VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME

CLASS

TUTOR NAME

PHYSICS 9749/03

Paper 3 Longer Structured Questions **18 September 2025**

2 hour

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and tutor 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 a HB pencil for any diagrams, 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.

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	
1	/ 7
2	/ 10
3	/ 8
4	/ 9
5	/ 7
6	/ 9
7	/ 10
8	/ 20
9	/ 20
Total	/ 80

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	$p = \rho gh$
gravitational potential	$\phi = -Gm / r$
temperature	$T / \text{K} = T / {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal 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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Fig. 1.1 shows a 1000 N uniform thin rod being towed by a force T and moving at constant horizontal velocity.

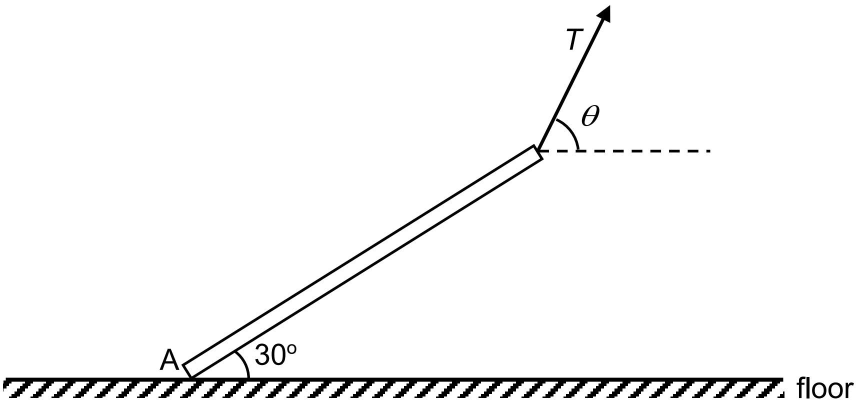

Fig. 1.1

(a) State the conditions required for a body to be in *equilibrium*.

....

....

....[2]

(b) On Fig. 1.1, draw and label the **two** other forces acting on the rod. [2]

(c) Given angle θ is 70°, determine force T.

force T = ... N [3]

[Total: 7]

2 The International Space Station (ISS) orbits the Earth at a height of 4.1×10^{5} m above the Earth's surface. The radius of the Earth is 6.37×10^{6} m.

(a) Both the ISS and the astronauts inside it are in free fall. Explain why this makes the astronauts feel weightless

....

....[1]

(b) **(i)** Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

g = ... N kg^{-1} [2]

(ii) State the value of the centripetal acceleration of ISS at this height.

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

(iii) The speed of the ISS in its orbit is 7.7 km s^{-1}. Show that the period of the ISS in its orbit is 92 minutes.

[2]

(iv) The ISS is in a low Earth orbit. Suggest an advantage of this orbit as compared to higher orbits.

....

....[1]

(c) The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

7% of the energy of the sunlight incident on the cells is stored in the batteries. The total area of the cells facing the solar radiation is 2500 m^2. The intensity of solar radiation at the orbit of the ISS is 1.4 kW m^{-2} outside of the Earth's shadow and zero inside it. The ISS passes through the Earth's shadow for 35 minutes during each orbit.

By reference to **(b)(iii)**, calculate the average power delivered to the batteries during one orbit.

average power = ... W [3]

[Total: 10]

3 **(a)** Define the term *angular velocity*.

....

.... [1]

(b) A 10 kg baggage is left on a rotating baggage carousel at an airport as shown in Fig. 3.1.

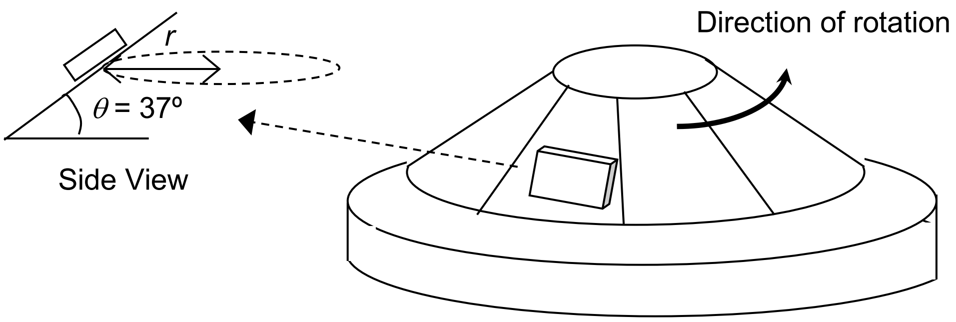

Fig. 3.1

The baggage stays at a fixed position on the slope of the carousel and rotates about in a circle of radius 10 m. The angle θ that the slanted surface makes with the horizontal is 37°. The frictional force acting on the baggage is 60 N. The baggage is moving in uniform circular motion.

