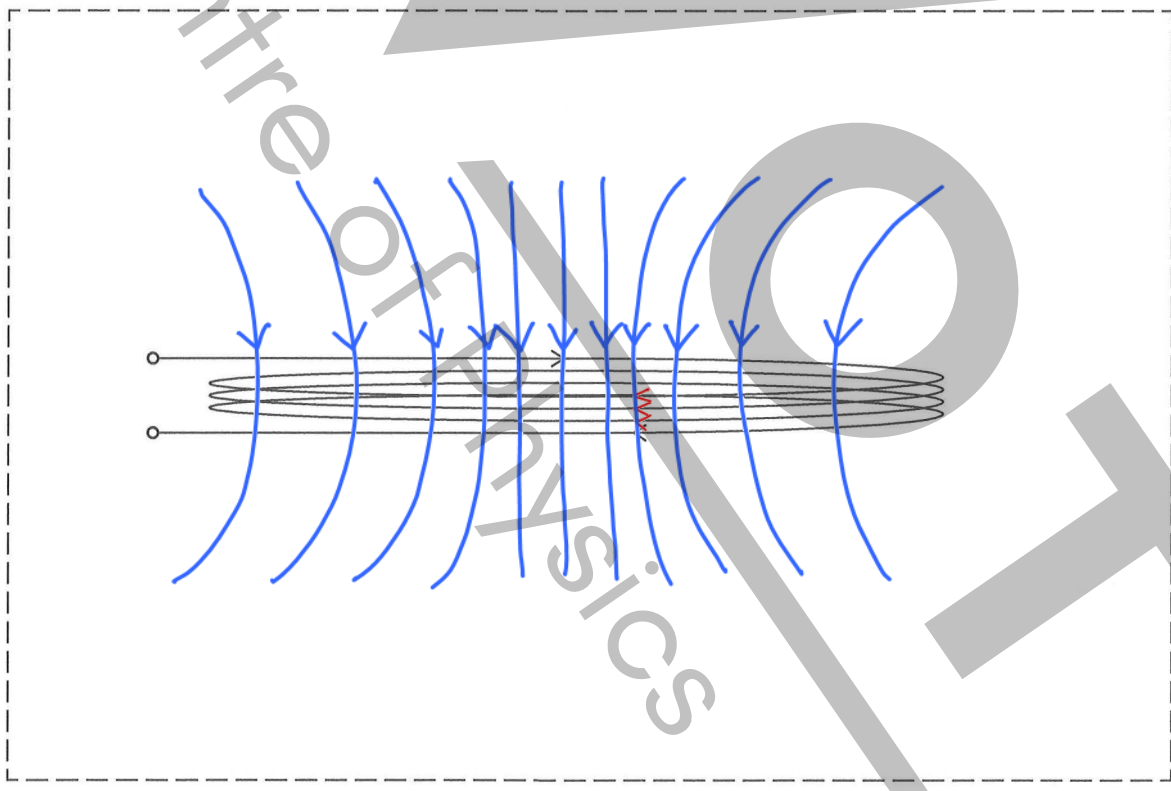


Fig. 8.4 (not to scale) [3]

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(c) The uniform magnetic field created by the two coils in Fig. 8.1 has a magnetic flux density of $1.43B$, where B is the magnetic flux density calculated in **(b)(i)**.

$B = 1.76\,mT$

Initially the electrons passing through the hole in the anode are travelling normally to the magnetic field. The magnetic field is directed out of the page, as shown in Fig. 8.5.

