H

TEMASEK JUNIOR COLLEGE

2025 JC2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

CENTRE NUMBER S

INDEX NUMBER

PHYSICS **9749/03**

Paper 3 **17 September 2025**

Longer Structured Questions **2 hour**

Candidates answer on the Question Paper.

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 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
You are advised to spend one and a half hour 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	
2	
3	
4	
5	
6	
7	
8	
s.f	
Total	

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_o	=	8.85×10^{-12} F m^{-1} or $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} Js
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
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-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	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	T/°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	=	$x_o \sin\omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos\omega t$
		=	$\pm\omega\sqrt{(x_o^{\,2} - x^2)}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	x	=	$x_o \sin\omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{ln 2}{t_{1/2}}$

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Section A

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

1 Using a handheld catapult, a student projected a stone of mass 130 g, horizontally from a building rooftop of height 32 m, as illustrated in Fig. 1.1, aiming for it to land in an adjacent river.

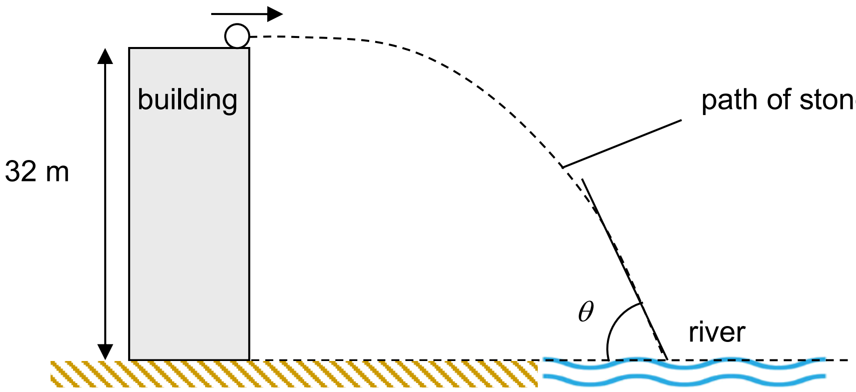

Fig. 1.1

Air resistance is negligible and the stone enters the water at a speed of 34 m s^{-1} after time t_S.

(a) Determine for the stone as it hits the water,

(i) the vertical component of the velocity of the stone

vertical component of velocity = ... m s^{-1} [2]

(ii) the angle θ to the horizontal of the stone's plunge

θ = ... ° [2]

(b) Use *energy* considerations to suggest why, if the stone causes a large splash on hitting the water surface, it decelerates in a shorter distance than when no splash is produced.

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....

....

.... [1]

(c) (i) On Fig. 1.2, sketch the variation with time t of the potential energy E_p of the stone with respect to the water level.

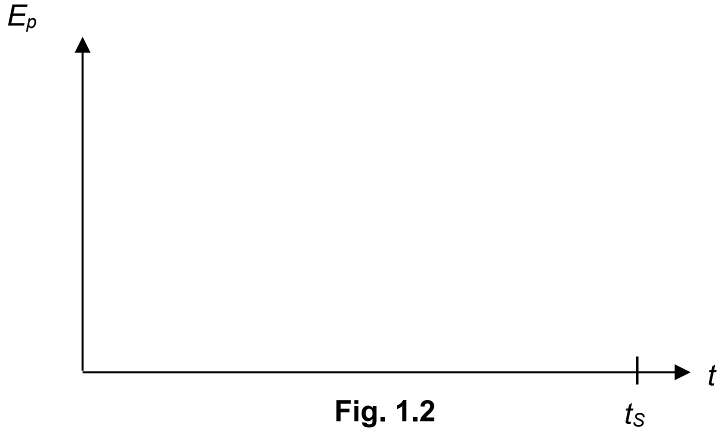

Fig. 1.2 [2]

(ii) On Fig. 1.3, sketch the variation with time t of the kinetic energy E_k of the stone for the same period.

Fig. 1.3 [1]

[Total: 8]

2 **(a)** State the relation between force and momentum.

....

....

.... [1]

(b) A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 2.1.

