



VICTORIA JUNIOR COLLEGE  
 JC 2 PRELIMINARY EXAMINATION  
 Higher 2

CANDIDATE  
 NAME

CLASS

TUTOR  
 NAME



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**PHYSICS**

**9749/01**

Paper 1 Multiple Choice

**22 September 2025**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet

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**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, class and tutor name in the spaces on the top of this page.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

**Read the instructions on the Answer Sheet very carefully.**

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

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This document consists of **16** printed pages.

**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

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$$

$$(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$$

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

$$g = 9.81 \text{ m s}^{-2}$$

**Formulae**

uniformly accelerated motion

$$s = ut + \frac{1}{2}at^2$$

work done on / by a gas

$$v^2 = u^2 + 2as$$

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -Gm/r$$

temperature

$$T/K = T/^\circ\text{C} + 273.15$$

pressure of an ideal gas

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

mean translational kinetic energy of an ideal 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

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$1/R = 1/R_1 + 1/R_2 + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

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

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

- 1 The e.m.f. induced in a coil by a changing magnetic flux is equal to the rate of change of flux with time. Which is a unit for magnetic flux?
- A  $\text{kg m}^2 \text{s}^{-2} \text{A}^{-1}$   
B  $\text{kg m}^2 \text{s}^{-2} \text{A}$   
C  $\text{kg m}^2 \text{s}^2 \text{A}^{-1}$   
D  $\text{m}^2 \text{s}^{-2} \text{A}^{-1}$
- 2 What is a reasonable estimate for the volume of a wooden metre rule found in a school laboratory?
- A  $1.5 \text{ cm}^3$       B  $15 \text{ cm}^3$       C  $150 \text{ cm}^3$       D  $1500 \text{ cm}^3$
- 3 A student carried out an experiment to determine the resistivity  $\rho$  of copper using a copper wire. The uncertainties in the measurements are shown.

uncertainty in length  $l$  of wire = 0.2%  
uncertainty in diameter  $d$  of wire = 1.6%

The equation for resistivity  $\rho$  is  $\rho = \frac{\pi d^2 R}{4l}$ .

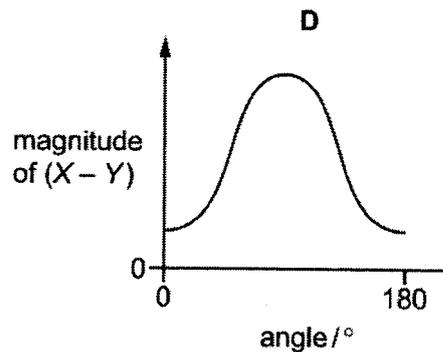
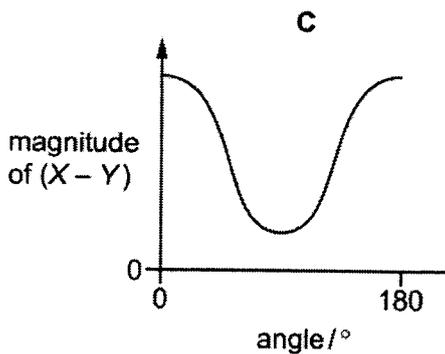
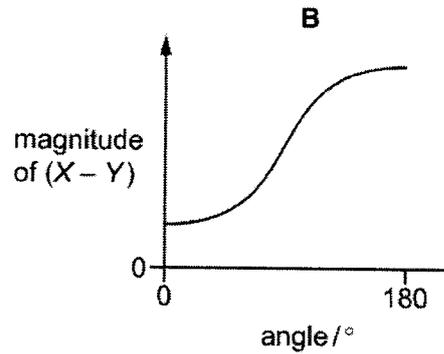
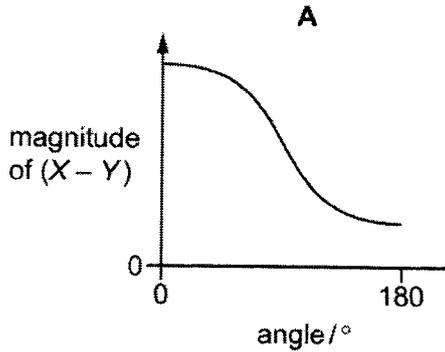
He obtains a resistivity value of  $(1.71 \pm 0.07) \times 10^{-8} \Omega \text{ m}$  with its associated uncertainty.

What is the uncertainty in the measurement of resistance  $R$  of the wire?

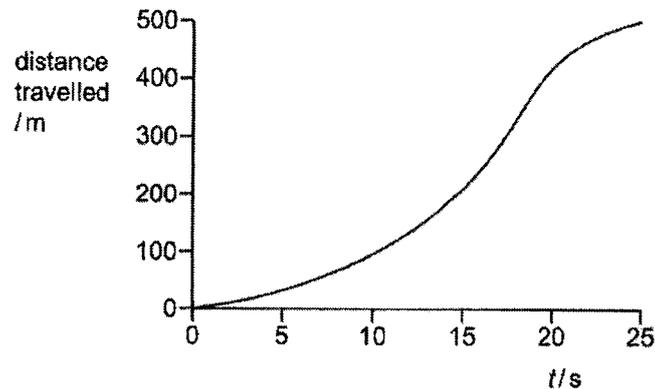
- A 0.007%      B 0.7%      C 0.9%      D 7%

- 4  $X$  and  $Y$  are vectors. The magnitude of  $X$  is less than the magnitude of  $Y$ . The vectors are initially in opposite directions.

As  $Y$  is rotated through  $180^\circ$ , how does the magnitude of the vector  $(X - Y)$  vary?



- 5 A car, starting from rest at time  $t = 0$ , travels along a road. The distance travelled from the starting point is measured over the next 25 seconds.



Which best describes the motion of the car?

- A** The maximum speed during the first 20 seconds is  $10 \text{ m s}^{-1}$ .
- B** At some instant during the first 20 seconds the speed is exactly  $20 \text{ m s}^{-1}$ .
- C** The average speed for the first 200 m of the journey is  $20 \text{ m s}^{-1}$ .
- D** The average speed between 20 and 25 seconds is greater than that between 15 and 20 seconds.

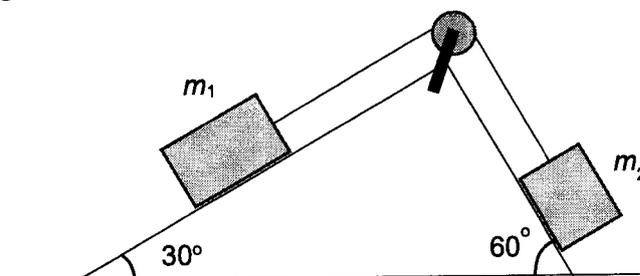
## 6

- 6 A boy with a ball was in a stationary lift. When the lift starts to accelerate upwards at  $1.2 \text{ m s}^{-2}$ , the boy released the ball from a height of  $1.5 \text{ m}$  above the floor of the lift.

What is the time taken by the ball to hit the floor of the lift?