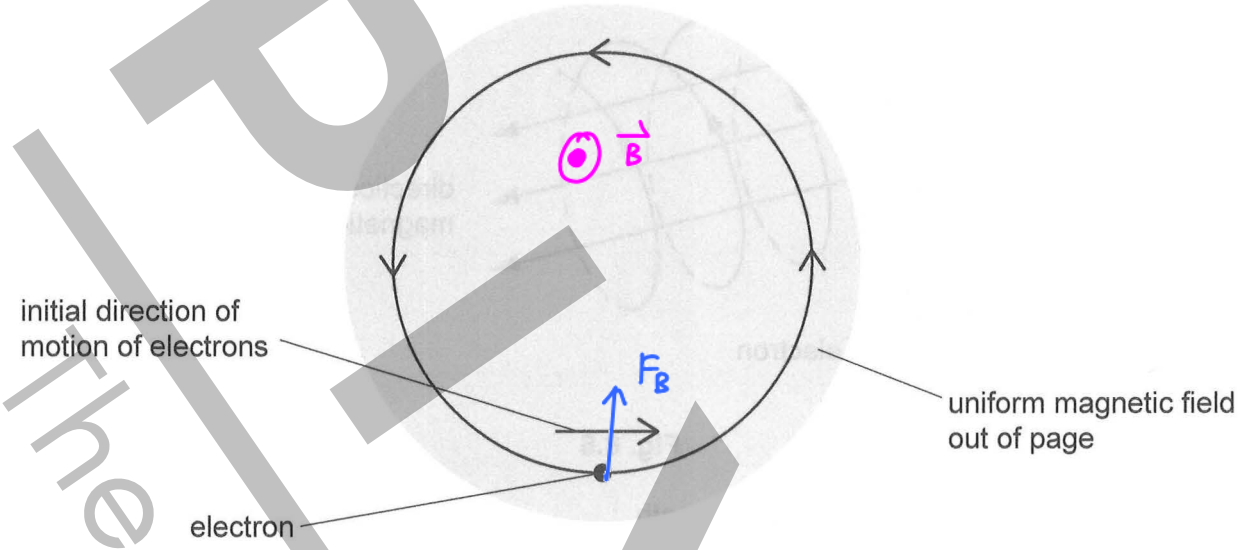


Fig. 8.5 (not to scale)

(i) Explain why the subsequent path of the electrons in the magnetic field is circular.

From Flemings Left hand rule, the magnetic force acting on the electron is perpendicular to its motion, and upwards. The magnetic force is always normal to the electrons' path and is directed towards a fixed point. This magnetic force provides for the centripetal force required for circular motion.

[3]

(ii) Calculate the radius of the circle followed by electrons that have a speed of $2.40 \times 10^7\,m\,s^{-1}$.

$F_B = F_c$

$\therefore Bqv = \frac{mv^2}{r}$

$r = \frac{mv}{Bq} = \frac{(9.11 \times 10^{-31})(2.4 \times 10^7)}{(1.43 \times 1.76 \times 10^{-3})(1.6 \times 10^{-19})} = 0.05429 = 0.0543\,m\ (3sf)$

radius = 0.0543 m [3]

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(d) An electron enters the magnetic field at an angle to the field of less than 90°. The electron follows the path shown in Fig. 8.6.

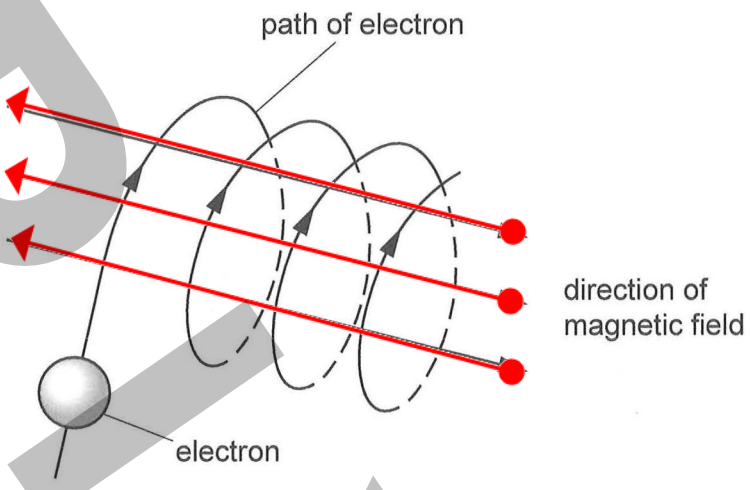


Fig. 8.6

Explain why the electron follows this path.

As the electron enters the magnetic field at an oblique angle, there will be 2 components of velocity. One component is parallel to the magnetic field, providing for horizontal, translational motion (magnetic force horizontally is 0). The other component of velocity is perpendicular to the magnetic field, providing for circular motion (magnetic force provides for centripetal force). [2]

The combination of translational and circular motion gives helical motion (with constant pitch) as shown.

[Total: 20]

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9 When a clean zinc plate is illuminated by electromagnetic radiation of variable frequency, photoelectrons are emitted from the plate. The following observations about the emitted photoelectrons are made:

1. For a constant frequency above a minimum value, the maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident radiation.

2. Below a certain frequency, there is no emission of photoelectrons regardless of the intensity of the radiation.

(a) Explain how these observations provide evidence for the particulate (photon) nature, and **not** the wave nature, of electromagnetic radiation.