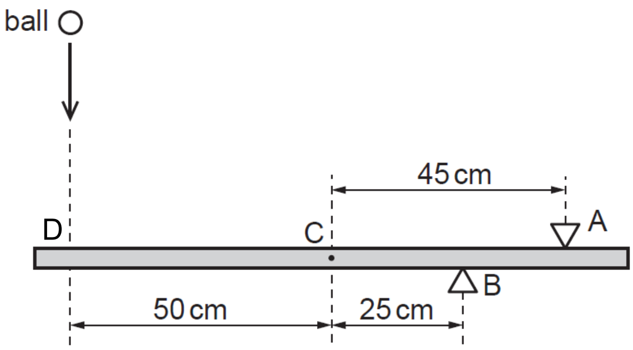

Fig. 2.1

Support A is 45 cm from the centre of mass C of the bar while support B is 25 cm from C.

A ball of mass 140 g falls vertically onto the bar such that it hits the bar at point D, a distance of 50 cm from C.

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The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 2.2.

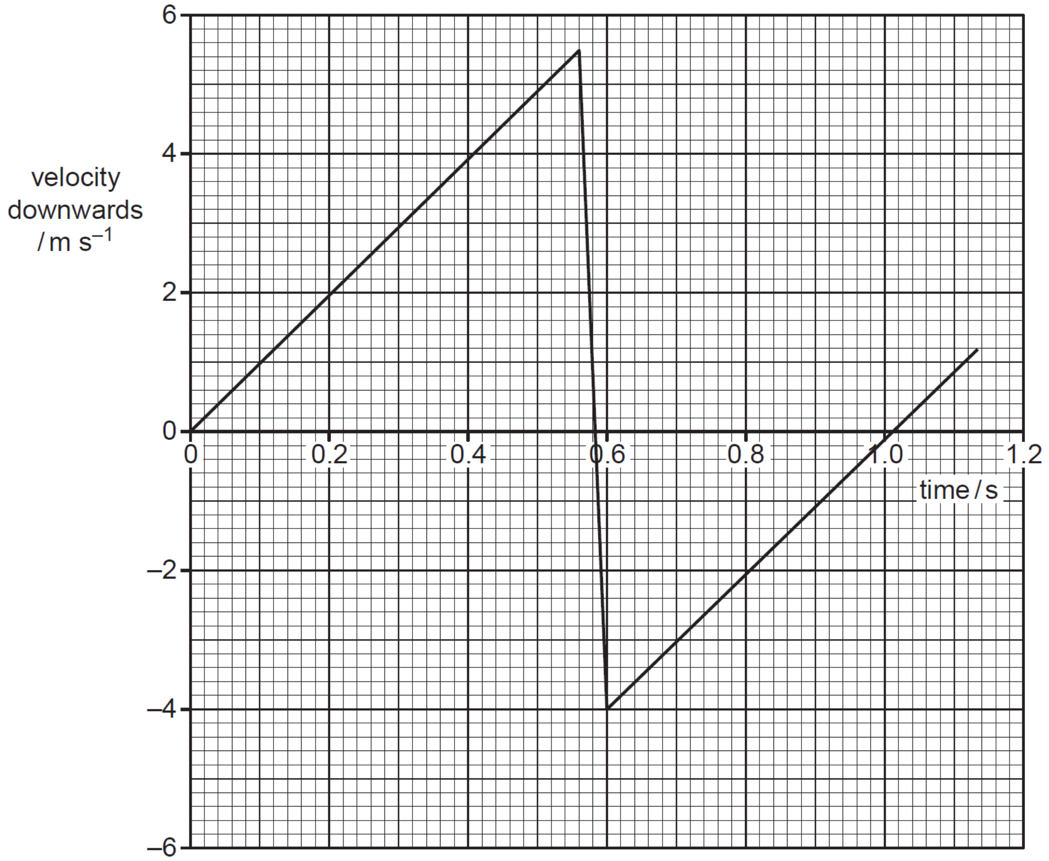

Fig. 2.2

For the time that the ball is in contact with the bar, use the data provided to

(i) determine the change in momentum of the ball,

change in momemtum = ... kg m s^{-1} [2]

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(ii) show that the magnitude of the average force exerted by the ball on the bar is 35 N,

[2]

(iii) calculate the average force exerted on the bar by the support A.

force = ... N [2]

(iv) determine the net energy lost by the ball due to the inelastic collision with the bar at D.

energy = ... J [1]

(c) The ball is now dropped under the same conditions, this time with a light cushion fitted at point D.