- A 0.27 s      B 0.52 s      C 0.55 s      D 0.59 s

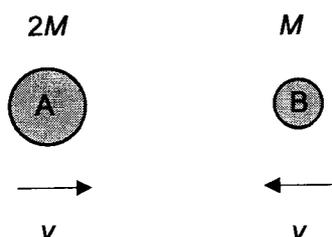
- 7 Two blocks of masses  $m_1 = 4.0 \text{ kg}$  and  $m_2 = 1.0 \text{ kg}$  are connected by a cord of negligible mass that passes over a frictionless pulley of negligible mass. The blocks slide on frictionless planes inclined at angles  $\theta_1 = 30^\circ$  and  $\theta_2 = 60^\circ$ .



What is the tension in the cord?

- A 2.3 N      B 5.8 N      C 8.0 N      D 10.7 N

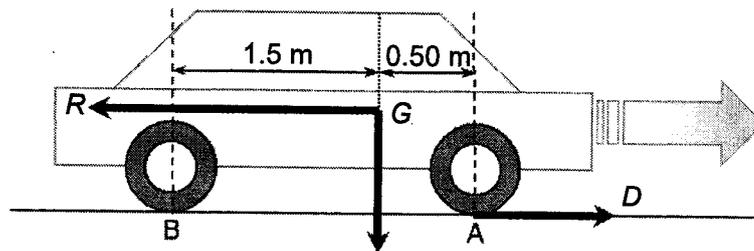
- 8 Two steel balls A and B of masses  $2M$  and  $1M$  respectively move towards each other with the same speed  $v$  and collide elastically.



What are the final velocities of the two balls in terms of  $v$ ? Take the rightward direction as positive.

	final velocity of ball A	final velocity of ball B
A	$\frac{4}{3}v$	$\frac{7}{3}v$
B	$-\frac{1}{3}v$	$\frac{5}{3}v$
C	$\frac{1}{3}v$	$\frac{2}{3}v$
D	$-v$	$2v$

- 9 A metal block is suspended by a spring balance and is fully submerged in a liquid. When the liquid is replaced with a less dense fluid, the reading on the spring balance
- A increases because upthrust decreases.  
 B increases because the object displaces less fluid.  
 C remains the same because the volume of the block is unchanged.  
 D decreases because upthrust increases.
- 10 The figure below represents the various forces acting on a car moving towards the right. The driving force  $D$  acts on the front wheels and the total resistive force is represented by the force  $R$ . The weight  $W$  of the car is 12000 N and it acts on the centre of mass  $G$  which is 90 cm above the ground.

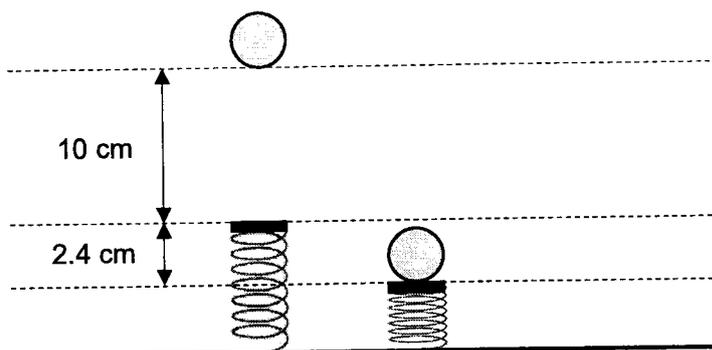


Given that the values of  $D$  and  $R$  are both 7000 N, what are the values of the normal reaction forces at A and at B acting on the wheels?

	normal reaction force at A / N	normal reaction force at B / N
A	8100	3900
B	6000	6000
C	6150	5850
D	5850	6150

- 11 A speed boat has two identical motors. When both motors are working, the speed boat attained a maximum speed of  $36.0 \text{ m s}^{-1}$ . Given that the drag force on the speed boat is proportional to the square of the speed, what is the maximum speed of the boat when only one motor is working?
- A  $9.0 \text{ m s}^{-1}$       B  $18.0 \text{ m s}^{-1}$       C  $24.2 \text{ m s}^{-1}$       D  $28.6 \text{ m s}^{-1}$

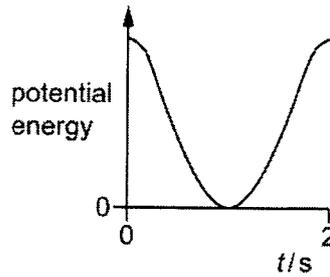
- 12 A 20 g ball bearing is released from rest 10 cm above the top of an unstretched spring. It compresses the spring and comes to rest when the spring is compressed by 2.4 cm as shown in the figure below.



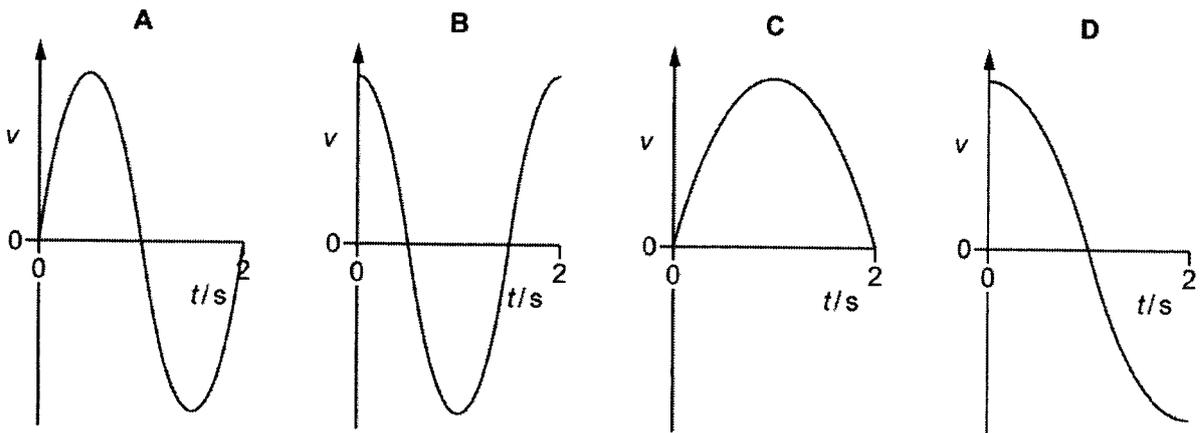
What is the spring constant of the spring?

- A 2.0 N m<sup>-1</sup>    B 8.6 N m<sup>-1</sup>    C 68 N m<sup>-1</sup>    D 84 N m<sup>-1</sup>
- 13 A stone of mass  $m$  attached to a string is whirled in a vertical circle of radius  $r$ . At the top of the circle, the tension in the string is four times the stone's weight. At this point the stone's speed is
- A  $\sqrt{rg}$     B  $\sqrt{3rg}$     C  $\sqrt{4rg}$     D  $\sqrt{5rg}$
- 14 Satellites A and B of masses  $m$  and  $2m$  are placed in geostationary orbits of radii  $r_A$  and  $r_B$  about the Earth, where the radii are measured from the centre of the Earth to the respective satellites. Which of the following statements is correct?
- A The radii  $r_A$  and  $r_B$  are the same.
- B Both satellites have the same centripetal force.
- C Both satellites have the same total energy.
- D Both satellites have the same gravitational force.
- 15 The escape speed of an oxygen molecule at the Earth's surface is  $1.1 \times 10^4$  m s<sup>-1</sup>. What is the escape speed at  $4R$  from the centre of the Earth, where  $R$  is the radius of the Earth?
- A  $5.5 \times 10^3$  m s<sup>-1</sup>
- B  $6.4 \times 10^3$  m s<sup>-1</sup>
- C  $1.1 \times 10^4$  m s<sup>-1</sup>
- D  $1.2 \times 10^4$  m s<sup>-1</sup>

- 16 A particle oscillates with simple harmonic motion. The graph shows the variation, with time  $t$ , of the potential energy of the particle from  $t = 0$  to  $t = 2$  s.