(i) Explain, using Newton's law(s) of motion, why the baggage will experience a net force towards the centre of the circle.

....

....

....

....[2]

(ii) Considering the forces acting on the baggage, show that the normal contact force is 78 N.

[2]

(iii) Calculate the time required for the baggage to complete one full rotation.

time = ... s [3]

[Total: 8]

4 **(a)** Explain what is meant by an *ideal gas*.

....

....

....[1]

(b) Two vessels X and Y of volumes 10.0×10^{-4} m^3 and 3.0×10^{-4} m^3 are connected by a tube of negligible volume and kept at temperatures 200 K and 100 K respectively. Assume both vessels contain the same monatomic ideal gas.

Calculate the ratio of $\dfrac{\text{number of moles of gas in X}}{\text{number of moles of gas in Y}}$.

ratio = ... [2]

(c) An ideal gas in a container with a movable piston is heated. At the same time, the volume is increased such that the temperature of the gas always remains constant. By considering the First Law of Thermodynamics, explain why the temperature of the gas remains constant even though it is heated.

....

....

....

....[2]

(d) Fig. 4.1 below shows how the pressure p of the gas varies with its volume V in part **(c)**. The volumes of the gas at initial and final states are V_A and V_B respectively. The pressures of the gas at initial and final are p_A and p_B respectively.

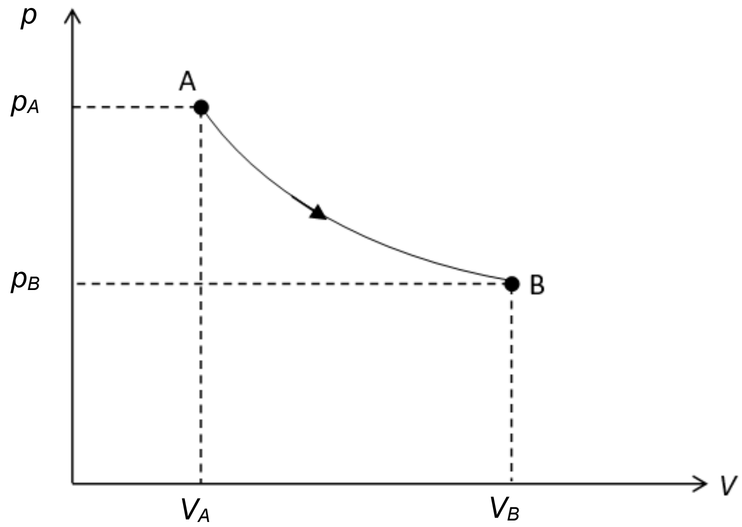

Fig. 4.1

The container in **(c)** is now insulated. The volume of the gas is increased to V_B again.

(i) Use the First law of Thermodynamics to explain whether the final pressure is higher or lower than p_B.

....

....

....

....

....[3]

(ii) Sketch, on Fig. 4.1, a graph to show the variation with volume of pressure of the gas as its volume increases in the insulated container. [1]

[Total: 9]

5 **(a)** The variation with time t of the potential difference V_1 across a resistor is shown in Fig. 5.1.