Explain the effect on your answer to **(b)(iii)** when the ball makes contact at point D.

....

....

.... [2]

[Total: 10]

3 A cycle of changes in pressure, volume and temperature of gas inside a cylinder of a petrol engine with a movable piston is illustrated in Fig. 3.1. The gas is assumed to be ideal.

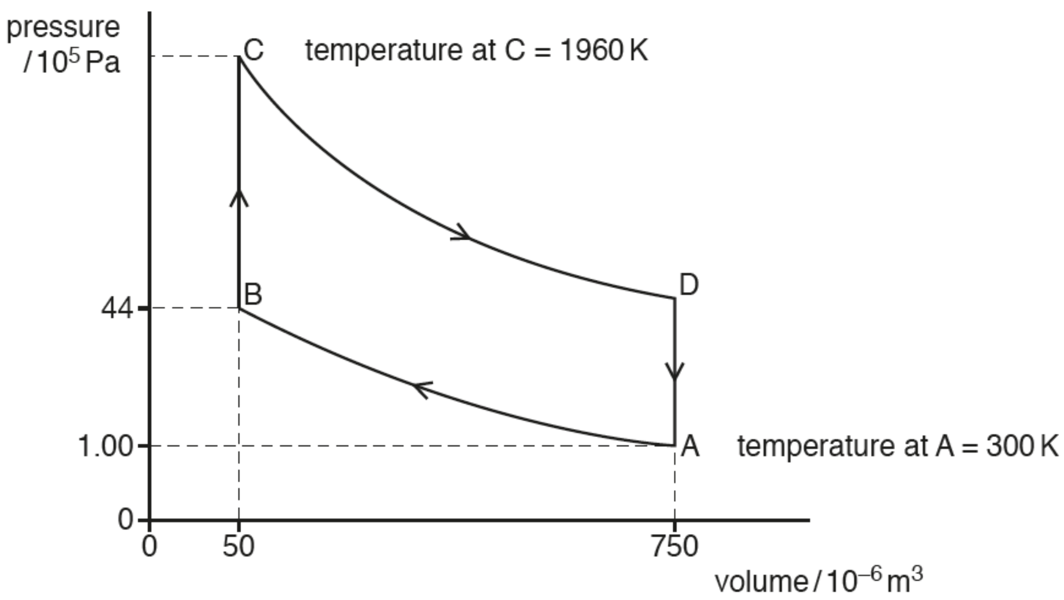

Fig. 3.1 (not to scale)

There are four stages in the cycle.

stage	description
A to B	Rapid compression of the gaseous petrol/air mixture with the temperature rising from 300 K at A and the pressure rising to 44×10^5 Pa at B.
B to C	The petrol/air mixture is exploded, resulting in an almost instant rise in pressure. At C the temperature has risen to 1960 K.
C to D	Rapid expansion and cooling of the hot gases.
D to A	Return to the starting point of the cycle.

(a) **(i)** State what is meant by an *ideal gas*.

....

....

.... [1]

(ii) Use the values in Fig. 3.1 to determine the number of moles present in the gases in the cycle.

number of moles = ... moles [2]

(b) Complete the table in Fig. 3.2 showing the work done on the gas, the heat supplied to the gas and the increase in the internal energy of the gas, during the four stages of one cycle.

stage	work done **on** gas /J	heat supplied **to** gas /J	**increase** in internal energy of gas / J
A to B	+ 360	0	
B to C		+ 670	
C to D		0	− 810
D to A			

[4]

Fig. 3.2

(c) Explain qualitatively how molecular movement causes the fall in temperature of the gas during the stage from C to D.

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.... [2]

(d) Explain using Fig. 3.2 why the engine can be used in cars.

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.... [1]

[Total: 10]

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4 A cell P, a fixed resistor *R* and a uniform resistance wire AB are connected in a circuit as shown in Fig. 4.1.