Which graph could represent the variation, with time  $t$ , of the velocity  $v$  of the particle from  $t = 0$  to  $t = 2$  s?



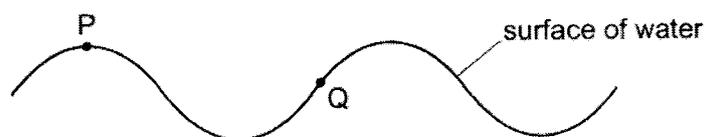
- 17 Two monoatomic ideal gases X and Y are mixed together in a sealed container. The molar mass of Y is twice that of X. At thermodynamic temperature  $T$ , the kinetic energy and root-mean-square speed of an atom of X are given by  $E$  and  $V$  respectively.

What is the kinetic energy and root-mean-square speed of an atom of Y at temperature  $T$ ?

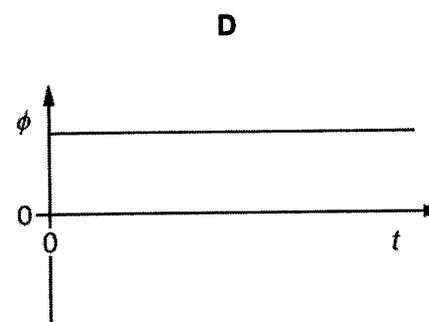
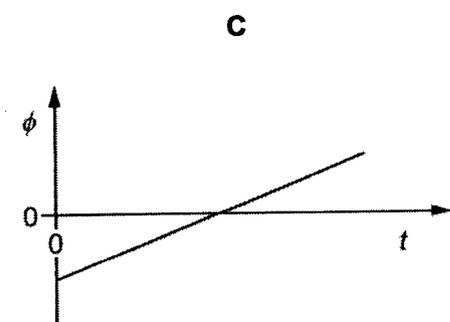
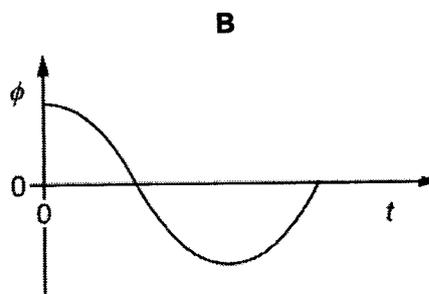
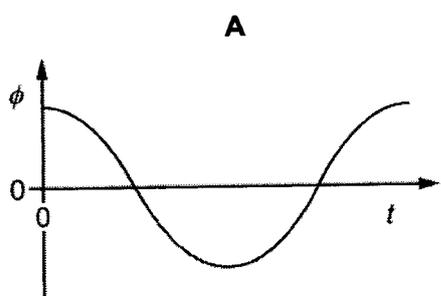
	kinetic energy	root-mean-square speed
<b>A</b>	$E$	$0.71V$
<b>B</b>	$E$	$V$
<b>C</b>	$E$	$1.4V$
<b>D</b>	$2E$	$0.71V$

- 18 In a progressive water wave, two particles P and Q, on the surface of the water, are a fixed horizontal distance apart. P and Q oscillate vertically.

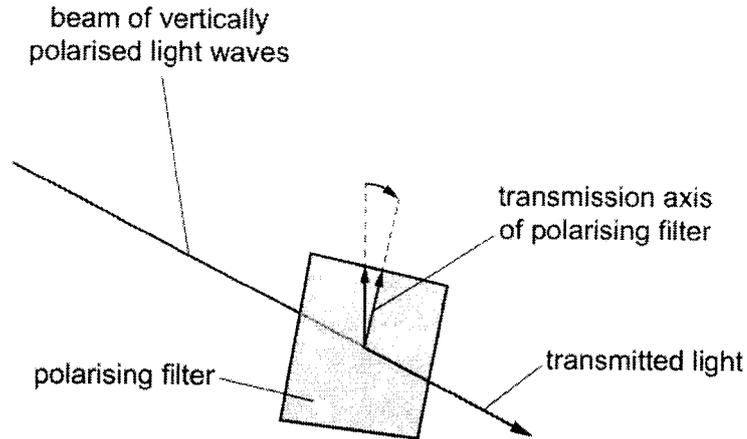
At time  $t = 0$ , the wave is as shown.



Which graph best represents the variation with time  $t$  of the phase difference  $\phi$  between the oscillation of the water particle P and the oscillation of the water particle Q?



- 19 A beam of vertically polarised light is incident normally on a polarising filter. The filter can be rotated so that it is always in a plane perpendicular to the beam. The transmission axis of the filter is initially vertical.

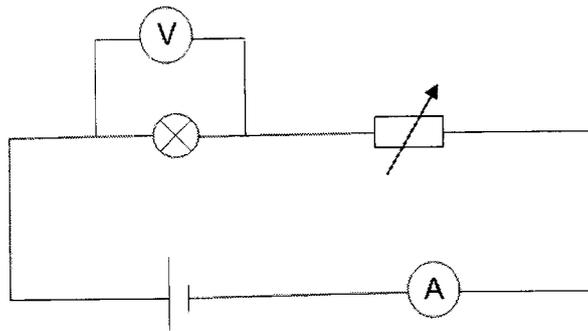


The filter is first rotated clockwise by an angle of  $30^\circ$  so that the transmitted light waves have intensity  $I_{30}$ . The filter is then rotated clockwise by a further angle of  $30^\circ$ .

What is the new intensity of the transmitted light waves?

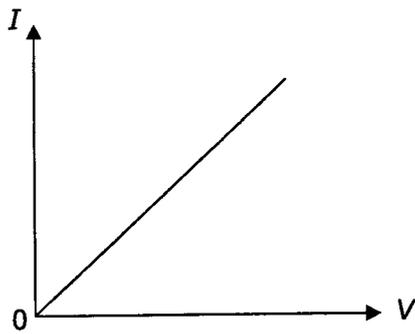
- A  $0.25I_{30}$       B  $0.33I_{30}$       C  $0.75I_{30}$       D  $0.87I_{30}$
- 20 Two waves of equal frequency and amplitude are travelling in opposite directions along a stretched string. When they meet, they form a stationary wave with three nodes and two antinodes. The frequency of both waves is doubled and a new stationary wave is formed.
- How many antinodes are there in the new stationary wave?
- A 1      B 3      C 4      D 5
- 21 A spherical water droplet with density  $1000 \text{ kg m}^{-3}$  and diameter  $1.20 \mu\text{m}$  is suspended in a uniform electric field. The electric field strength is  $462 \text{ N C}^{-1}$  and is directed downwards. How many excess electrons does it have?
- A  $1.92 \times 10^{-17}$       B 120      C 192      D  $1.20 \times 10^{11}$

22 In the circuit shown below, the current can be varied by means of the rheostat.

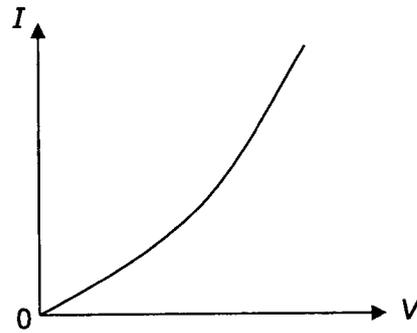


Which one of the following graphs best shows how the ammeter reading  $I$  varies with the voltmeter reading  $V$ ?