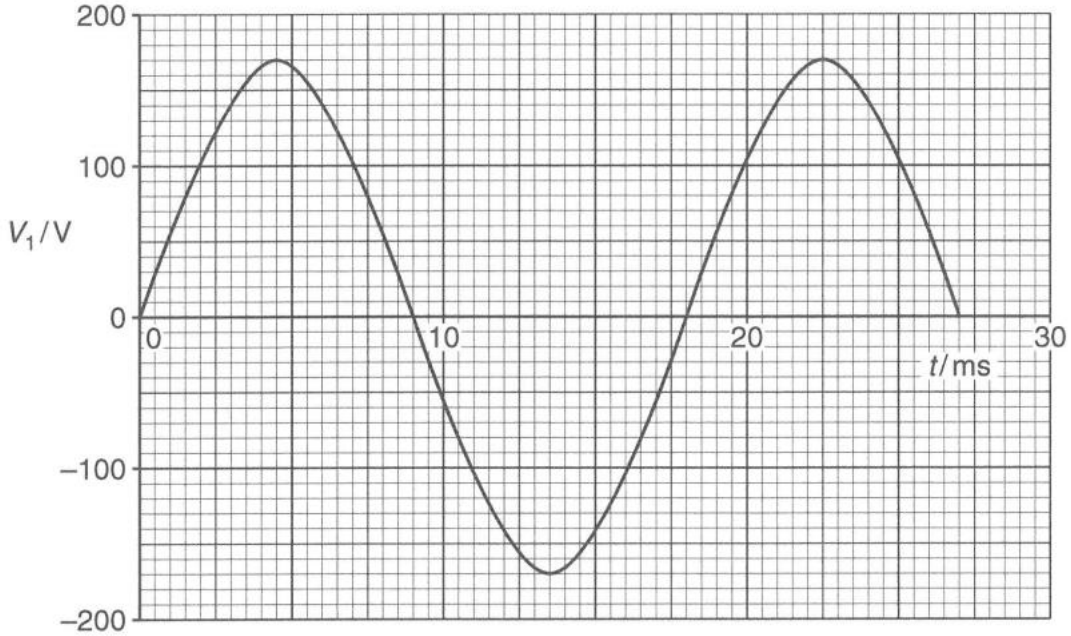

Fig. 5.1

The relation between V_1 and t is given by

$$V_1 = V_0 \sin \omega t\ .$$

Use Fig. 5.1 to determine the root-mean-square voltage of V_1.

root-mean-square voltage = ... V [1]

(b) The potential difference V_1 shown in Fig. 5.1 is connected to an ideal transformer, as shown in Fig. 5.2. The primary coil has 500 turns and the secondary coil has 20 turns. The secondary coil is connected to an open switch and a 15 Ω resistor.

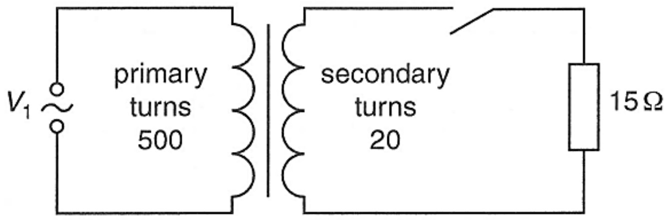

Fig. 5.2

The switch in the secondary circuit is now closed.

Determine

(i) the peak current in the 15 Ω resistor,

peak current = ... A [2]

(ii) the mean power dissipated in the 15 Ω resistor.

mean power dissipated = ... W [2]

(c) For a non-ideal transformer, suggest why thermal energy is generated in the soft iron core when the transformer is in use.

....

....

....

....[2]

[Total: 7]

6 A single-turn copper square frame of length L is rotated with constant angular speed ω by an external torque in a constant magnetic field of flux density B. The frame rotates counterclockwise about the axis of rotation as shown in Fig. 6.1.

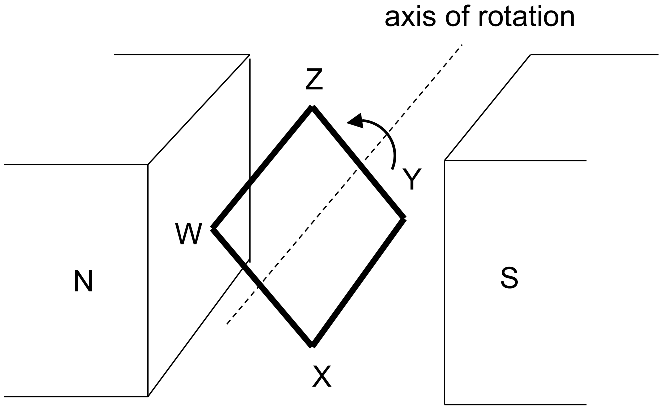

Fig. 6.1

Fig. 6.2 shows the side view of the coil when WX is at an angle θ above the horizontal.