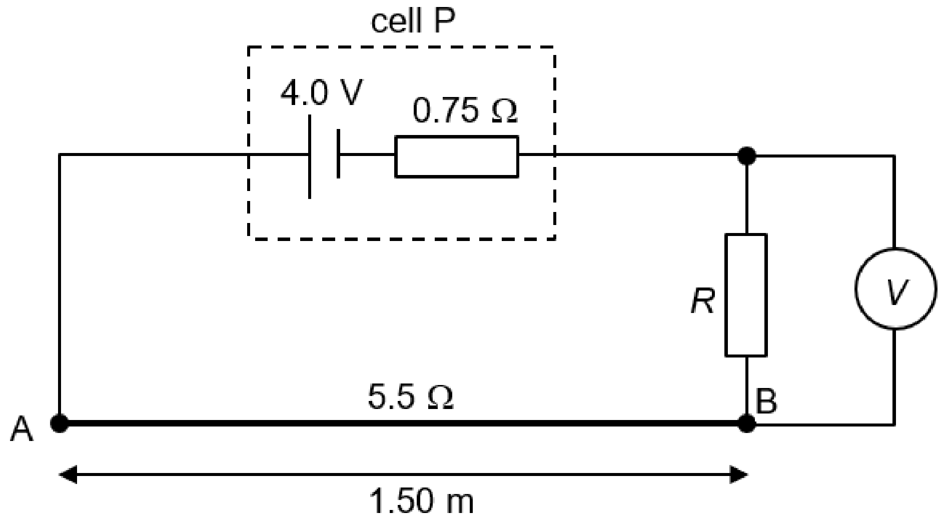

Fig. 4.1

Cell P has e.m.f. 4.0 V and internal resistance 0.75 Ω. Wire AB has length 1.50 m and resistance 5.5 Ω. The voltmeter reads 1.3 V.

(a) Show that the potential difference across AB is 2.4 V.

[2]

(b) A cell Q and a sensitive ammeter are connected to the circuit in Fig. 4.1, as shown in Fig. 4.2.

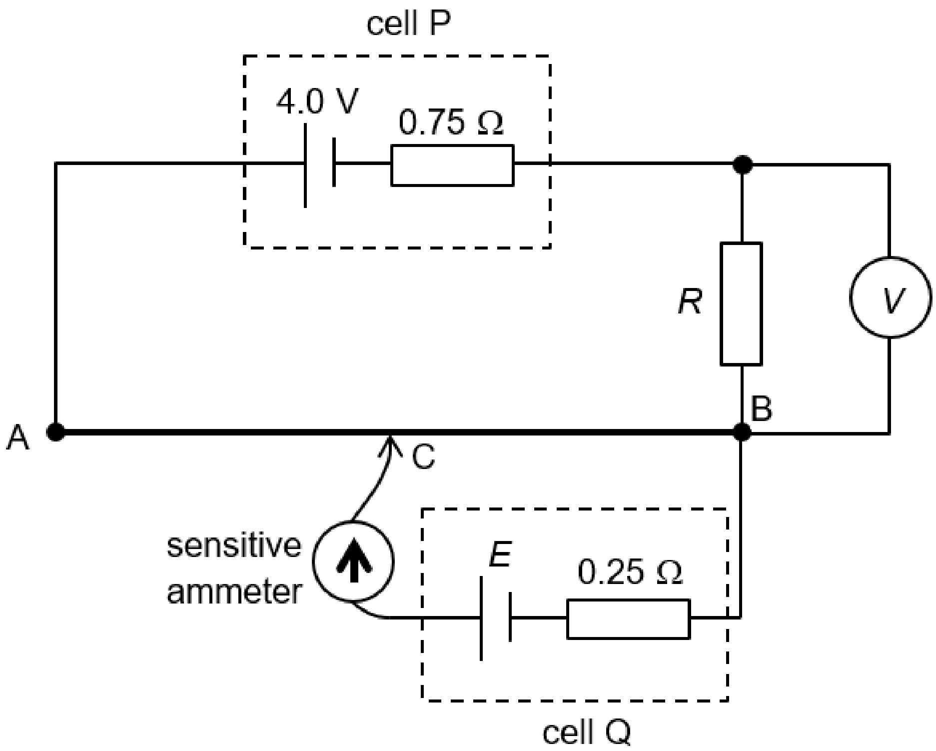

Fig. 4.2

Cell Q has e.m.f. *E* and internal resistance 0.25 Ω. The ammeter reads zero when the length of AC is 0.56 m.

(i) Determine *E*.