1. Electromagnetic (EM) radiation arrives as discrete packets (particles) called photons. Every electron on the metal interacts with the incoming photons on a 1-1 basis. The photon ceases to exist after interaction, by transferring its (constant) energy to an electron. A higher intensity EM radiation (with constant frequency) has more incoming photons (with same energy/power), and liberates more photoelectrons (with constant maximum kinetic energy according to conservation of energy).

2. Below the threshold frequency (or workfunction) of the metal, no photoelectrons are ejected. The workfunction (threshold frequency × Planck constant) is the minimum energy required by the incoming photons to liberate the electrons. Photons are discrete packets, whose energy is non-cumulative. The photon-electron interaction is 1-1. Even with higher intensity, if photon energy is smaller than workfunction of metal, no electrons are liberated. Classical physics suggests that with higher intensity, over time, energy is accumulated and electrons are liberated, but this is not observed in real life. [4]

(b) State the name of the frequency described in observation 2.

threshold frequency [1]

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(c) The zinc plate has a work function energy of 4.33 eV. Electromagnetic radiation of wavelength 210 nm is incident on the plate.

Calculate the maximum kinetic energy of the emitted photoelectrons.

$hf = \phi + |KE_{max}|$

$\therefore |KE_{max}| = \frac{hc}{\lambda} - \phi = \frac{(1.989 \times 10^{-25}}{210 \times 10^{-9}} - (4.33)(1.6 \times 10^{-19}) = 2.543 \times 10^{-19} = 2.54 \times 10^{-19}$ J (3sf) #

maximum kinetic energy = ... 2.54×10^{-19} ..... J [3]

(d) In order to measure the maximum kinetic energy of the emitted photoelectrons in **(c)**, the zinc plate is placed in the apparatus shown in Fig. 9.1.

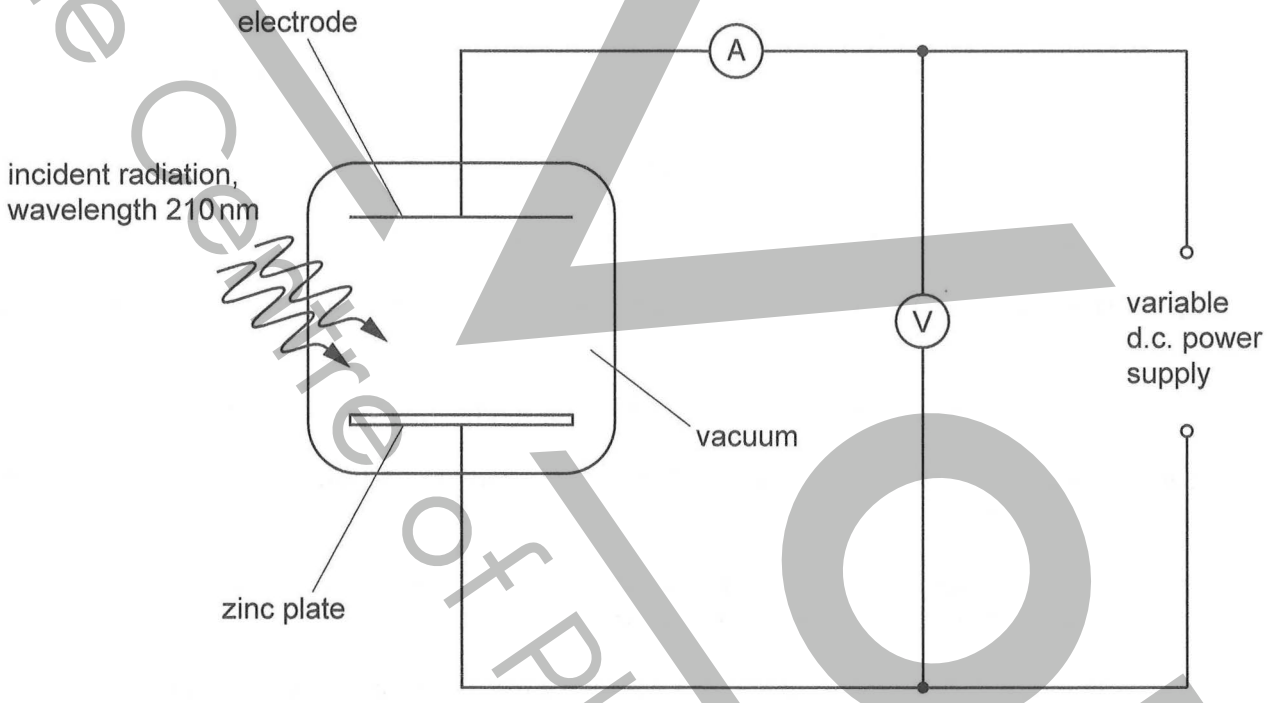


Fig. 9.1

The potential difference between the electrode and the zinc plate is gradually increased from zero until the current reading on the ammeter just decreases to zero. The potential of the electrode is negative with respect to the zinc plate.