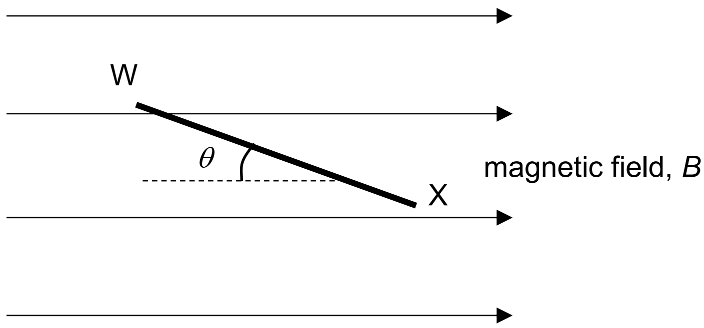

Fig. 6.2

(a) State the direction of the induced current in the frame.

....[1]

(b) Explain why an external torque is required to maintain the rotation of the frame at a constant angular speed.

....

....

....

....[2]

(c) **(i)** At the instant shown in Fig. 6.2, write down an expression for the flux linkage in the coil in terms of B, θ and L.

[1]

(ii) Hence show that the magnitude of the induced e.m.f. in the coil at this instant is $|\varepsilon| = BL^2\omega\cos\theta$.

[2]

(d) The resistance of the frame is 5.0 Ω and the length L of the square frame is 0.20 m. The frame is rotated in the magnetic field of flux density 1.0 T at an angular frequency of 10 rad s^{-1}. Using your expression in **(c)(ii)**, calculate the average power dissipated in the frame.

average power dissipated = ... W [3]

[Total: 9]

7 **(a)** **(i)** Describe the *photoelectric effect* in terms of energy.

....

....

....

....

....[2]

(ii) Explain one way in which the photoelectric effect provides evidence for the particulate nature, and not wave nature, of electromagnetic radiation.

....

....

....

....

....[2]

(b) The graph drawn in Fig. 7.1 shows how the maximum kinetic energy E_k of a photoelectron from a particular material varies with the frequency f of the electromagnetic radiation that causes the emission of photoelectrons.

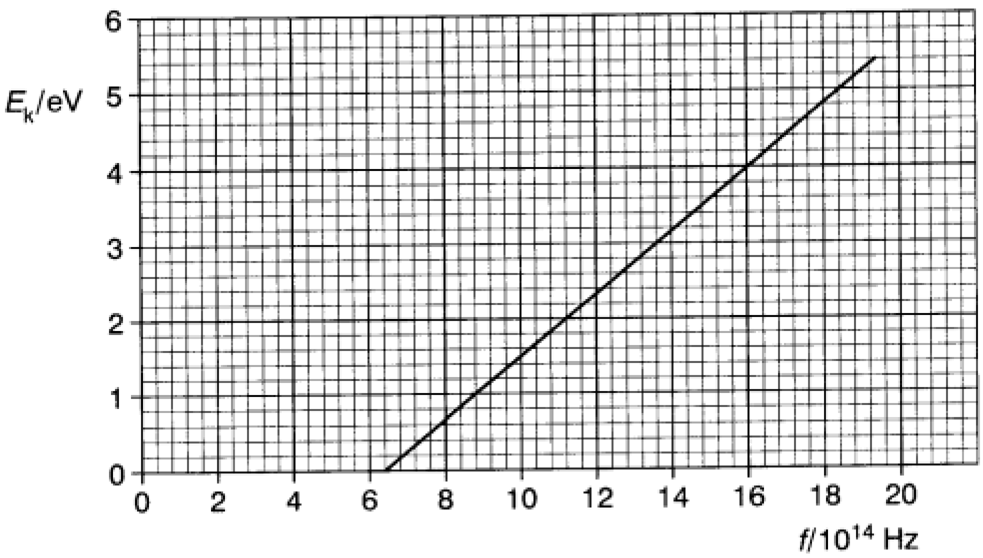

Fig. 7.1

(i) Use the graph to determine

1. the threshold frequency for this material,

threshold frequency = ... Hz [1]

2. the maximum kinetic energy of photoelectrons from this material when it is illuminated with electromagnetic radiation of frequency 18.0×10^{14} Hz.

maximum kinetic energy = ... J [2]

(ii) Determine the minimum potential difference between the electrodes in the photoelectric experiment that is needed to reduce the photocurrent to zero.

minimum potential difference = ... V [2]

(c) Electromagnetic waves have a wave nature as well as a particulate nature. This is known as the wave-particle duality. Describe an experiment in which particles exhibit wave nature.

