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Cambridge Assessment International Education

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PHYSICS **9702/42**

Paper 4 A Level Structured Questions **February/March 2025**

2 hours

You must answer on the question paper.

No additional materials are needed.

INSTRUCTIONS
- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

INFORMATION
- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This document has **28** pages. Any blank pages are indicated.

DC (PB/SG) 342332/5

Data

acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$
speed of light in free space	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ \text{C}$
unified atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ $(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{m F}^{-1})$
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$
Stefan–Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
hydrostatic pressure	$\Delta p = \rho g \Delta h$
upthrust	$F = \rho g V$
Doppler effect for sound waves	$f_o = \dfrac{f_s v}{v \pm v_s}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

gravitational potential	$\phi = -\dfrac{GM}{r}$
gravitational potential energy	$E_P = -\dfrac{GMm}{r}$
pressure of an ideal gas	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion	$a = -\omega^2 x$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $v = \pm \omega \sqrt{(x_0^{\,2} - x^2)}$
electric potential	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
electrical potential energy	$E_P = \dfrac{Qq}{4\pi\varepsilon_0 r}$
capacitors in series	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
discharge of a capacitor	$x = x_0 e^{-\frac{t}{RC}}$
Hall voltage	$V_H = \dfrac{BI}{ntq}$
alternating current/voltage	$x = x_0 \sin \omega t$
radioactive decay	$x = x_0 e^{-\lambda t}$
decay constant	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$
intensity reflection coefficient	$\dfrac{I_R}{I_0} = \dfrac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$
Stefan–Boltzmann law	$L = 4\pi\sigma r^2 T^4$
Doppler redshift	$\dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$

1 A steel ball is placed on the inside surface of a hollow circular cone. The ball moves in a horizontal circle at constant speed, as shown in Fig. 1.1.

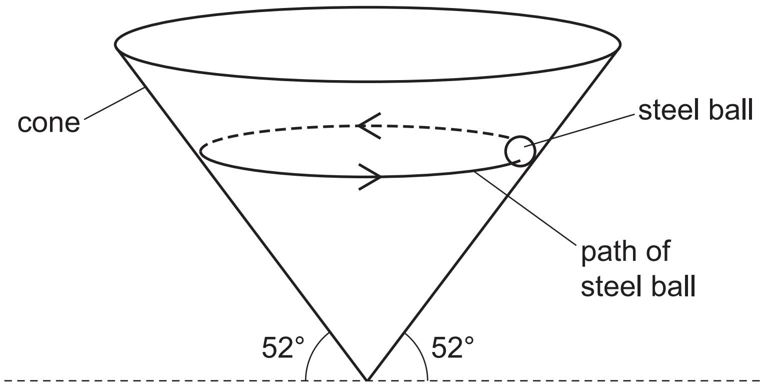

Fig. 1.1

The angle of the side of the cone to the horizontal is 52°. There is no friction between the ball and the cone.

(a) Fig. 1.2 shows a cross-section through the cone and the steel ball.

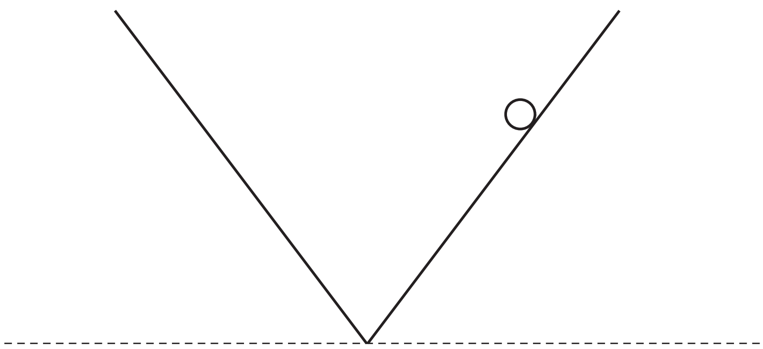

Fig. 1.2

On Fig. 1.2, draw labelled arrows to show the **two** forces acting on the ball. [1]

(b) Describe how the forces acting on the ball cause its acceleration to be centripetal.

....

....