E = ... V [2]

(ii) There is a reading on the ammeter when the connection C is shifted closer to A. State and explain the direction of the current across cell Q.

....

....

....

.... [2]

(c) The resistance wire AB is detached from the circuit and wound in a circular manner such that there are 2 semi-circular turns above and 3 semi-circular below XY as shown in Fig. 4.3.

X and Y are two metallic fasteners with negligible resistance. They are used to secure the wire so that the distance between X and Y is the diameter of the coil.

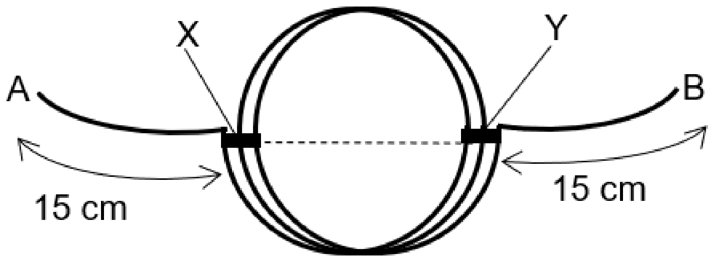

Fig. 4.3

(i) Show that the resistance of wire AB when coiled in this manner is 1.3 Ω.

[2]

(ii) An e.m.f. source is again connected across AB. State and explain whether the drift velocity of electrons is greater in section AX or section XY.

....

....

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.... [2]

[Total: 10]

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5 Charged particles, of speed 4500 m s^{-1} and mass 2.66×10^{-26} kg, are travelling in a narrow beam in a vacuum as shown in Fig. 5.1.

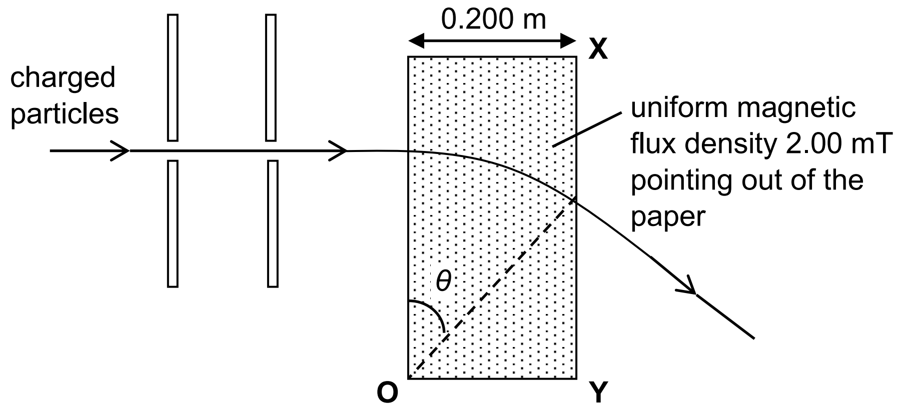

Fig.5.1

The charged particles enter a region of uniform magnetic flux density which is 0.200 m wide. The direction of the magnetic flux is pointing out of the paper.

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(a) **(i)** Using Newton's Law of motion, explain any changes in the speed of the particles as they move within and exit from the uniform magnetic field.

....

....

.... [2]

(ii) Given that the magnitude of the charge on the particles is *e*, calculate the radius of the circular motion of the charged particles in the uniform magnetic field.

radius = ... m [3]

(b) In another experiment, similar charged particles are now fired into the magnetic field in Fig. 5.1 with different momentum.
Determine the maximum momentum of particles such that the particles will not exit the magnetic field through XY.

momentum = ... kg m s^{-1} [3]

[Total: 8]

6 **(a)** Some electron energy levels of the hydrogen atom are illustrated in Fig. 6.1.