....

....

....[1]

[Total: 10]

Section B

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

8 **(a)** State what is meant by the *binding energy* of a nucleus and how it is related to the mass defect.

....

....

....

....[2]

(b) The binding energy graph on Fig. 8.1 shows the variation with nucleon number *A* of the binding energy per nucleon. Some common nuclides are plotted on the graph, with a few of them labelled as shown.

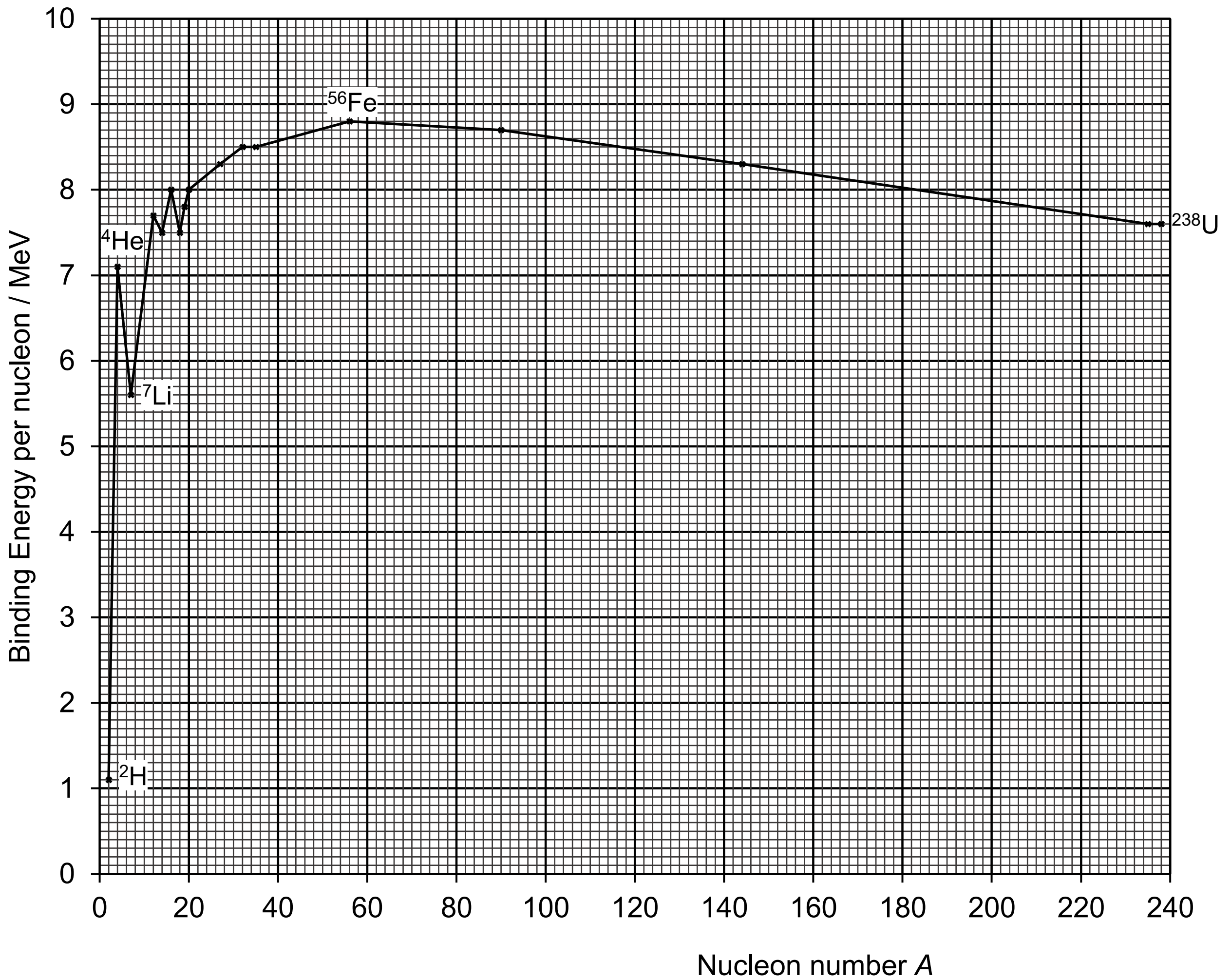

Fig. 8.1

(i) Explain why hydrogen-1 is not typically included in a binding energy graph.

....

....[1]

(ii) A nuclear power station uses uranium-235 as fuel in fission reactions. One possible fission reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{144}_{54}\text{Xe} + ^{90}_{38}\text{Sr} + 2^{1}_{0}\text{n} .$$

1. Use data from Fig. 8.1 to show that energy released in the reaction is about 190 MeV.

[2]

2. Hence, calculate the energy released in the fission of 1.0 kg of uranium-235.

energy released = ... MeV [2]

(c) A small sample of waste produced by the reactor in **(b)(ii)** contains strontium-90 ($^{90}_{38}$Sr). Strontium-90 is radioactive and undergoes beta decay into a daughter nuclide Yttrium- 90 (Y).

(i) In beta decay, it was discovered that an antineutrino ($\bar{\nu}$) must be emitted given that two conservation laws are not violated. State the two conservation laws.

....

....[1]

(ii) Complete the beta decay equation, including all the decay products.

$^{90}_{38}\text{Sr} \rightarrow$ [1]

(iii) A radiation detector is placed close to the sample to measure the count rate for strontium-90 found in the sample. Fig. 8.2 below shows the variation with time *t* of the count rate.