....

.... [2]

(c) The ball moves in a circle of radius 0.15 m.

Show that the speed of the ball is $1.4\,\text{m}\,\text{s}^{-1}$.

[3]

(d) Calculate the angular speed ω of the ball.

ω = ... $\text{rad}\,\text{s}^{-1}$ [2]

(e) The speed of the ball is increased.

Explain why the radius of the circular path of the ball increases.

....

....

.... [1]

[Total: 9]

2 **(a)** The magnitude of the gravitational potential on the surface of a planet of radius R is ϕ. The planet can be considered to be an isolated sphere.

On Fig. 2.1, sketch the variation of the gravitational potential with distance x from the centre of the planet for values of x between R and $4R$.

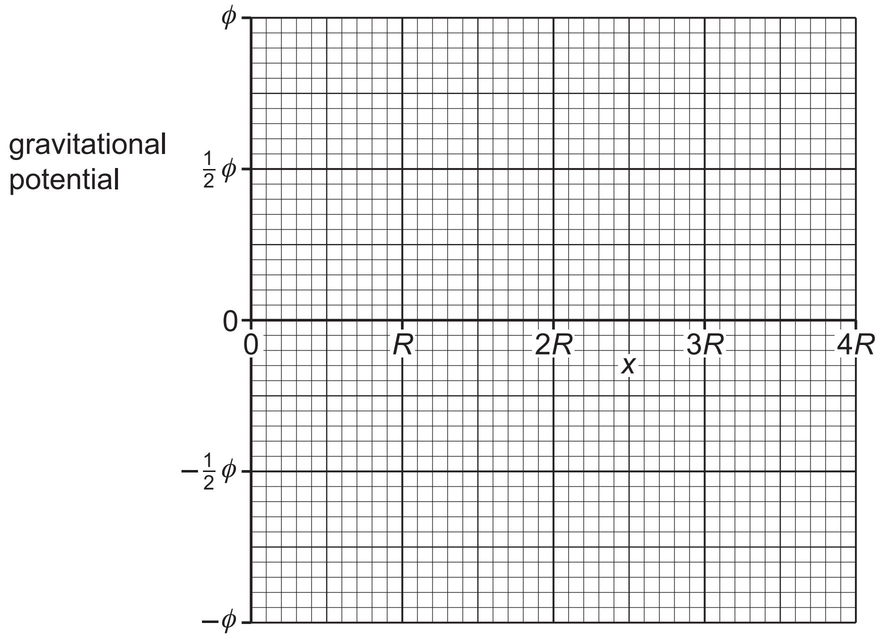

Fig. 2.1

[3]

(b) A satellite is in a geostationary orbit above the Earth. At time t = 0, the magnitude of the gravitational potential due to the Earth at the location of the satellite is ϕ.

On Fig. 2.2, sketch the variation of the gravitational potential due to the Earth at the location of the satellite for values of t between t = 0 and t = 24 hours.