The minimum potential difference for zero current is called the stopping potential.

Use your answer in **(c)** to calculate the stopping potential for the emitted photoelectrons.

$|eV_s| = |KE_{max}|$

$\therefore V_s = \frac{KE_{max}}{e} = \frac{2.543 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.589 = 1.59$ V #

stopping potential = ... 1.59 ..... V [2]

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(e) The potential of the electrode in Fig. 9.1 is varied from –5.0 V to +5.0 V with respect to the zinc plate.

The variation of the current I with the potential difference V is shown in Fig. 9.2.

(ii) ① $\frac{hc}{\lambda} = \phi + eV_s$ ↑ ; $\frac{hc}{\lambda}$ ↓ ; const

② $I = \frac{P}{A} = \frac{E}{tA} = \frac{nhc}{tA\lambda}$; const ; λ ↓

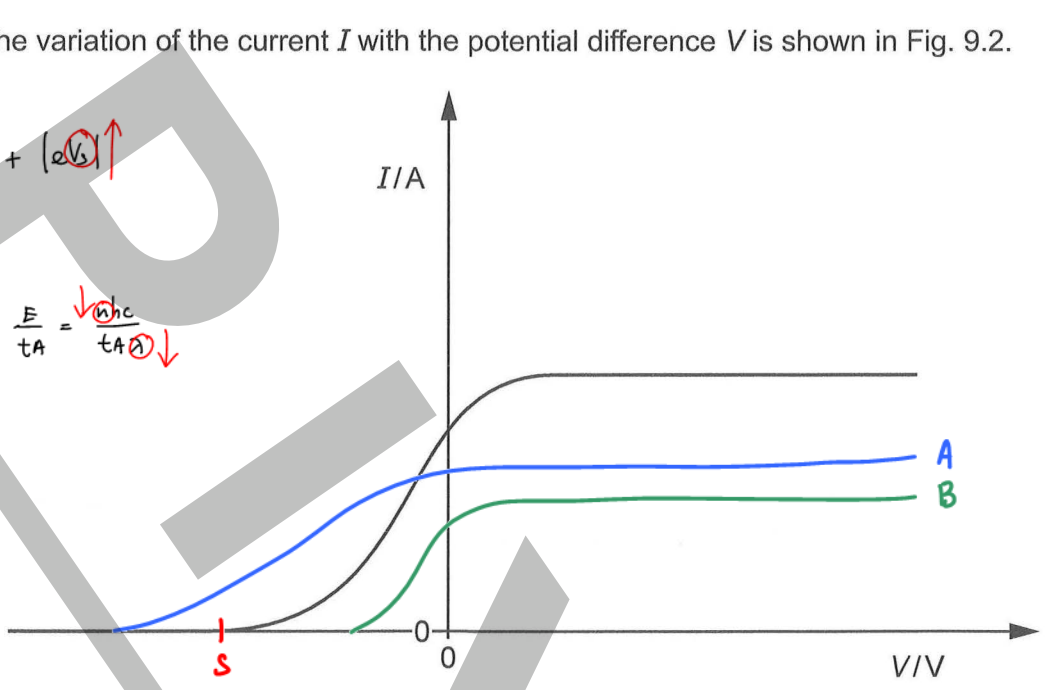


Fig. 9.2

~~(i)~~ On Fig. 9.2, mark with the letter S, the stopping potential. [1]

~~(ii)~~ The zinc plate is now illuminated with radiation of a shorter wavelength but the same intensity as in **(c)**.

On Fig. 9.2, draw the variation of I with V for the new wavelength. Label this line A. [2]

~~(iii)~~ The wavelength of the incident radiation is returned to 210 nm. The intensity remains the same as in **(c)**.