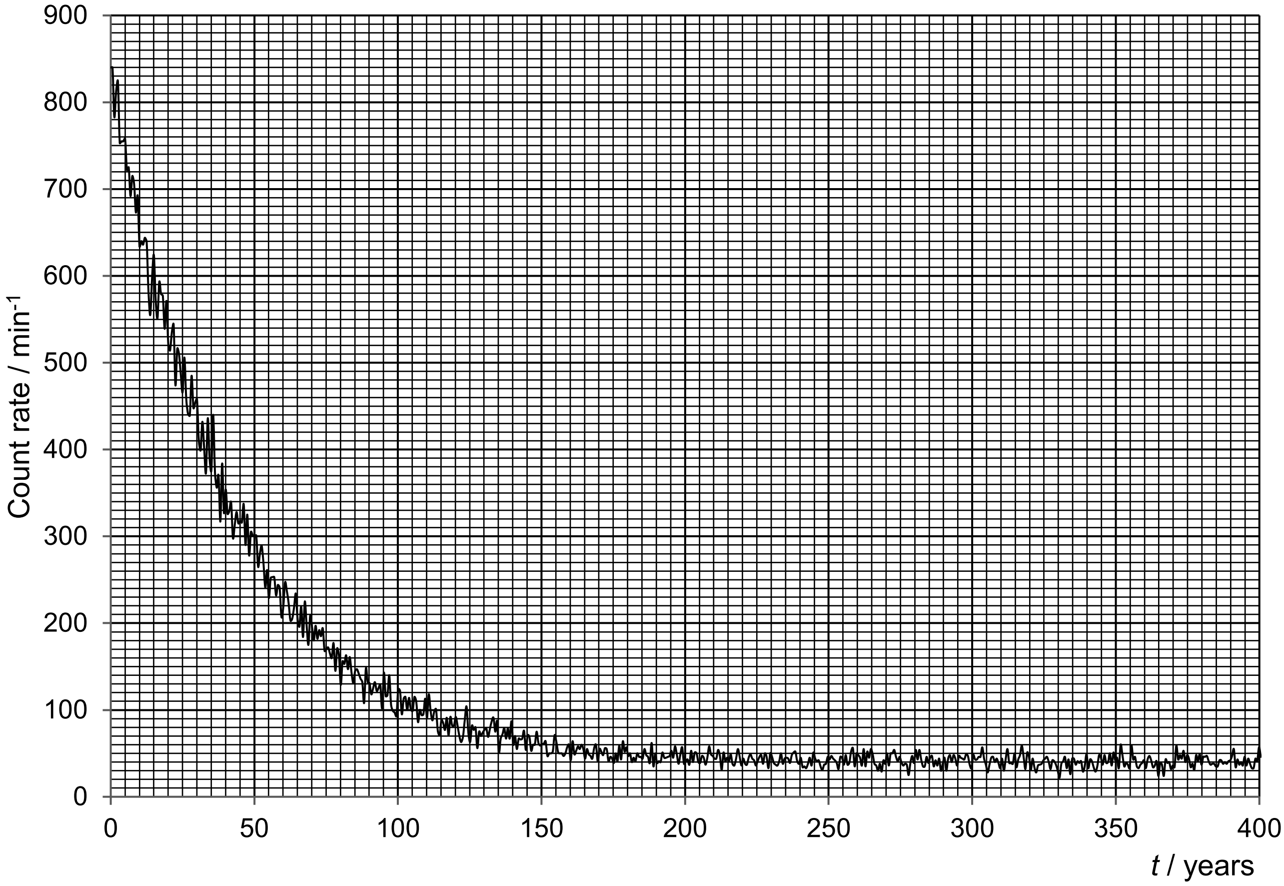

Fig. 8.2

1. State the feature of Fig. 8.2 that indicates the random nature of radioactive decay.

....[1]

2. Use Fig. 8.2 to determine the half-life of strontium-90.

half-life = ... years [4]

3. Hence, determine the probability that a nuclide of strontium-90 will undergo decay in 1 year.

probability = ...[1]

(d) Nuclear fusion occurs in the core of stars composed of ionised gas. A possible fusion reaction is

$${}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} \rightarrow {}^{2}_{1}\text{H} + {}^{0}_{1}\text{e} \;.$$

Each ${}^{1}_{1}\text{H}$ nuclide can be considered to be a sphere of radius 0.0010 pm. Fusion occurs when the two nuclides are able to overcome the force of repulsion between them and collide.

(i) Show that the minimum total kinetic energy required of the two ${}^{1}_{1}\text{H}$ nuclides for fusion to occur is 1.2×10^{-13} J.