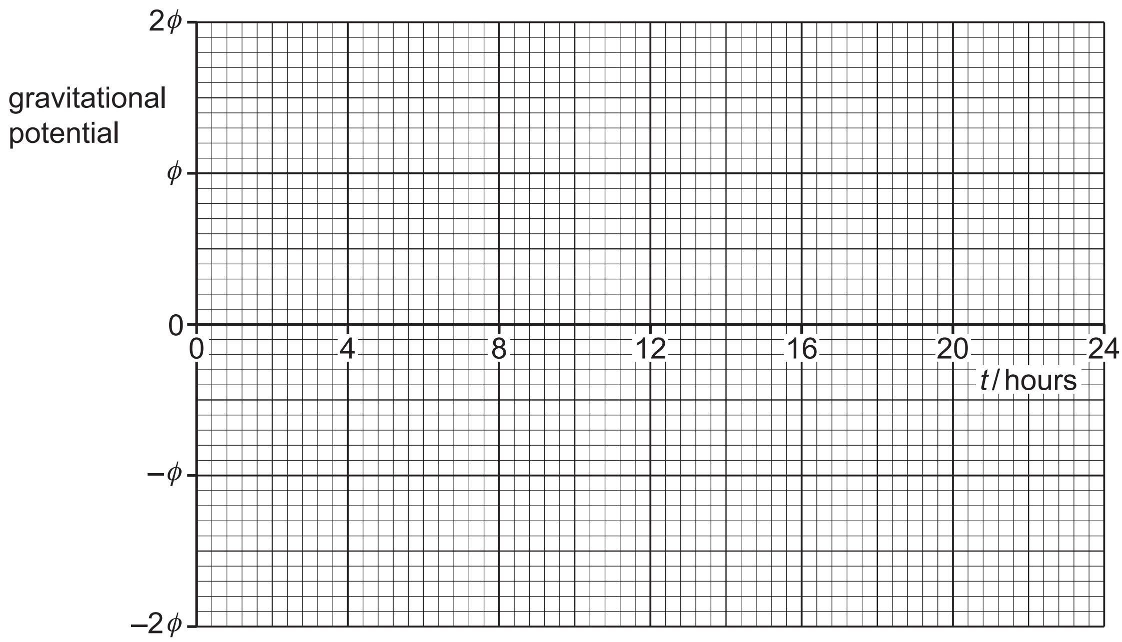

Fig. 2.2

[2]

(c) The electric potential difference (p.d.) between two parallel plates is V, as shown in Fig. 2.3.

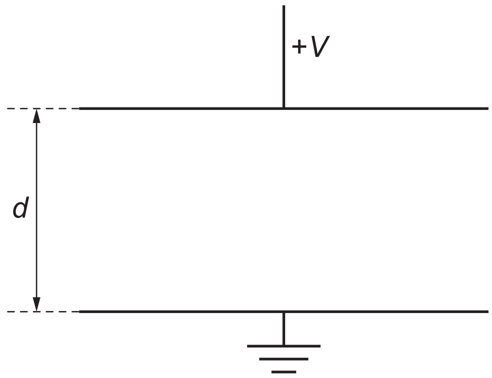

Fig. 2.3

The distance between the plates is d. The region between the plates is a vacuum.

On Fig. 2.4, sketch the variation of the electric potential with distance from the positive plate.

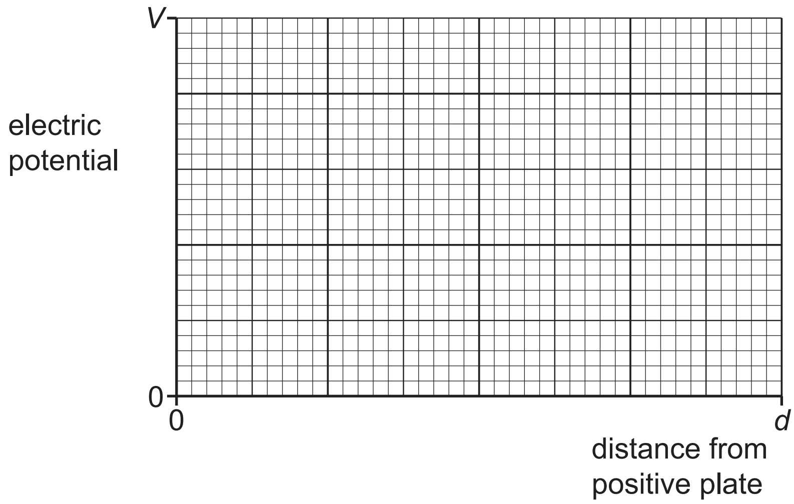

Fig. 2.4

[2]

[Total: 7]

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3 **(a)** Two metal cuboids P and Q are in thermal contact with each other.

(i) P and Q are in thermal equilibrium.

State what is meant by the term thermal equilibrium.

....

....

.... [2]

(ii) Data for P and Q are given in Table 3.1.

Table 3.1

	P	Q
specific heat capacity / $J\,kg^{-1}\,K^{-1}$	390	910
mass / kg	0.54	0.37

P and Q are initially both at the same temperature.

P is supplied with 24 kJ of thermal energy. After some time, P and Q are once again both at the same temperature as each other.

P and Q are perfectly insulated from the surroundings.