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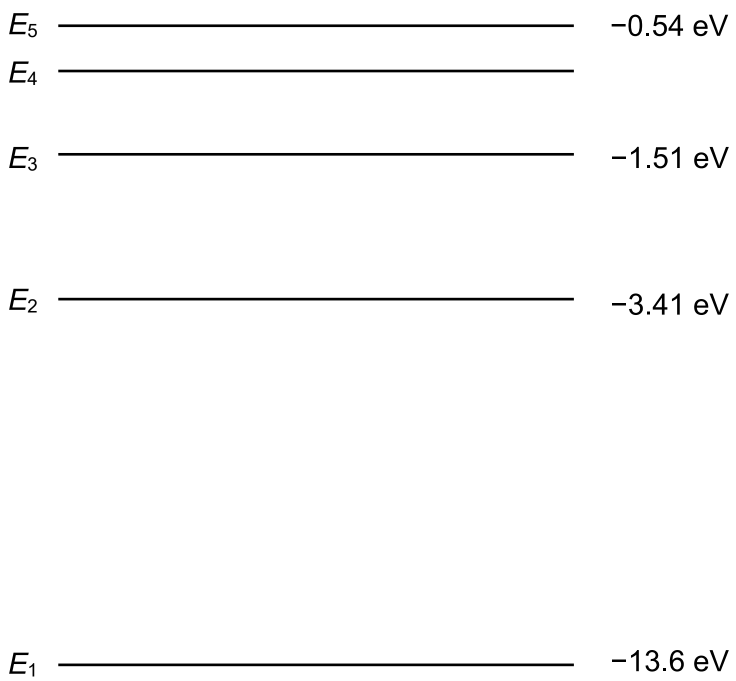

Fig. 6.1 (not to scale)

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(i) By considering the transitions between these energy levels, state how many spectral emission lines might be produced by transitions among these levels.

number of lines = ... [1]

(ii) The wavelength of a photon produced by the transition from energy level E_4 to E_1 is 97.5 nm. Calculate the energy level E_4.

energy = ... eV [2]

(b) The radiation emitted from hydrogen atoms is incident on the surface of a sheet of gold. The stopping potential for photoelectrons emitted from the gold surface is 8.13 V.

(i) Calculate the work function of the metal surface.

work function = ... eV [2]

(ii) Calculate the momentum of the most energetic electrons emitted from the gold surface.

momentum = ... N s [2]

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(iii) Hence, determine the de Broglie's wavelength of the electrons in **(b)(ii)**.

wavelength = ... m [2]

(iv) The speed of one of the photoelectrons emitted is measured to be 1.2×10^6 m s^{-1} to an precision of 0.0025 %.
Calculate the minimum uncertainty in the position of this photoelectron.

minimum uncertainty in position = ... m [2]

(v) In theory, these emitted photoelectrons could be accelerated into a tungsten target via a very strong electric field to emit x-rays. Explain how a continuous spectrum of x-rays could be produced from this process.

....

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....

....

.... [3]

[Total: 14]

Section B

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

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

....

....

.... [1]

(ii) Define electric field strength.

....

....

.... [2]

(iii) Suggest why, when defining electric field strength, the test particle must be stationary.

....

....

.... [1]

b **(i)** State the relation between electric field strength *E* and potential *V*.

....

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.... [1]

(ii) Two charged metal spheres A and B, of diameters 18 cm and 12 cm respectively, are isolated in space, as shown in Fig. 7.1.

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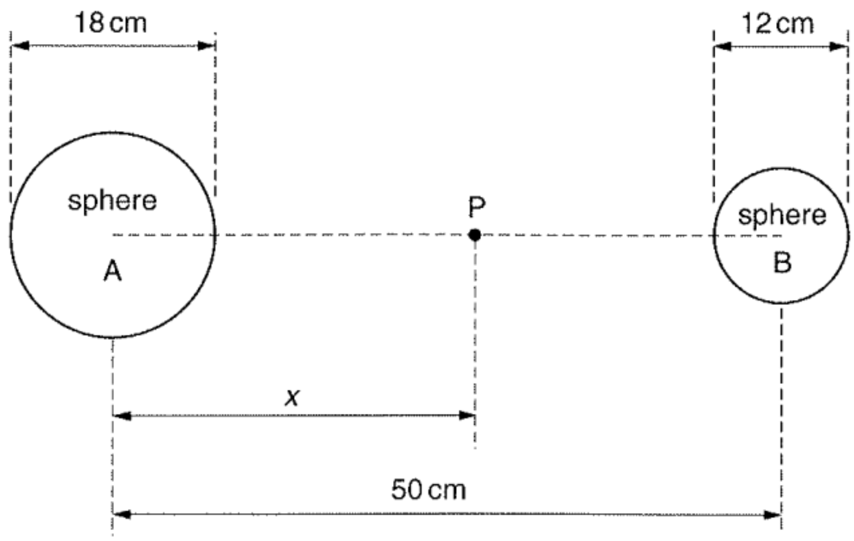

Fig. 7.1

The centres of the spheres are separated by a distance of 50 cm. Point P is at a distance *x* from the centre of sphere A along the line joining the centres of the two spheres. The variation with *x* of the electric potential *V* at P is shown in Fig. 7.2.