[2]

(ii) If the ionised gas is assumed to be ideal, determine the temperature of the gas required for fusion to occur.

temperature = ... K [2]

(iii) The temperature of the core of the Sun is known to be about 1.5×10^{7} K. With reference to **(d)(i)** and **(d)(ii)**, comment on the actual kinetic energy of the nuclei in the Sun's core.

....

....[1]

[Total: 20]

9 **(a)** State what is meant by a *field of force*.

....

....[1]

(b) Two parallel metal plates are separated by a distance of 6.0 cm in a vacuum, as shown in Fig. 9.1. The plates have length 16 cm and potential difference of 2400 V.

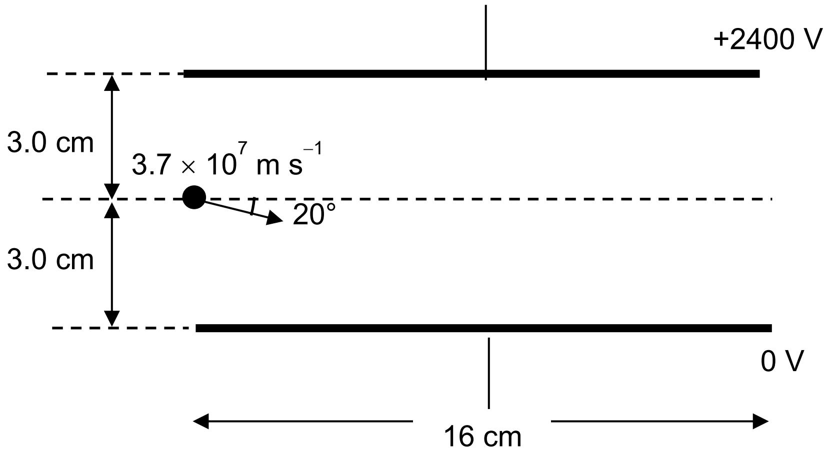

Fig. 9.1

An electron with speed 3.7×10^7 m s^{-1} enters the region between the plates. The initial direction of the electron is 20° below the midline between the plates.