Determine the change in temperature ΔT of Q.

ΔT = ... K [3]

(b) Nitrogen may be assumed to be an ideal gas. A fixed amount of nitrogen gas is contained at a constant pressure of 1.6×10^5 Pa.

The variation of the volume V of the gas with the temperature θ of the gas is shown in Fig. 3.1.

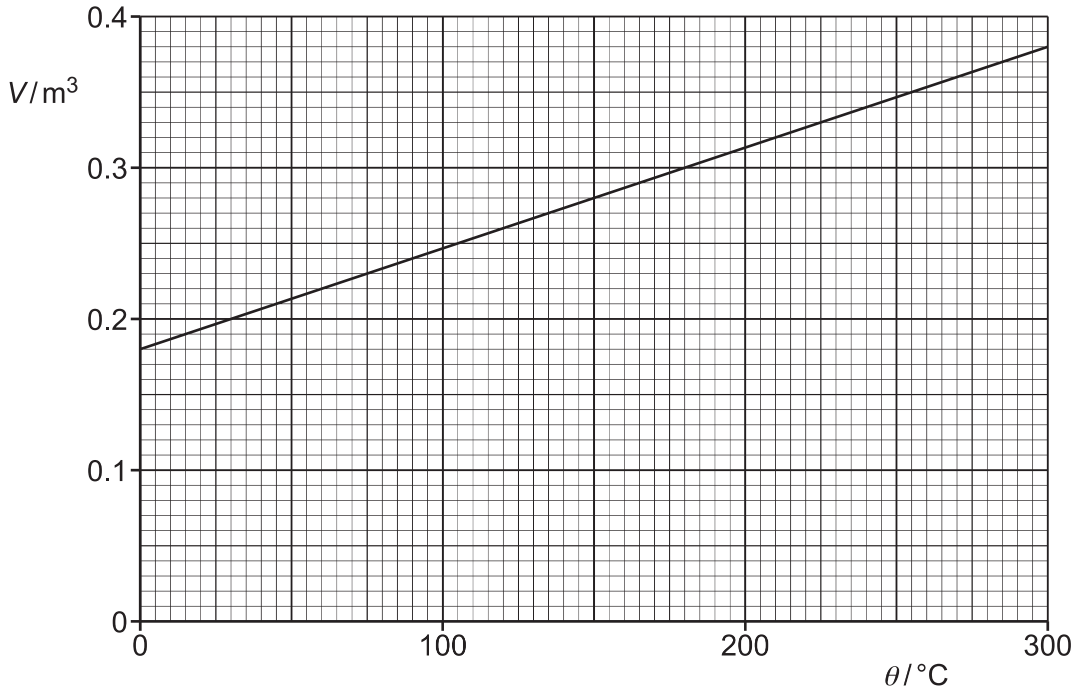

Fig. 3.1

(i) The temperature of the nitrogen gas is increased from 0 °C to 210 °C.
Determine the work done on the gas.

work done = ... J [3]

(ii) Determine the number N of molecules of nitrogen gas.

N = ... [2]

(iii) The mass of a nitrogen molecule is 4.7×10^{-26} kg.

Calculate the root-mean-square (r.m.s.) speed of a nitrogen molecule at 210 °C.

r.m.s. speed = ... $\mathrm{m\,s^{-1}}$ [2]

[Total: 12]

4 A small crystal is made to vibrate with simple harmonic motion. The variation with time t of the displacement x of one surface of the crystal from its equilibrium position is shown in Fig. 4.1.

