Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2024 Preliminary Examination

PHYSICS **8867/02**
Higher 1

11 September 2024
Paper 2 Structured Questions **2 hours**

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

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only. **Circle the question that you had attempted.**

You are advised to spend one and 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	
	1	/ 8
	2	/ 9
	3	/ 5
	4	/ 8
	5	/ 5
	6	/ 8
	7	/ 9
	8	/ 8
Circle either number	**9 or 10**	/ 20
	Deduction	
	Total	/ 80

This document consists of **24** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
elementary charge	e	=	1.60×10^{-19} C
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
gravitational constant	G	=	6.67×10^{-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	=	$u^2 + 2as$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

Section A

Answer ALL questions from this section.

1 A small ball at the bottom of a frictionless slope is projected up the slope with speed u, as shown in Fig. 1.1.

The slope has a height of 4.0 m and makes an angle of 30° to the horizontal ground.

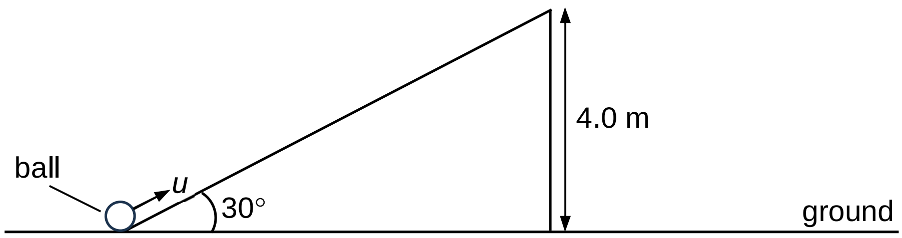

Fig. 1.1

(a) In one instance, $u = 7.0$ m s^{-1}.

(i) Calculate the maximum distance s_0 from the bottom of the slope that the ball reaches.

s_0 = ... m [2]

(ii) As the ball moves up the slope from the bottom, draw on Fig. 1.2 the variation with distance s travelled by the ball from the bottom of the slope of its

1. kinetic energy (label as E_K),

2. potential energy (label as E_P). Potential energy at the bottom of the slope is zero. [2]

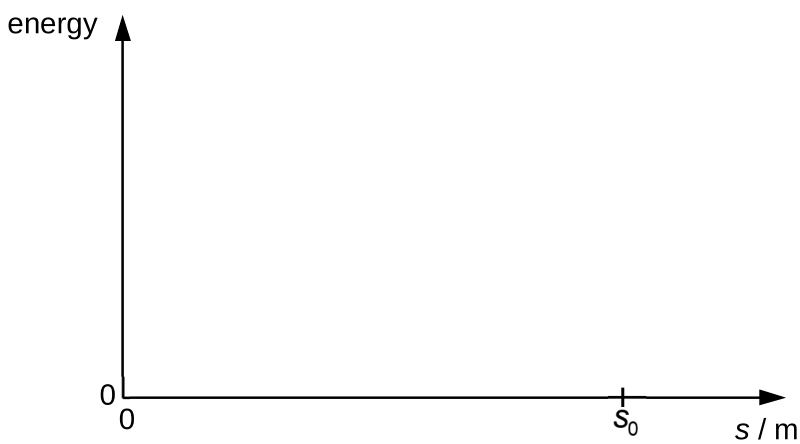

Fig. 1.2

(b) In another instance, $u = 14.0\ \text{m s}^{-1}$.

The ball travels to the top of the slope, leaves the slope and hits the ground.

(i) Show that the speed of the ball at the top of the slope is $10.8\ \text{m s}^{-1}$.

[1]

(ii) Calculate the horizontal distance travelled by the ball after it leaves the slope.

distance = ... m [3]

[Total: 8]

2 Two identical balls A and B approach each other along the same straight line on a smooth horizontal surface, as shown in Fig 2.1.