(iii) ① $\frac{hc}{\lambda} = \phi + eV_s$; $\frac{hc}{\lambda}$ ↑ ; eV_s ↓ ; const

② ϕ ↑ means harder to eject photoe⁻. ∴ I_{max} ↓

The zinc plate is replaced with a metal plate that has a greater value of work function energy. Photoelectrons are still emitted.

On Fig. 9.2, draw the variation of I with V for the new plate. Label this line B. [1]

(iv) By reference to the photoelectrons explain why, for certain values of V, the current I is zero.

When V is at (or more negative than) the stopping potential, even the fastest and most energetic photo-electron (photo-electron ejected from metal surface) is stopped from reaching the electrode. By conservation of energy, the kinetic energy of the photo-electrons is converted to electric potential energy, before reaching the electrode. Current is rate of flow of charges (electrons) with respect to time. [2]
Since no photo-electrons reach the electrode, current registered is 0.

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(f) The electromagnetic radiation in **(c)** comprises photons which are emitted from an atom when electrons change energy levels within the atom.

A representation of some energy levels and their associated energies is shown in Fig. 9.3.

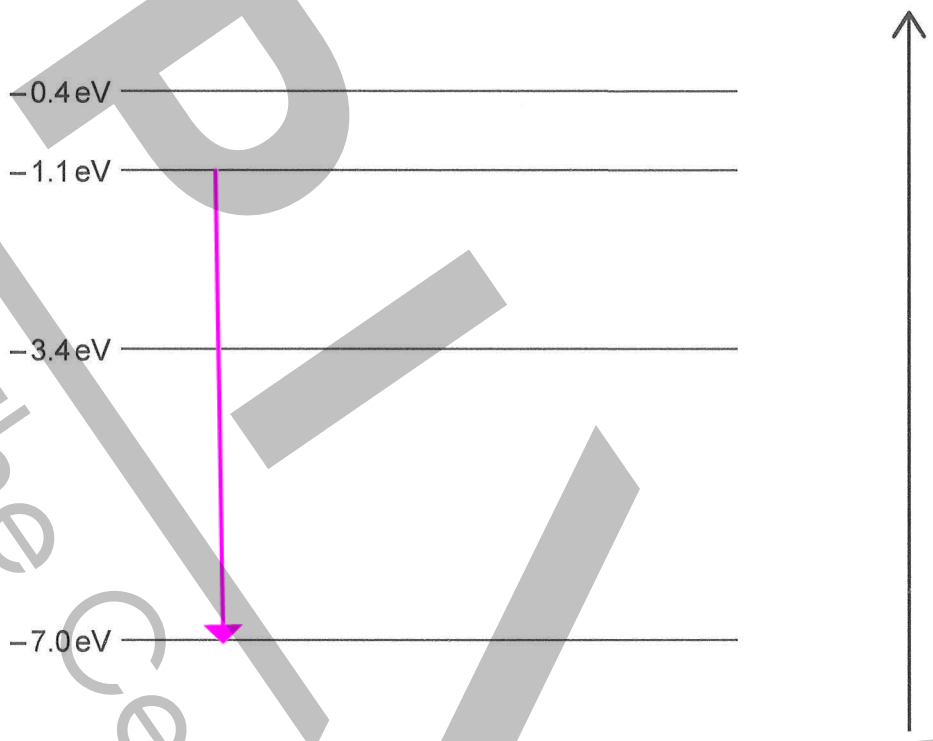


Fig. 9.3

~~(i)~~ On Fig. 9.3, draw an arrow to show the electron transition between energy levels that causes the emission of the photons in **(c)**. [2]

(ii) Calculate the wavelength of the photon with the longest wavelength that can be emitted by the transition of an electron between the energy levels shown in Fig. 9.3.

Explain your working.

① $\downarrow E = \frac{hc}{\lambda} \uparrow$

② for longest λ to be emitted, ΔE must be smallest

③ $\therefore \Delta E = \frac{hc}{\lambda}$

So, $\lambda = \frac{hc}{\Delta E} = \frac{1.989 \times 10^{-25}}{(1.1-0.4)(1.6 \times 10^{-19})} = 1.7758 \times 10^{-6} = 1.78\,\mu m$

(i) $E = \frac{hc}{\lambda} = \frac{1.989 \times 10^{-25}}{210 \times 10^{-9}}$

$= 9.4714 \times 10^{-19}$ J

$= 5.919$ eV

wavelength = ... 1.78 μ ..... m [2]

[Total: 20]

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