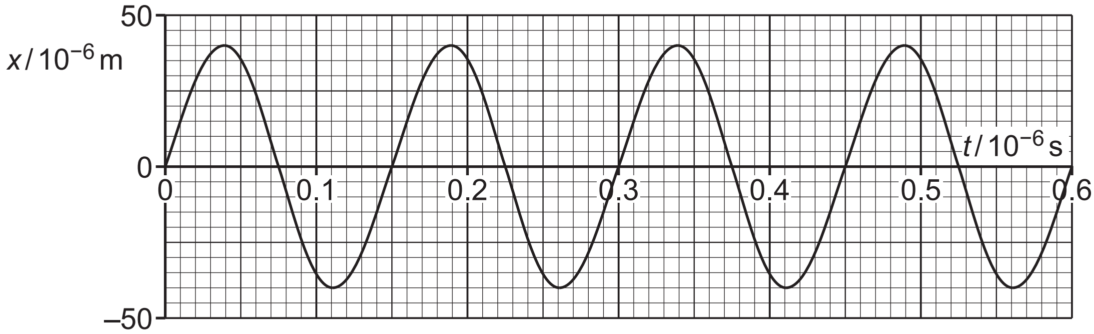

Fig. 4.1

(a) Show that the angular frequency of the vibration of the surface is 4.2×10^{7} rad s^{-1}.

[2]

(b) Determine the maximum acceleration a_0 of the vibration of the surface.

a_0 = ... m s^{-2} [2]

(c) The crystal may be modelled as a single mass of 2.4×10^{-4} kg that vibrates as shown in Fig. 4.1.

Calculate the total energy E of the vibrations.

E = ... J [3]

(d) The crystal generates ultrasound waves that are used to obtain diagnostic information about internal structures.

(i) The crystal is made from piezoelectric material.

Explain how the crystal is made to vibrate.

....

....

....

.... [2]

(ii) A parallel beam of ultrasound waves is incident on a muscle-bone boundary. Data for muscle and bone are given in Table 4.1.

Table 4.1

material	density / $kg\,m^{-3}$	speed of sound / $m\,s^{-1}$
muscle	1100	1600
bone	1900	4100

Calculate the percentage of the intensity of the ultrasound beam that is transmitted at this boundary.

percentage transmitted = ... % [3]

[Total: 12]

5 **(a)** A capacitor of capacitance C_1 is connected in series with a second capacitor of capacitance C_2.

Show that the combined capacitance C of the two capacitors is given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}.$$

[2]

(b) Three identical capacitors, each of capacitance C, are connected in a network as shown in Fig. 5.1.

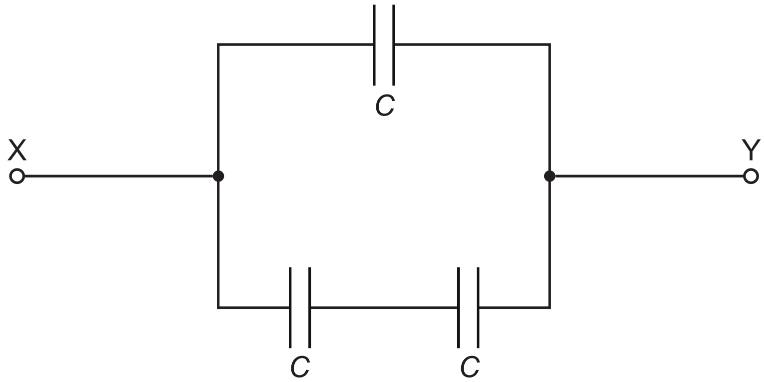

Fig. 5.1

The variation of the charge Q with the potential difference (p.d.) V between the terminals X and Y is shown in Fig. 5.2.

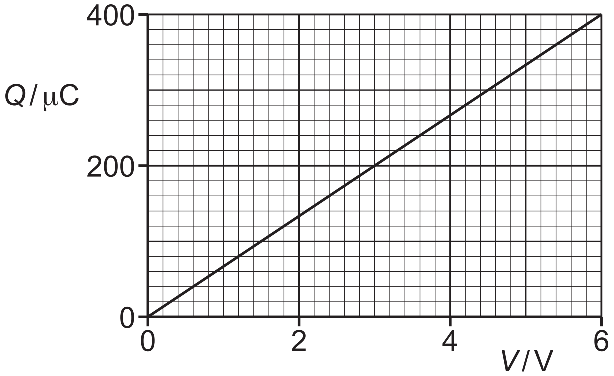

Fig. 5.2

Show that C is equal to $44\,\mu F$.

[3]

(c) The capacitor network in Fig. 5.1 is charged and then connected to a resistor of resistance $54\,k\Omega$. The capacitor network discharges through the resistor.