Fig. 2.1

At time $t = 0$ s, ball A moves towards ball B with a speed of 4.0 m s^{-1}, while ball B moves towards ball A with a speed of 1.0 m s^{-1}. Each ball has a mass of 0.50 kg.

At time $t = 0.50$ s, the balls undergo a head-on elastic collision and are in contact for a duration of 0.25 s.

After the collision, ball A moves with velocity v_A and ball B moves with velocity v_B.

(a) Explain whether both balls could be stationary at the same time during the collision.

....

....

....

....

.... [2]

(b) Show that v_B is 4.0 m s^{-1}.

[2]

(c) Calculate the magnitude of the average force on ball A during the collision. Explain your working.

force = ... N [3]

(d) Fig. 2.2 shows the variation with time t of the momentum p_A of ball A and momentum p_B of ball B before the collision.

On Fig. 2.2, complete the graphs for p_A and p_B from $t = 0.50$ s to $t = 1.5$ s .

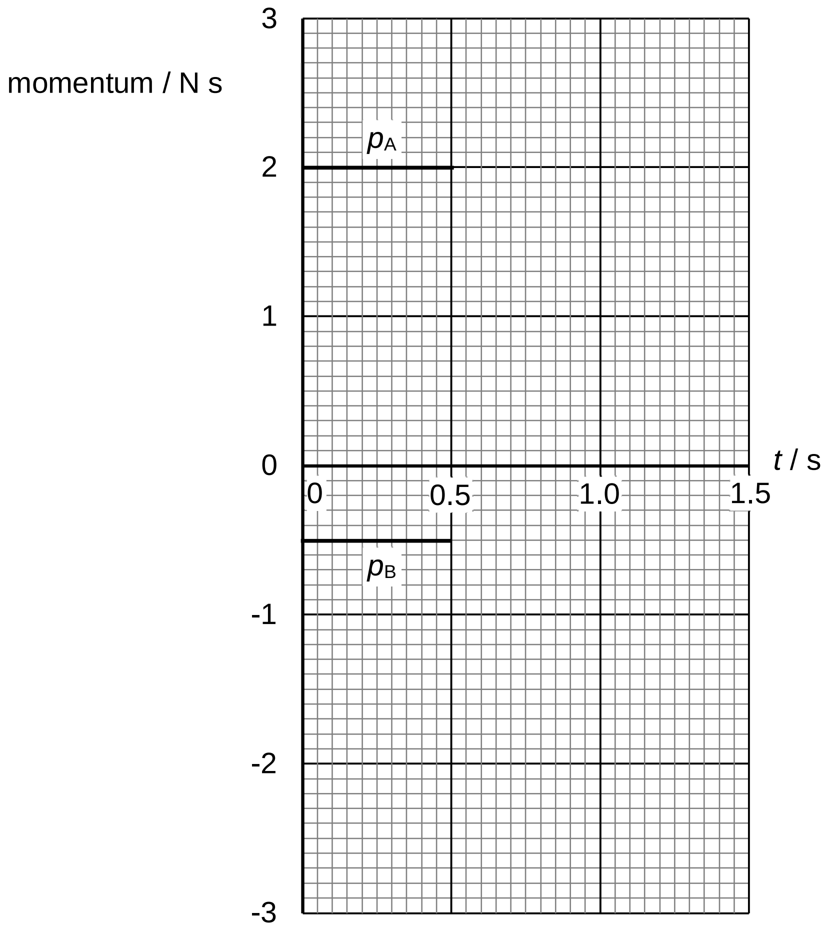

Fig. 2.2

[2]

[Total: 9]

3 A uniform circular disc of radius R and weight W is in contact with a smooth horizontal ground and the corner of a box of height $\frac{R}{2}$, as shown in Fig. 3.1.

A horizontal force F acts at the centre O of the disc to keep the disc in equilibrium.