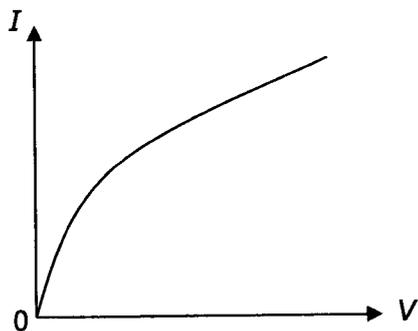
A



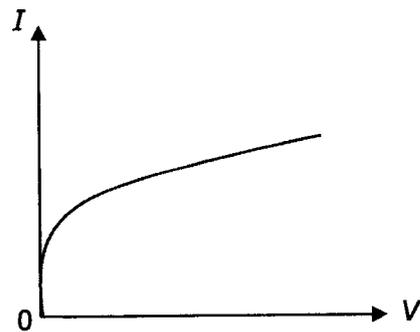
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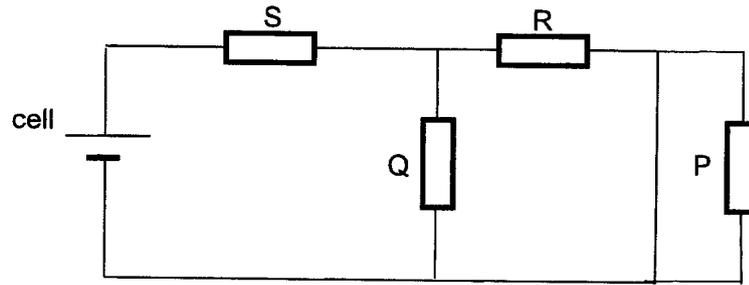
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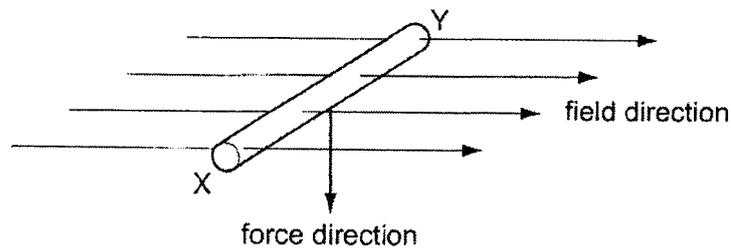
D



- 23 A cell is connected across four identical resistors P, Q, R and S. If the source is supplying a total power of 12.0 W, what is the power dissipated as heat in resistor R?



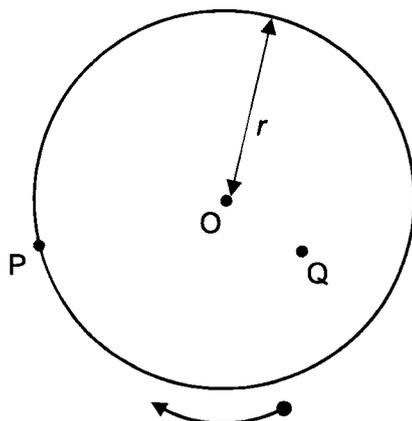
- A 2.0 W      B 3.0 W      C 4.0 W      D 5.0 W
- 24 A current-carrying conductor is placed at right angles to a uniform magnetic field of flux density 0.50 T. A 10 cm length of conductor lies within the field and experiences a force of 2.4 mN.



What is the direction of electron flow and rate of flow of electrons in the conductor?

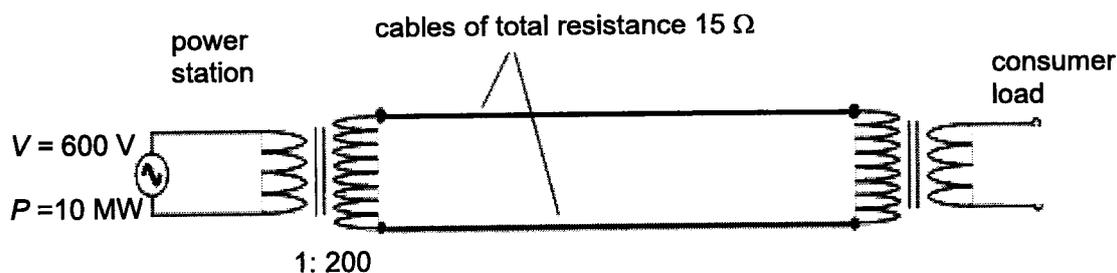
	direction of electron flow	rate of flow of electrons / s
A	X to Y	$4.8 \times 10^{-2}$
B	Y to X	$4.8 \times 10^{-2}$
C	X to Y	$3.0 \times 10^{17}$
D	Y to X	$3.0 \times 10^{17}$

- 25 An aluminium disc of radius  $r$  rotates about its centre at a constant speed. It is placed in a uniform magnetic field perpendicular to its surface. A steady electromotive force (e.m.f.)  $E$  is generated between the centre  $O$  and the rim at  $P$ .



What is the e.m.f. generated between points  $Q$  and  $P$ , where  $Q$  is a distance  $\frac{r}{2}$  from the centre?

- A zero      B  $\frac{E}{4}$       C  $\frac{E}{2}$       D  $\frac{3E}{4}$
- 26 An alternating potential difference is connected across a fixed resistor and the frequency  $f$  of the supply is varied, keeping the r.m.s voltage constant. The mean rate of production of heat in the resistor is
- A proportional to  $f$   
 B proportional to  $f^{1/2}$   
 C inversely proportional to  $f$   
 D independent of  $f$
- 27 A 10 MW nuclear power station produces electrical power at 600 V. It uses an ideal step-up transformer with a turns ratio of 1: 200 to increase the voltage before transmitting it over long-distance cables of total resistance  $15 \Omega$ . At the consumer load, a second ideal transformer steps down the voltage.