(i) Determine the time constant τ of the circuit. Give a unit with your answer.

τ = ... unit .... [2]

(ii) Determine the time taken for the discharge current to reduce to 15% of the initial discharge current.

time = ... s [2]

[Total: 9]

6 An electric field and a magnetic field are used to form a velocity selector. Charged particles, called ions, pass into a region of uniform electric and magnetic fields that is between parallel plates, as shown in Fig. 6.1.

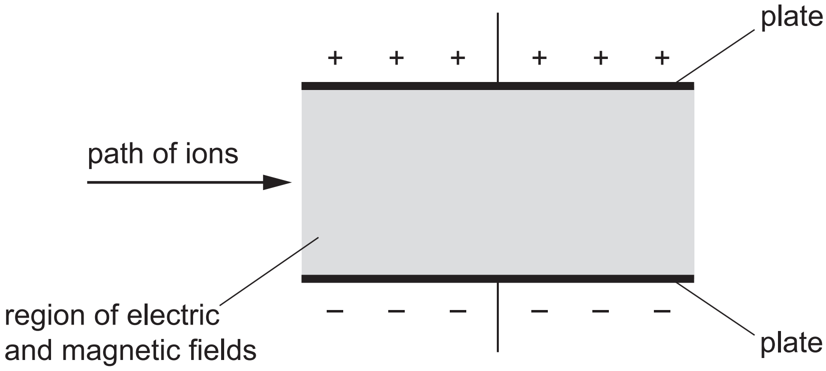

Fig. 6.1

(a) The potential difference (p.d.) between the plates of the velocity selector is V. The separation of the plates is d and the magnetic flux density is B.

Show that the speed u of ions that pass undeviated through the velocity selector is given by

$$u = \frac{V}{Bd}.$$

[2]

(b) Positive ions with kinetic energy 4.1×10^{-17} J and mass 3.2×10^{-27} kg pass undeviated through the velocity selector when V is equal to 980 V and d is equal to 3.6×10^{-2} m.

Determine B.

B = ... T [3]

(c) A proton passes undeviated through the velocity selector.

An alpha particle enters the velocity selector at the same speed as the proton.

State how the expression in **(a)** predicts that the alpha particle also passes undeviated through the velocity selector.

....

.... [1]

(d) By reference to Fig. 6.1 and to the forces acting on a positive ion, determine the direction of the magnetic field. Explain your reasoning.

....

....

....

....

....

.... [3]

(e) The positive ions in **(b)** enter the velocity selector with greater kinetic energy.

On Fig. 6.1, sketch the path of these ions. [2]

[Total: 11]

7 **(a)** State Faraday's law of electromagnetic induction.

....

....

.... [2]

(b) A metal rod is accelerated uniformly from rest in a uniform magnetic field as shown in Fig. 7.1.

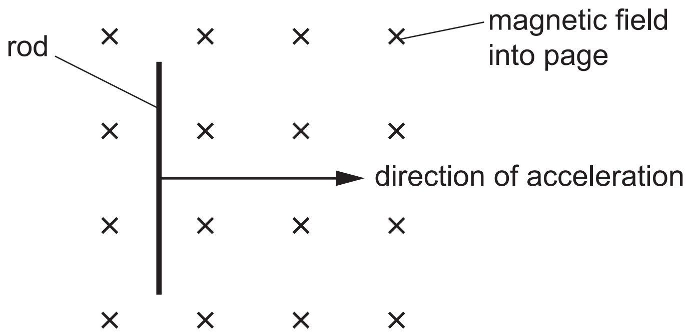

Fig. 7.1

The rod has length l and the flux density of the magnetic field is B.

An electromotive force (e.m.f.) is induced in the rod. The variation with time t of the induced e.m.f. E is shown in Fig. 7.2.

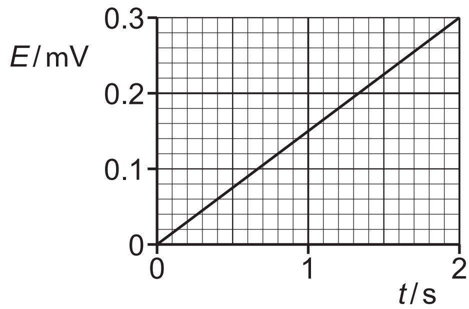

Fig. 7.2

(i) Explain how Fig. 7.2 shows that E is proportional to the velocity v of the rod.