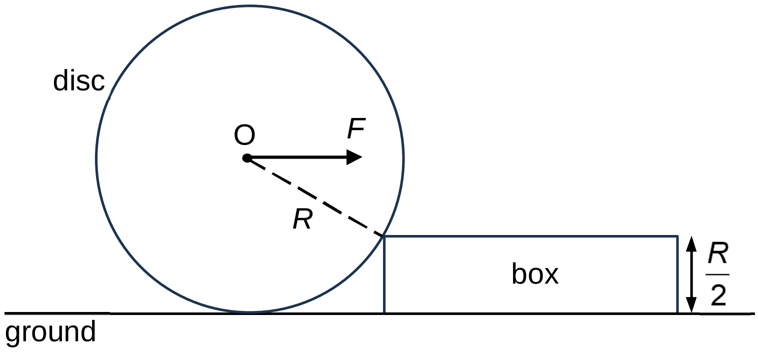

Fig. 3.1

(a) Force F is increased until the disc is just about to rotate about the corner of the box. Use the principle of moments to determine the ratio $\frac{F}{W}$. Explain your working.

$\frac{F}{W}$ = ... [3]

(b) The box is replaced with one of height R.

State and explain how the force F acting at the centre O would need to be changed for the disc to rotate about the corner of the box.

....

....

....

.... [2]

[Total: 5]

4 A ball of mass m is attached to one end of a light inextensible string of length L. The other end of the string is attached to a fixed point O.

(a) The ball is swung around in a vertical circle, as shown in Fig. 4.1. The speeds of the ball at the top and bottom of the vertical circle are v_T and v_B respectively.

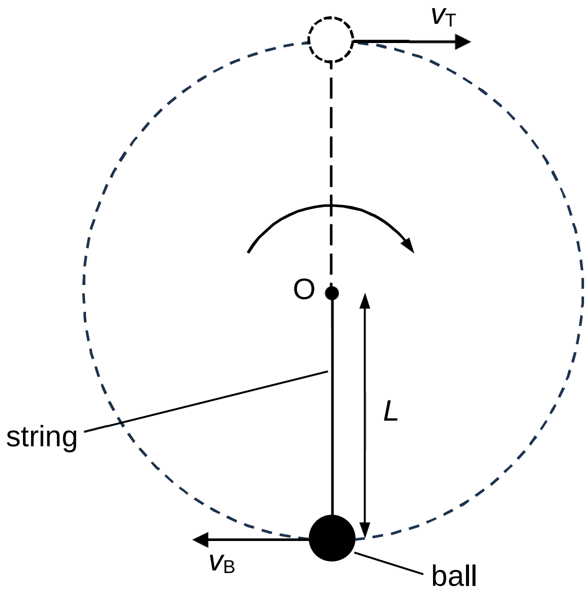

Fig. 4.1

(i) Show that for the ball to just complete the vertical circle, $v_T = \sqrt{gL}$.
Explain your working.

[2]

(ii) Explain why the ratio $\frac{v_B}{v_T}$ must be greater than 1 for the ball to complete the vertical circle.

....

....

.... [1]

(iii) A student wishes to swing the ball in a vertical circle such that $\frac{v_B}{v_T} = 3$.

With appropriate calculations, state and explain if this ratio is achievable.

....

....

.... [3]

(b) The ball is now swung in a horizontal circle around the fixed point O, as shown in Fig. 4.2.

When the ball is swinging around with angular velocity ω, the string is at an angle θ from the vertical and the tension in the string is T.

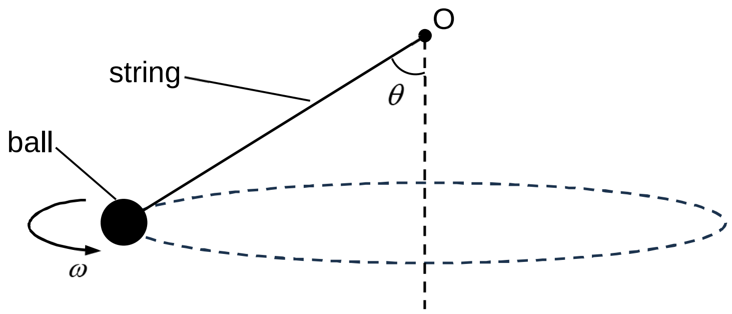

Fig. 4.2

Determine the tension in the string, in terms of T, when the angular velocity of the ball is doubled.

tension = ... [2]

[Total: 8]

5 **(a)** State *Newton's law of gravitation*.