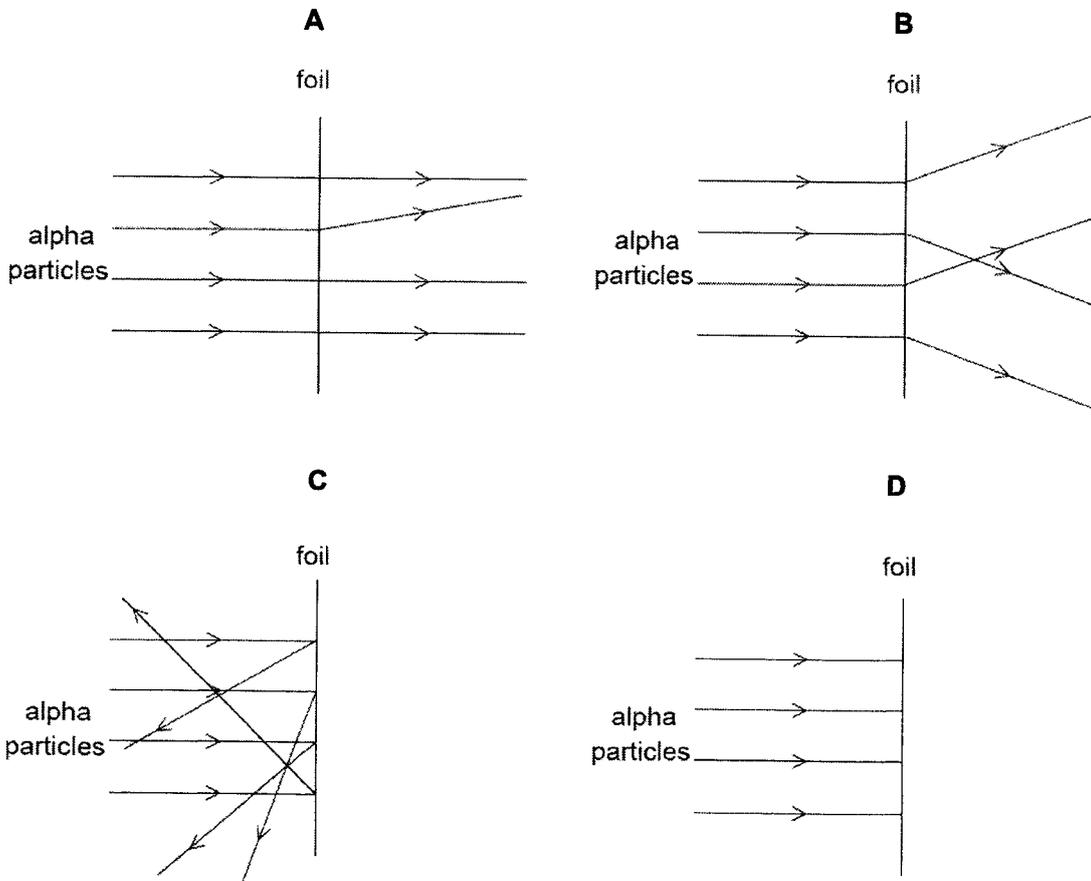
What is the power lost as heat in the cables?

- A 50 kW      B 100 kW      C 1.0 MW      D 960 MW

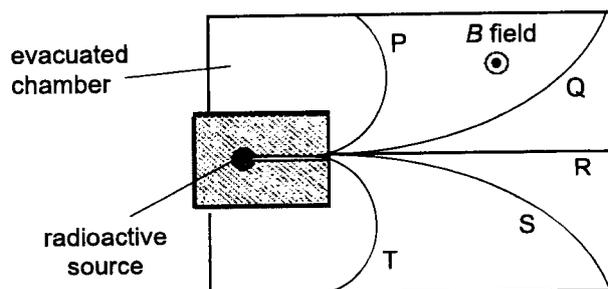
28 What is the wavelength of a particle of mass  $1.88 \times 10^{-28}$  kg when traveling with a speed equal to 10% of the speed of light?

- A  $7.1 \times 10^{-9}$  m    B  $4.4 \times 10^{-10}$  m    C  $1.3 \times 10^{-12}$  m    D  $1.2 \times 10^{-13}$  m

29 In the Rutherford alpha particle scattering experiment, alpha particles were directed at a thin gold foil. Which of the following shows how the majority of the alpha particles behave after reaching the foil?



- 30 A source undergoing alpha, beta and gamma decay is placed in an evacuated chamber with magnetic field directed out of the page. Which of the following represents the paths of the radiation particles emitted?



	$\alpha$ -particle	$\beta$ -particle	$\gamma$ -ray
<b>A</b>	Q	T	R
<b>B</b>	S	P	R
<b>C</b>	T	R	S
<b>D</b>	S	T	Q



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 JC 2 PRELIMINARY EXAMINATION  
 Higher 2

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## PHYSICS

**9749/02**

Paper 2 Structured Questions

**16 September 2025**

**2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

### READ THESE INSTRUCTIONS FIRST

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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.

Answer **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 7
2	/ 7
3	/ 8
4	/ 9
5	/ 8
6	/ 12
7	/ 10
8	/ 19
<b>Total</b>	<b>/ 80</b>

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pressure of an ideal gas

$$T / K = T / ^\circ C + 273.15$$

mean translational kinetic energy of an ideal molecule

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

displacement of particle in s.h.m.

$$E = \frac{3}{2}kT$$

velocity of particle in s.h.m.

$$x = x_0 \sin \omega t$$

electric current

$$v = v_0 \cos \omega t$$

resistors in series

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

resistors in parallel

$$I = Anvq$$

electric potential

$$R = R_1 + R_2 + \dots$$

alternating current/voltage

$$1/R = 1/R_1 + 1/R_2 + \dots$$

magnetic flux density due to a long straight wire

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

magnetic flux density due to a flat circular coil

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long solenoid

$$B = \frac{\mu_0 I}{2\pi d}$$

radioactive decay

$$B = \frac{\mu_0 NI}{2r}$$

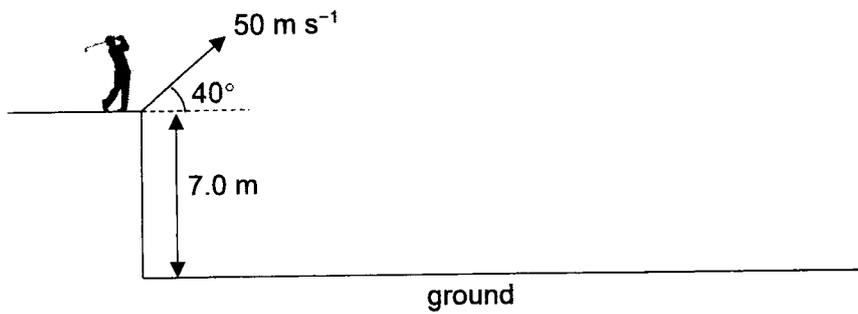
decay constant

$$B = \mu_0 nI$$

$$x = x_0 \exp(-\lambda t)$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

- 1 A golfer is practising his tee shot from a platform 7.0 m off the ground as shown in Fig. 1.1. The golf ball was launched at a speed of  $50 \text{ m s}^{-1}$ ,  $40^\circ$  above the horizontal. Assume air resistance is negligible.



**Fig 1.1**

- (a) Determine the maximum height above the ground attained by the ball.

maximum height = ..... m [3]

- (b) Calculate the time of flight of the ball.

time of flight = ..... s [2]

(c) A golf ball typically bounces a few times after a tee shot as shown in Fig. 1.2. The first time the ball touches the ground is indicated by A and the fourth time it touches the ground is indicated by B. Take the upward direction as positive.

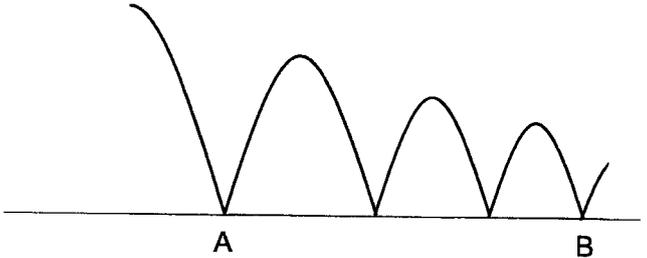


Fig. 1.2

Sketch, on Fig. 1.3, a graph to show the variation with time of the vertical velocity of the ball between from the instant it leaves A to the instant it reaches B.