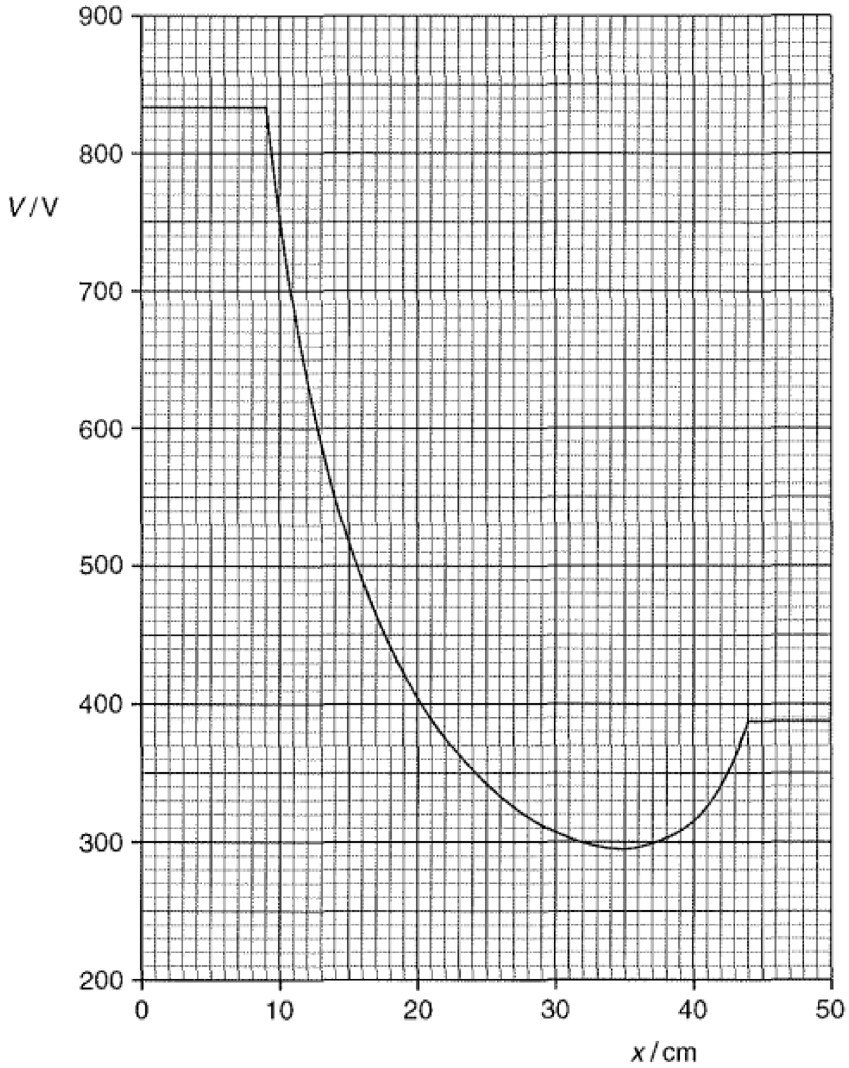

Fig. 7.2

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1. State and explain the direction of the electric field at the point P, where x = 25.0 cm .

....

....

.... [2]

2. Use Fig. 7.2 to determine the force on an electron placed at point P, where *x*= 35.0 cm.

force = ... N [3]

3. By making reference to electric fields, explain why the potential is constant for distances between *x* = 0 and *x* = 9.0 cm.

....

....

.... [2]

(c) A student states that the potential *V* decreases with distance *x* for distances between *x* = 10 cm and *x* = 25 cm according to the expression

$$Vx = \text{constant.}$$

(i) Without drawing a graph, use data from Fig. 7.2 to show whether the student is correct.

[3]

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(ii) Suggest an explanation for your conclusion in **(i)**

....