(i) Calculate the acceleration of the electron and state its direction.

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

direction = ...

[3]

(ii) Calculate the time taken for the electron to reach the other end of the plate.

time = ... s [1]

(iii) Use your answers in **(b)(i)** and **(ii)** to determine whether the electron will collide with any metal plate as it passes through the region between the plates.

[3]

(iv) Hence, sketch, on Fig. 9.1, the path of the electron. [1]

(iv) Describe the path of the electron in the field.

....[1]

(c) Another electron of the same speed now enters a region of uniform magnetic field of flux density 4.5 mT as shown in Fig. 9.2.

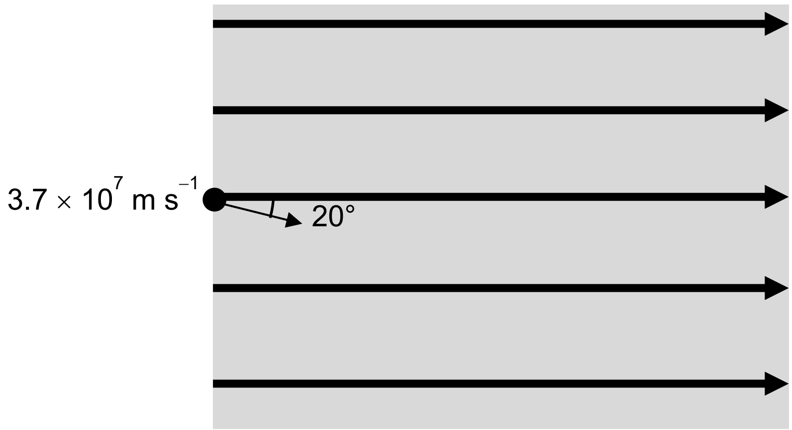

Fig. 9.2

The initial direction of the electron is at an angle of 20° to the direction of magnetic field.

(i) When the electron enters the magnetic field, the component of its velocity $v_{\perp}$ normal to the direction of the magnetic field causes the electron to begin to follow a circular path. Explain why.

....

....

....[2]

(ii) Calculate the radius of this circular path.

radius = ... m [3]

(iii) State the magnitude of the force on the electron due to the component of its velocity along the direction of the field.

....[1]

(iv) Use your answers in **(c)(ii)** and **(iii)** to describe the resultant path of the electron in the field.

....[1]

(d) Another electron of the same speed is projected downwards in the magnetic field as shown in Fig. 9.3. A uniform electric field is now switched on in the same region as the magnetic field. The magnitude of the electric field is adjusted so that the electron moves undeviated through the two fields.

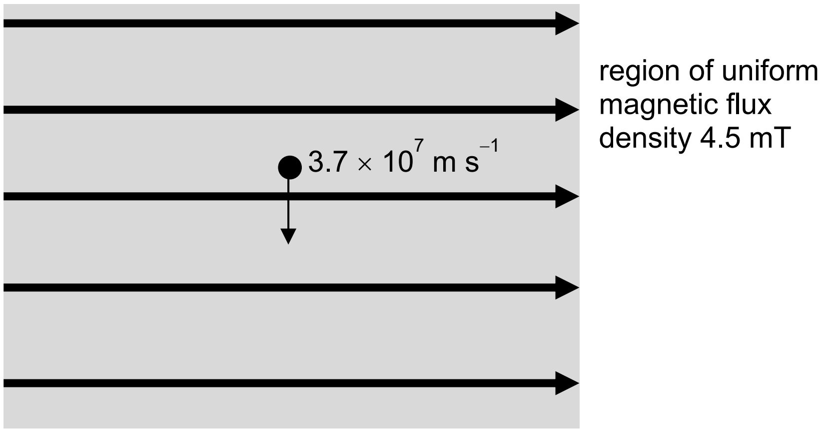

Fig. 9.3

(i) On Fig. 9.3, draw the direction of the electric field. [1]

(ii) Determine the magnitude E of the electric field strength.

E = ... V m^{-1} [2]

[Total: 20]