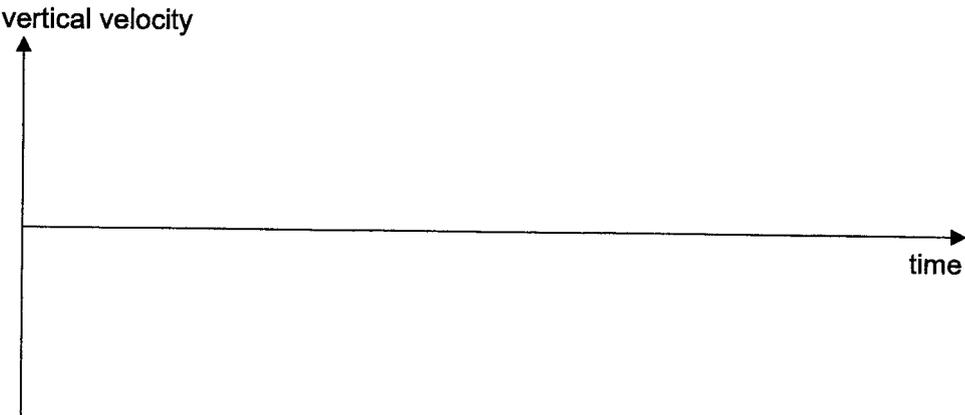


Fig. 1.3

[2]

[Total: 7]

- 2 (a) Define Newton's second law.

.....

.....

.....[1]

- (b) A light rope is attached to a 120 kg box on the ground. The other end of the rope runs over a light frictionless pulley.

A 80 kg man climbs up the free-hanging rope. As the man climbs up the rope, he pulls on the rope hard enough to cause himself to accelerate upwards. The only point of contact between the rope and the man occurs at his hands.

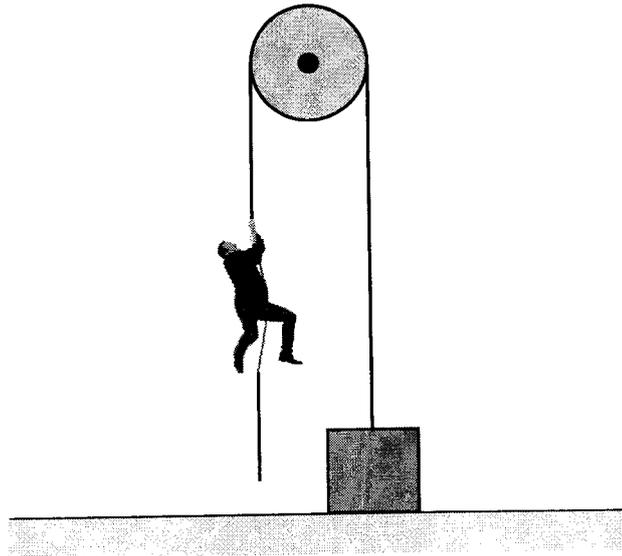


Fig. 2.1

- (i) Draw, on the outline of the man in Fig. 2.2, the forces acting on the man as he climbs.

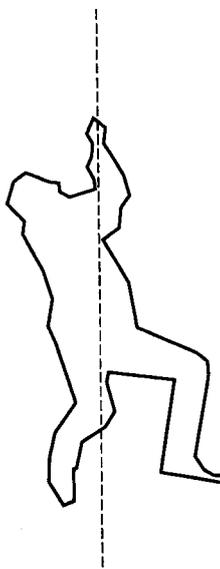


Fig. 2.1

[1]

7

- (ii) If the man climbs the rope with an acceleration of  $8.0 \text{ m s}^{-2}$ , determine the acceleration of the box.

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

- (c) The man releases the rope and the box falls. The box hits the ground with a speed of  $2.0 \text{ m s}^{-1}$  and sinks into the ground over a vertical distance of 10 cm before coming to a stop.

Calculate the force exerted by the ground on the box during the deceleration.

force = ..... N [3]

[Total: 7]

- 3 A peg is fixed to the rim of a vertical turntable of radius  $r$  rotating with a constant angular speed  $\omega$ , as shown in Fig. 3.1.

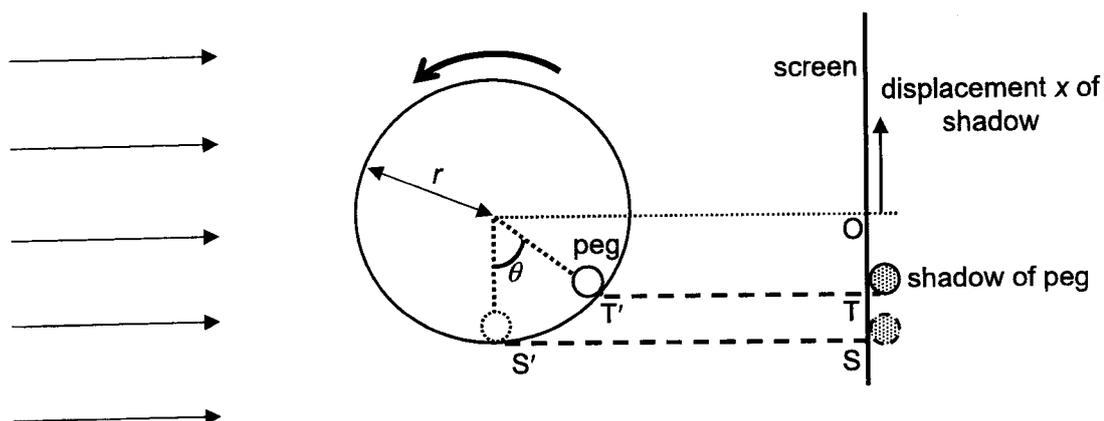


Fig. 3.1

A parallel beam of light is incident on the turntable such that the shadow of the peg is observed on the screen. Initially, the peg is at position  $S'$  and its shadow is at  $S$ . After time  $t$ , the peg moves through an angle of  $\theta$  and it is positioned at  $T'$  while its shadow is at  $T$ .

The displacement  $x$  of the shadow from  $O$  is shown in Fig. 3.1 where the upward direction is taken to be positive.

- (a) (i) Express the angular displacement  $\theta$  of the peg in terms of  $\omega$  and  $t$ .

[1]

- (ii) Write down an expression for the displacement  $x$  of the shadow on the screen in terms of  $\omega$ ,  $t$  and  $r$ .

[1]

- (iii) Hence, prove that the shadow of the peg is moving in simple harmonic motion. Explain your working.