....

....

.... [2]

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(ii) Use Faraday's law to show that the variation of E with time t is given by

$$E = Blat$$

where a is the acceleration of the rod.

[3]

(iii) The length of the rod is 0.45 m. The acceleration a of the rod is $7.8\,\text{m}\,\text{s}^{-2}$.

Determine the value of B.

B = ... T [2]

[Total: 9]

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8 **(a)** State what is meant by a photon.

....

....

.... [2]

(b) A laser emits red light of a single wavelength. The light is produced when electrons move from a higher energy level to a lower energy level. The difference in energy between the two levels is 1.96 eV.

(i) Calculate the wavelength of the light.

wavelength = ... m [3]

(ii) The power of the beam emitted by the laser is 1.0×10^{-2} W.

Calculate the number of photons emitted per unit time by the laser.

number per unit time = ... s^{-1} [1]

(iii) The photons are incident normally on a surface. Half of the number of photons are absorbed by the surface, and half are reflected.

Determine the average force exerted by the beam of photons on the surface.

average force = ... N [4]

[Total: 10]

9 Polonium-193 ($^{193}_{84}Po$) is an unstable nuclide. A nucleus of polonium-193 decays to a nucleus of lead-189 ($^{189}_{82}Pb$) by emitting an alpha-particle.

(a) Radioactive decay is both random and spontaneous.

State what is meant by:

(i) random

....

.... [1]

(ii) spontaneous.

....

.... [1]

(b) Define half-life.

....

....

.... [1]

(c) Data for the binding energy per nucleon of the particles involved in the decay of a nucleus of polonium-193 are given in Table 9.1.

Table 9.1

particle	binding energy per nucleon / eV
$^{193}_{84}Po$	7.774
$^{189}_{82}Pb$	7.826
$^{4}_{2}\alpha$	7.074

Determine the energy, in eV, released when a nucleus of polonium-193 decays into a nucleus of lead-189.

energy = ... eV [2]

(d) A pure sample of polonium-193 contains N_0 nuclei. After a time t the sample contains N nuclei of polonium-193. The variation of $\ln(N/N_0)$ with t is shown in Fig. 9.1.