....

.... [1]

(d) An electron, initially at rest a long distance from the spheres in (b), approaches the spheres and passes between the two spheres.

(i) Calculate the minimum speed of the electron as it crosses the line joining the centres of the two spheres.

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

(ii) Describe the path of the electron for the minimum speed in **(i).**

....

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.... [2]

[Total: 20]

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8 (a) An unstable nucleus of nucleon number (mass number) A undergoes α-decay, as illustrated in Fig. 8.1.

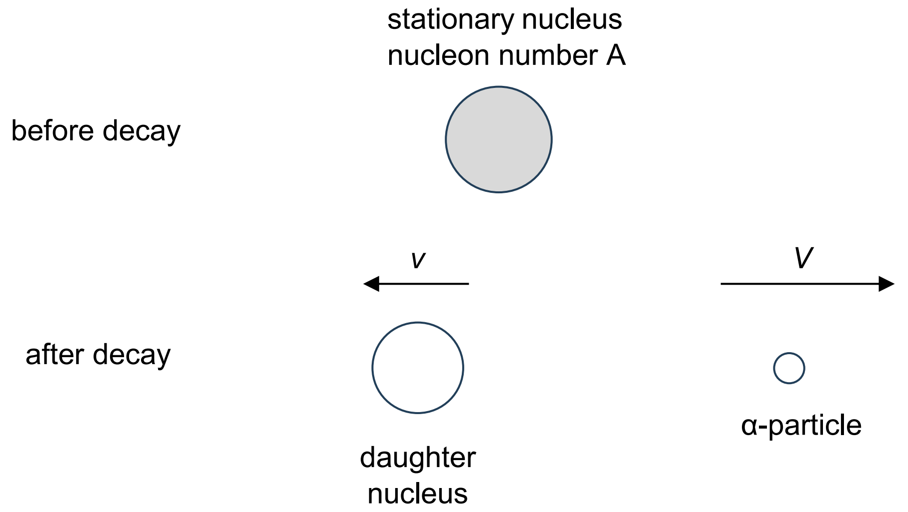

Fig. 8.1

The nucleus is stationary before the decay.

After the decay, the initial speed of the α-particle is V and that of the daughter nucleus is v.

(i) State an equation, in terms of A, v and V, to represent conservation of linear momentum for this decay.

....

.... [2]

(ii) Show that the ratio

$$\frac{\text{initial kinetic energy of α-particle}}{\text{initial kinetic energy of daughter nucleus}}$$

is equal to ($\frac{1}{4}A - 1$).

[3]

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(b) Data for the α-decay of bismuth-212 ($^{212}_{83}Bi$) to form thallium-208 ($^{208}_{81}Tl$) are given in Fig. 8.2.

nucleus	mass of nucleus/ u
bismuth-212	211.9459
thallium-208	207.9374
helium-4	4.0015

Fig. 8.2

(i) Use the data of Fig. 8.2 to calculate, to two places of decimals, the energy released during the decay.

energy = ... MeV [4]

(ii) Use your answer in **(i)** to show that, based on the expression in **(a)(ii),** the energy of the α-particle is 6.42 MeV.

[2]

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(c) In practice, the α-particle is found to have an energy of 6.10 MeV, rather than 6.42 MeV, as calculated in **(b)(ii)**.

Suggest

(i) an explanation for the difference in energy,

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.... [1]

(ii) why it is likely that the thallium nucleus and the α-particle do not move off in opposite directions.

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.... [3]

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(d) Some data for the half-lives and decay constants of bismuth-212 and thallium-208 are given in Fig. 8.3.

nucleus	half-life/ s	decay constant/ s^{-1}
bismuth-212	....	1.9×10^{-4}
thallium-208	190	3.7×10^{-3}

Fig. 8.3

(i) Complete Fig. 8.3 by calculating the half-life of bismuth-212.

[1]

(ii) Initially, a radioactive source contains *N* nuclei of bismuth-212.

After two hours, it is found that the number of bismuth-212 nuclei has reduced to approximately ¼*N*. However, although bismuth-212 decays to form thallium-208, the number of thallium nuclei is much less than ¾*N*.

Suggest an explanation for these observations.

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.... [4]

[Total: 20]

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