[2]

(b) The turntable has a radius of 20.0 cm and angular speed of  $3.5 \text{ rad s}^{-1}$ . For the motion of the shadow on the screen,

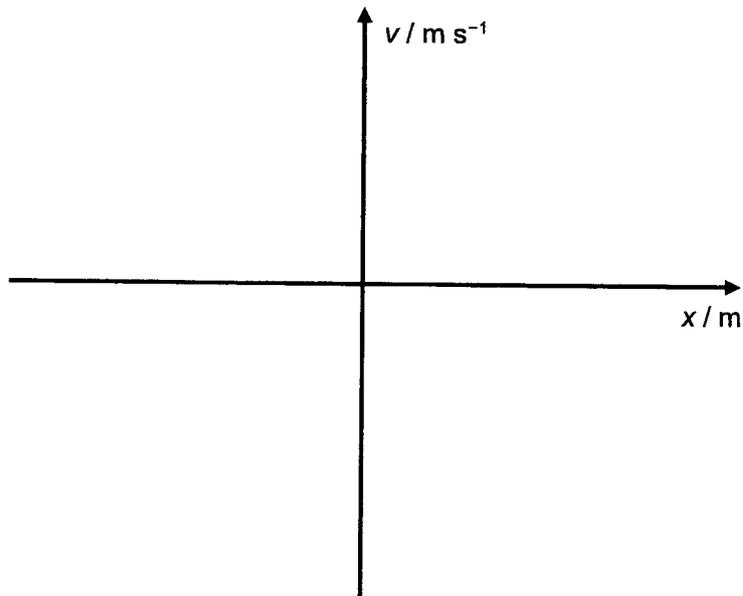
(i) calculate the acceleration of the shadow when the shadow is instantaneously at rest,

acceleration = .....  $\text{m s}^{-2}$  [1]

(ii) determine the velocity of the shadow as it passes through O,

velocity = .....  $\text{m s}^{-1}$  [1]

(iii) sketch the variation with displacement  $x$  of the velocity  $v$  of the shadow.



[2]

[Total: 8]

- 4 (a) Two waves are of the same frequency.

Explain with the aid of a diagram what, for the two waves, is meant by *phase difference*.

.....  
 .....[2]

- (b) Monochromatic light is incident normally on a double slit as shown in Fig. 4.1. Light passes through the two slits B and C and is incident on the screen.

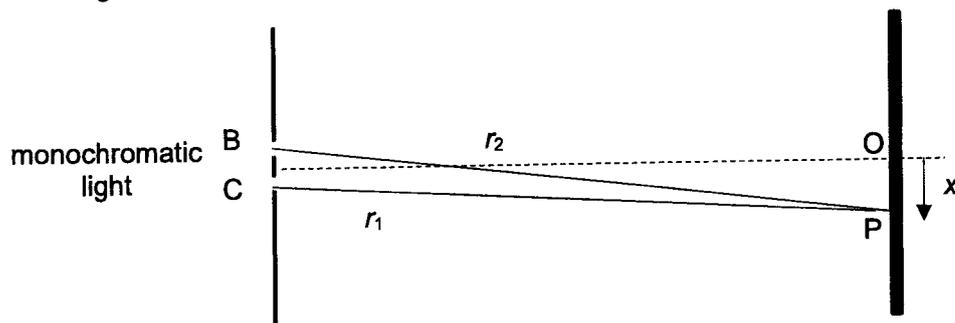


Fig. 4.1

The centre of the interference pattern formed on the screen is at O. The separation between the fringes is  $y$ .

$r_1$  and  $r_2$  are two waves arriving at P.

- (i) 1. Deduce the relationship between the phase difference of the two waves arriving at point P and the distance  $x$  from point O.

[1]

2. The waves have a phase difference of 12.6 radians when they meet at point P. Distance OP on the screen is 5.2 mm. Calculate the separation  $y$  between the fringes.

$y = \dots\dots\dots$  m [2]

- (ii) The light is adjusted so that the intensity of the light passing through slit B is reduced to a quarter that through slit C. The intensity of light from slit C alone at O is  $I$ . Deduce in terms of  $I$ , the intensity of the light at O due to the two slits.

intensity = ..... [2]

- (iii) Sketch, on Fig. 4.2, a graph to show the variation with distance  $x$  from point O of the intensity of light observed on the screen. Label your answer to (b)(ii) on Fig. 4.2. Ignore the single slit diffraction envelope.

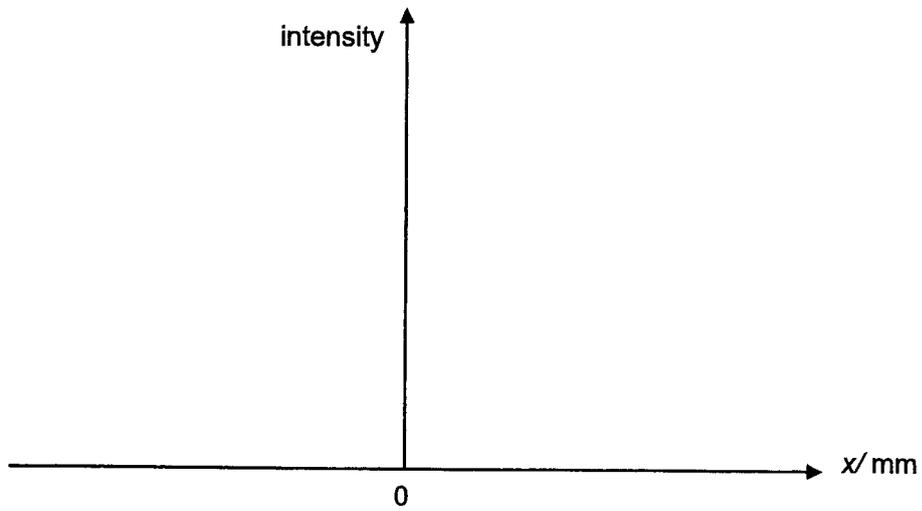


Fig. 4.2

[2]

[Total: 9]

- 5 Fig. 5.1 below shows an isolated, metal sphere in a region of vacuum that carries a negative electric charge.

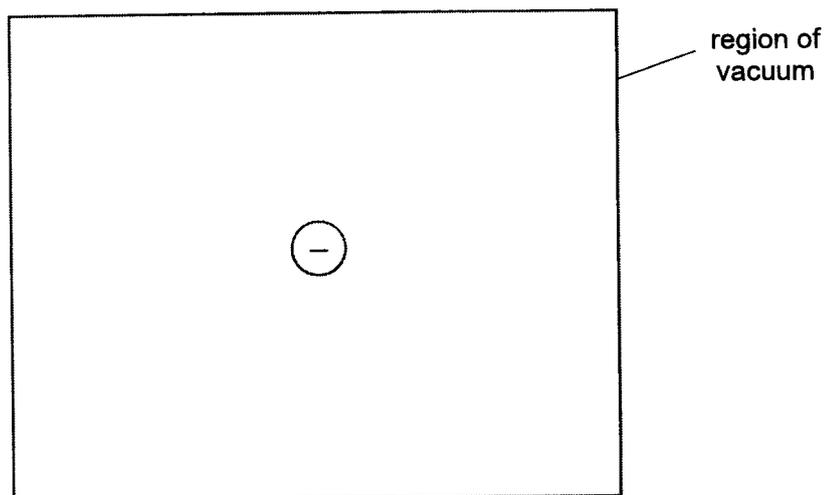


Fig. 5.1 (not to scale)

- (a) The electric potential at the surface of the sphere is  $-1800\text{ V}$ . In the region of vacuum on Fig. 5.1, draw
- arrows to represent the electric field pattern outside the sphere [1]
  - dotted lines to represent three equipotential surfaces of  $-1400\text{ V}$ ,  $-1000\text{ V}$  and  $-600\text{ V}$  outside the sphere. Label the potentials clearly. [1]
- (b) On the axes given in Fig. 5.2, sketch a graph to show the variation with distance  $r$  from the centre of the sphere of the potential  $V$ . The dotted line is drawn at  $r = R$  where  $R$  is the radius of the sphere.