....

....

.... [1]

(b) A satellite is launched from the surface of the Earth so that it orbits about the centre of the Earth. The height of the orbit from the surface of the Earth is 2.1×10^{7} m.

(i) Show that the speed v of the satellite in its orbit is given by the expression

$$v = \sqrt{\frac{GM_{E}}{r}}$$

where M_{E} is the mass of the Earth and r is the radius of orbit.

Explain your working.

[2]

(ii) When the satellite of mass 1600 kg reaches the height of its orbit, the increase in gravitational potential energy is 7.67×10^{10} J. The Earth has a radius of 6400 km and a mass of 6.0×10^{24} kg.

Calculate the energy required to launch the satellite into orbit. Neglect the effects of the rotation of the Earth.

energy = ... J [2]

[Total: 5]

6 A battery of e.m.f. 9.0 V and negligible internal resistance is connected to resistors P and Q, a light dependent resistor (LDR) and ammeters A_1 and A_2, as shown in Fig. 6.1.

The resistance of P is $4.0\ \text{k}\Omega$ and the resistance of Q is $6.0\ \text{k}\Omega$.

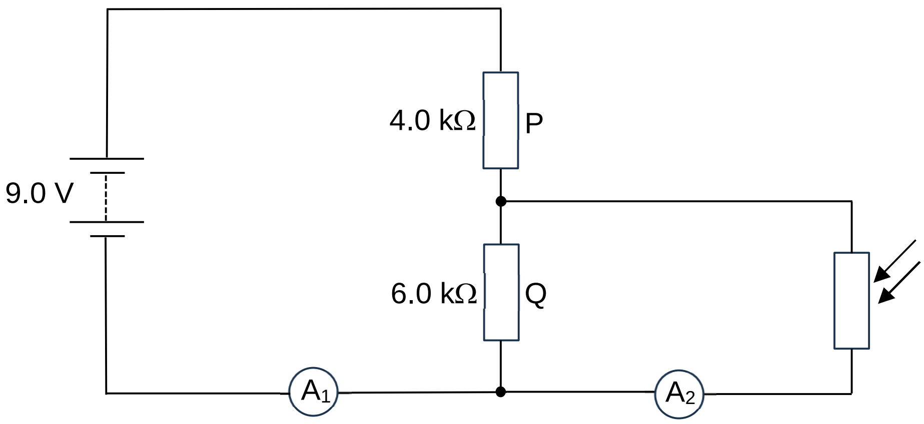

Fig. 6.1

(a) The intensity of the light incident on the LDR is such that the resistance of the LDR is $8.0\ \text{k}\Omega$.

Determine the current reading on

(i) ammeter A_1,

current = ... A [2]

(ii) ammeter A_2.

current = ... A [2]

(b) The intensity of the light incident on the LDR is lowered.

State and explain the following changes:

(i) The potential difference across Q increases.

....

....

....

....

.... [2]

(ii) The current reading on ammeter A_2 decreases.

....

....

....

....

.... [2]

[Total: 8]

7 A cell of e.m.f. 1.50 V and internal resistance 0.25 Ω is connected in series with a resistor R, as shown in Fig. 7.1. A current of 0.24 A passes through resistor R for a time of 5.0 minutes.