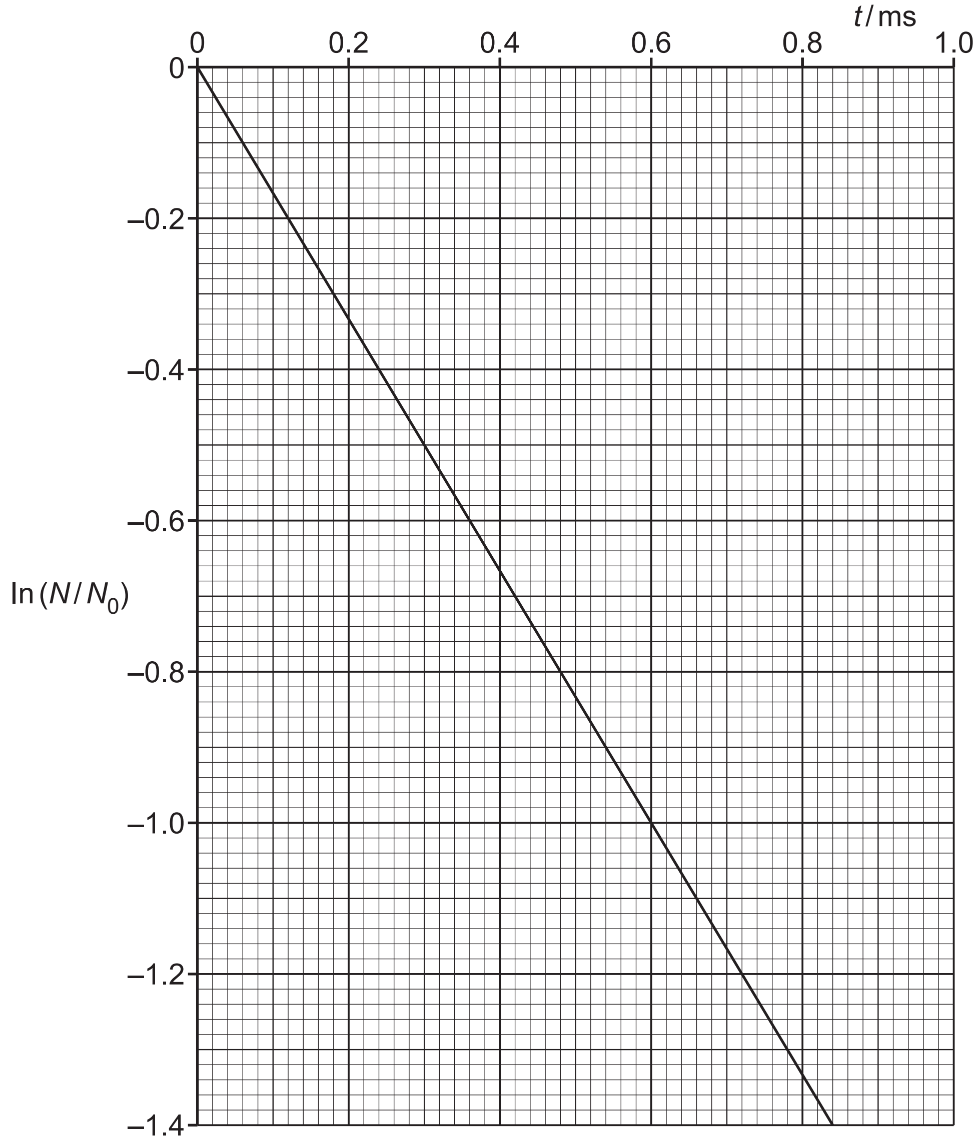

Fig. 9.1

(i) State the name of the quantity that is represented by the magnitude of the gradient of the line in Fig. 9.1.

.... [1]

(ii) Use Fig. 9.1 to determine the half-life, in ms, of polonium-193.

half-life = ... ms [2]

(e) Positron emission tomography (PET scanning) uses a radioactive tracer.

(i) State what happens to the positrons emitted by the tracer.

....

.... [1]

(ii) Explain why a tracer with a half-life of approximately 2 hours is a suitable tracer to use.

....

.... [1]

[Total: 10]

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10 **(a)** **(i)** State what is meant by the luminosity of a star.

....

.... [1]

(ii) Explain how standard candles are used to determine the distance to a galaxy.

....

....

....

....

....

.... [3]

(b) The Sun rotates on its axis. Points X, Y and Z are on the equator of the Sun as shown in Fig. 10.1.

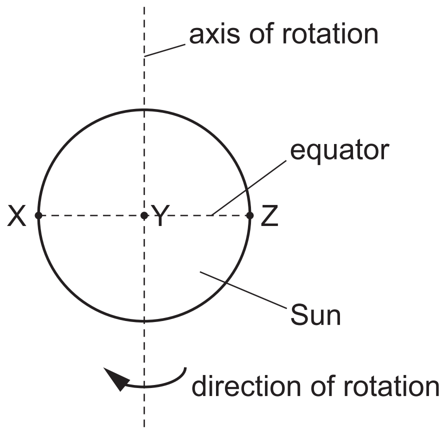

Fig. 10.1

The wavelengths of light from points X and Y are observed and recorded in Table 10.1.

Table 10.1

observed wavelength from X / nm	observed wavelength from Y / nm
656.2877	656.2831

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(i) The Sun rotates with a period of 2.07×10^6 s.

Show that the radius of the Sun is 6.93×10^8 m.

[3]

(ii) State and explain how the expected wavelength of the light observed from Z compares with the emitted wavelength.

....

....

.... [2]

(iii) The luminosity of the Sun is 3.8×10^{26} W.

Use the information in **(b)(i)** to calculate the surface temperature of the Sun.

temperature = ... K [2]

[Total: 11]

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