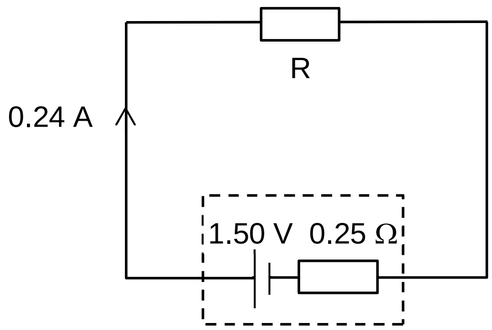

Fig. 7.1

Calculate

(a) the total number of electrons that pass through the cell,

number = ... [3]

(b) the potential difference across resistor R,

potential difference = ... V [2]

(c) the resistance of R,

resistance = ... Ω [2]

(d) the energy transferred in the resistor R.

energy = ... J [2]

[Total: 9]

8 Hydrogen is the most abundant material in the universe and the most basic nuclear fusion reaction is the fusion of two hydrogen nuclei ($^{1}_{1}H$).

(a) State what is meant by *nuclear fusion*.

....

....

.... [1]

(b) The minimum kinetic energy of each hydrogen nucleus needed to trigger a $^{1}_{1}H$ - $^{1}_{1}H$ fusion reaction is 0.30 MeV. The radius of a hydrogen nucleus is 1.2×10^{-15} m , and t

Calculate the minimum speed of each hydrogen nucleus to cause a fusion reaction.

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

(c) There are two possible outcomes of such a fusion reaction. In reaction (1), a helium isotope $^{2}_{2}He$ is formed. In reaction (2), a deuteron $^{2}_{1}H$ and an unknown elementary particle X is formed.

reaction (1): $^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{2}He$

reaction (2): $^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + X$

(i) State the nuclear notation for X.

$^{\boxed{}}_{\boxed{}}X$

[1]

(ii) Deuteron ${}^{2}_{1}H$ is readily found on Earth, but not the helium isotope ${}^{2}_{2}He$.
Suggest a possible reason for this observation and hence deduce which reaction releases more energy.

....

....

.... [1]

(d) Data for the nuclei in reaction (2) are given in Fig. 8.1.

nucleus	mass / u
${}^{1}_{1}H$	1.007825
${}^{2}_{1}H$	2.014102
X	0.000549

Fig. 8.1

Calculate the energy released in reaction (2).

energy = ... J [2]

(e) Suggest one significant advantage in generating electrical power by a fission reaction compared to a fusion reaction.

....

....

.... [1]

[Total: 8]

Section B

Answer ONE question from this section.

9 **(a)** State what is meant by

(i) the *resistance* of a wire,

....

.... [1]

(ii) the *resistivity* of the material of a wire.

....

....

.... [2]

(b) A flat circular coil of diameter 22.0 cm is connected in series with a battery of e.m.f. 6.0 V and internal resistance 0.10 Ω, as shown in Fig. 9.1. The current in the circuit is 1.2 A.

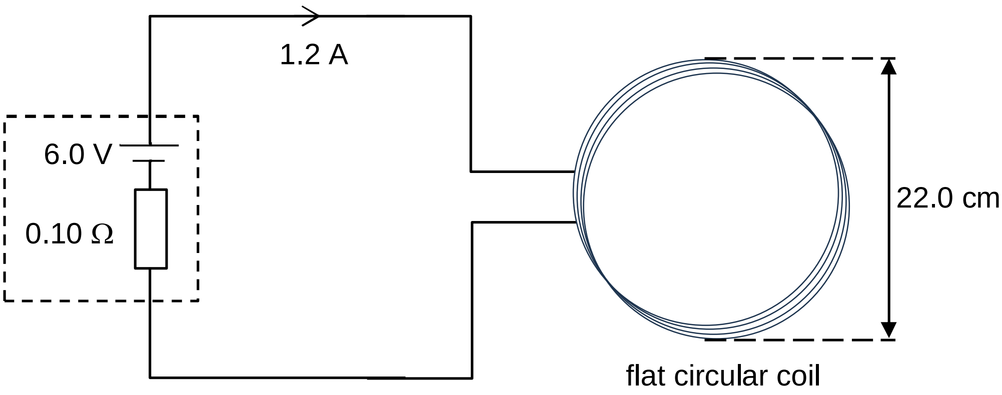

Fig. 9.1

(i) Show that the resistance of the coil is 4.9 Ω.

[2]

(ii) The coil is made of copper wire of diameter 0.60 mm and resistivity $1.7 \times 10^{-8}\ \Omega$ m.

Determine the number of turns in the coil.

number = ... [2]

(c) Two coils, each one similar to that in **(b)**, are fixed so that their planes are parallel and are separated by a constant distance, as shown in Fig. 9.2. The current I in both coils is 1.2 A.

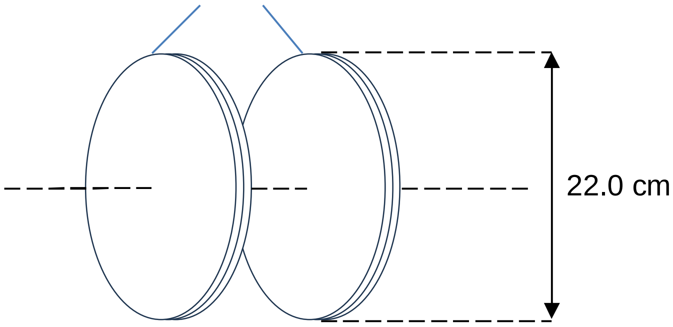

Fig. 9.2

The magnetic flux density B in the region between the two coils is uniform and given by the expression

$$B = 9.05 \times 10^{-7} \frac{NI}{r}$$

where N is the number of turns in each of the coil of radius r.

Calculate the magnetic flux density B.

B = ... mT [2]

(d) The space between the coils in **(c)** is a vacuum.

An electron travels at right-angles to the uniform magnetic field produced by the two coils in **(c)** with a kinetic energy of 250 eV.

Calculate, for the electron,

(i) the magnitude of its momentum,

momentum = ... N s [2]

(ii) the radius of its orbit in the magnetic field.

radius = ... m [2]

(e) The magnetic field in **(d)** is rotated such that the initial direction of the electron is now at an angle to the direction of the uniform magnetic field, as shown in Fig. 9.3.

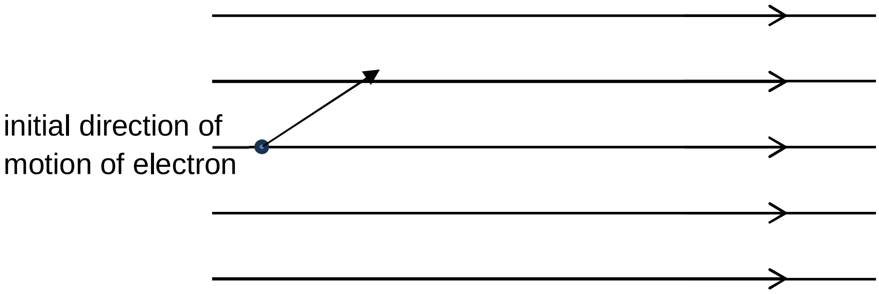

Fig. 9.3

By considering the components of the velocity parallel to the magnetic field and at right-angles to the magnetic field, describe and explain qualitatively the motion of the electron in the field.

....

....

....

....

....

....

....

.... [4]

(f) The magnetic field in **(e)** is replaced with an electric field acting in the same direction as shown in Fig. 9.3.

(i) State the direction of the force on the electron when it enters the electric field.

.... [1]

(ii) Describe and explain qualitatively the motion of the electron in the electric field.

....

....

.... [2]

[Total: 20]

10 **(a)** Two parallel, vertical plates are connected to a battery of e.m.f. 24 V, as shown in Fig. 10.1. The length of each plate is 24 mm and the distance between the plates is 12 mm.

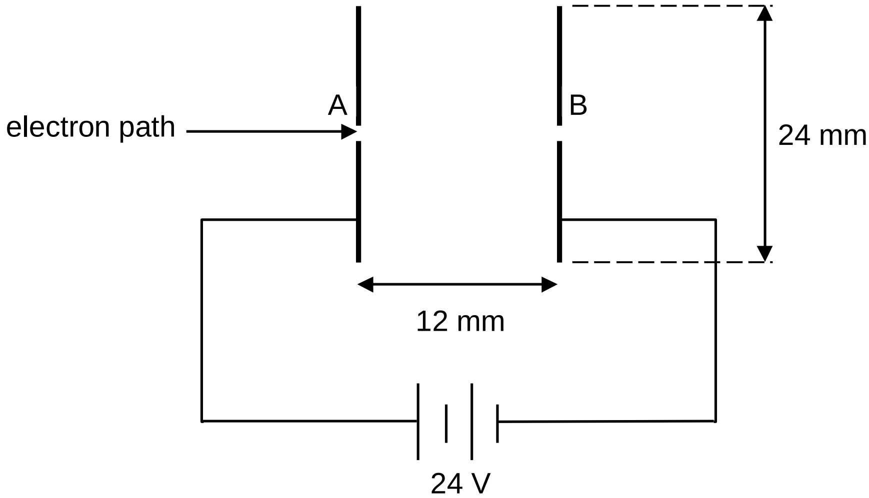

Fig. 10.1 (not drawn to scale)

An electron travels with a horizontal speed of 4.5×10^6 m s^{-1} in a vacuum and passes through holes A and B, which are at the centre of each plate.

(i) Define *electric field strength*.

....

.... [1]

(ii) On Fig. 10.1, draw six lines to represent the electric field between the plates. [2]

(iii) The magnitude of the electric field strength between two parallel plates is given by the ratio of the potential difference between the plates to the distance between them.

Calculate

1. the electric field strength between the parallel plates of Fig. 9.1,

electric field strength = ... N C^{-1} [1]

2. the force F of the electric field on the electron,

F = ... N [1]

3. the work done by the force *F* on the electron as it moves from A to B.

work done = ... J [2]

4. the speed of the electron as it exits hole B.

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

(b) The parallel plates of Fig. 10.1 are re-arranged such that they are now horizontal and the electron enters mid-way between the plates with the same horizontal speed of 4.5×10^6 m s^{-1}, as shown in Fig. 10.2.

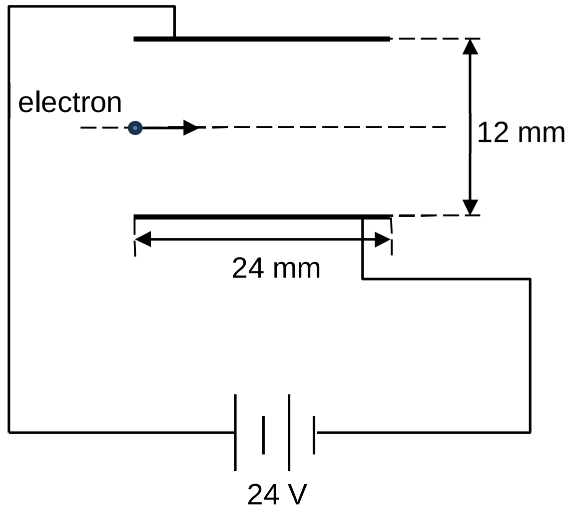

Fig. 10.2 (not drawn to scale)

(i) Describe and explain qualitatively the motion of the electron in the regions between and beyond the plates.

....

....

....

....

....

.... [3]

(ii) Calculate

1. the acceleration of the electron in the region between the parallel plates,

acceleration = ... m s^{-2} [2]

2. the speed of the electron as it exits the region between the parallel plates,

speed = ... m s^{-1} [4]

3. the angle of deflection of the electron from its original path as it exits the region between the parallel plates.

angle = ... ° [2]

[Total: 20]

End of Paper 2