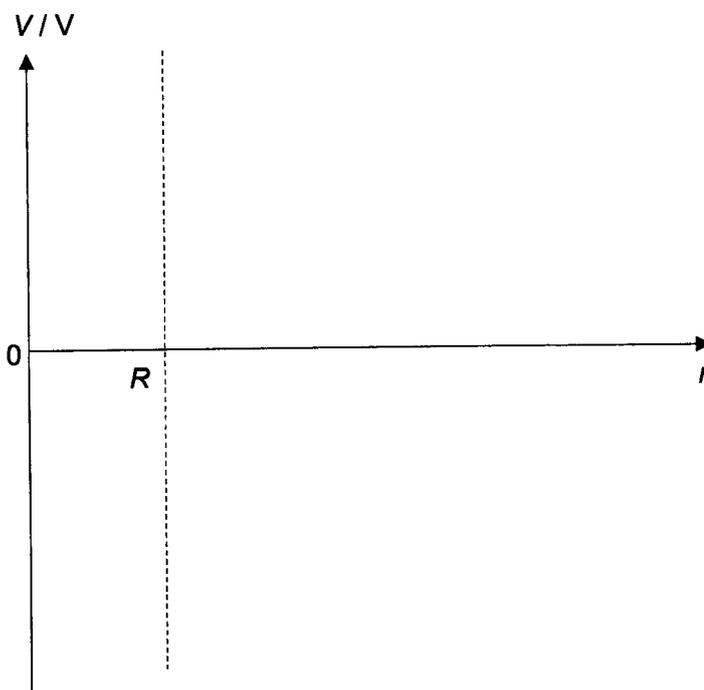


Fig. 5.2

[2]

(c) The sphere carries an electric charge of  $-9.0 \text{ nC}$  and has a radius of  $4.5 \text{ cm}$ . An electron is initially at rest at the surface of the sphere.

(i) Describe the motion and path followed by the electron as it leaves the surface of the sphere.

.....  
 .....  
 .....[2]

(ii) Determine the speed of the electron when it reaches a point a distance  $0.30 \text{ m}$  from the centre of the sphere.

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

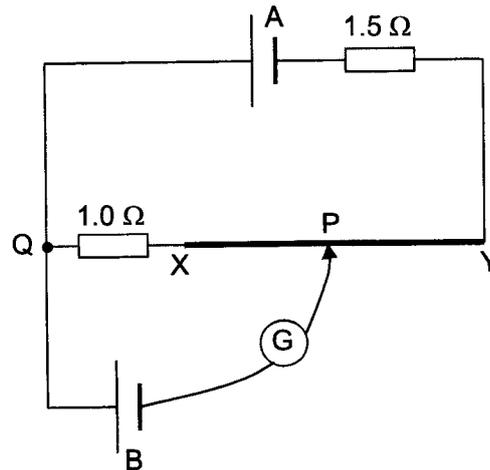
[Total: 8]

6 (a) A length of copper wire of cross-sectional area  $1.2 \times 10^{-6} \text{ m}^2$  carries a steady current of  $2.5 \text{ A}$ . The wire has a density of  $8.9 \times 10^3 \text{ kg m}^{-3}$ . Assume the wire is made entirely of copper atoms, each contributing one free electron to conduction. The molar mass of copper is  $63.5 \text{ g mol}^{-1}$ .

Calculate the average drift velocity of the electrons in the wire.

average drift velocity = .....  $\text{m s}^{-1}$  [3]

- (b) In the circuit below, cell A has an e.m.f. 2.0 V and negligible internal resistance. Wire XY is 100.0 cm long with a resistance of 5.0  $\Omega$ .



- (i) Distinguish between *electromotive force e.m.f.* and *potential difference p.d.* using energy considerations.

.....  
 .....  
 .....[1]

- (ii) Calculate the current flowing from Q to Y when the galvanometer registers a null deflection.

current = ..... A [2]

- (iii) Cell B has an e.m.f. of 1.5 V. At balance point P,

1. show that resistance across X and P is 4.6  $\Omega$ ,

[2]

2. calculate the balance length XP.

length XP = ..... m [2]

(iv) State and explain how the length XP in (b)(iii)2. will change if the internal resistance of cell A is not negligible.

.....  
.....[2]

[Total: 12]

- 7 X-rays are produced when electrons accelerated by a large electrical potential difference impinge upon a metal target. The X-ray spectrum of copper shown in Fig. 7.1 is produced by bombarding a copper target with high-energy electrons. The spectrum consists of two main components: a continuous spectrum (bremsstrahlung) and a line spectrum (characteristic X-rays).

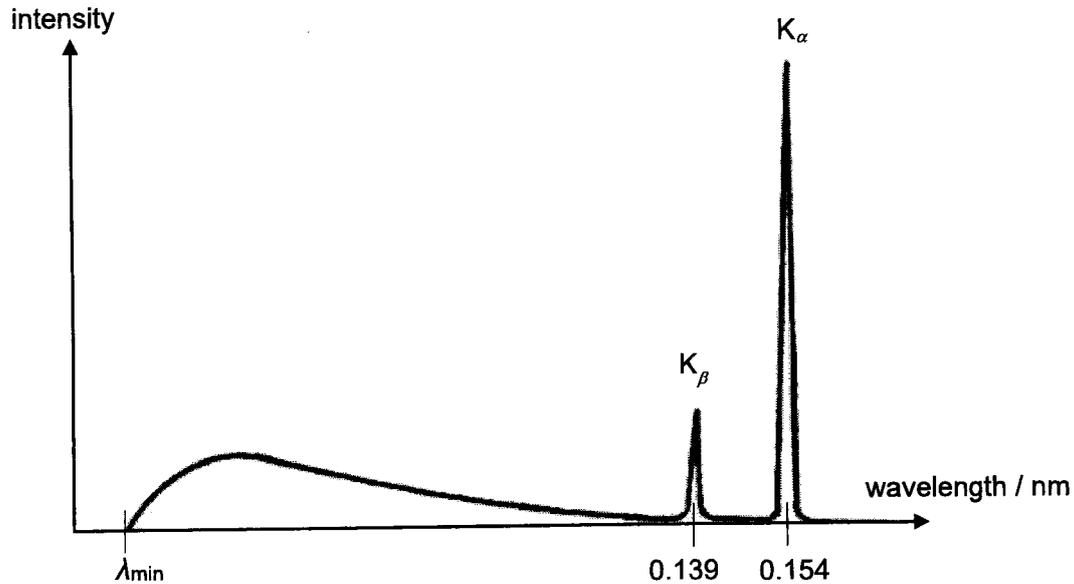


Fig. 7.1

(a) Explain the shape of:

(i) the continuous spectrum,

.....  
 .....  
 .....  
 ..... [2]

(ii) the sharp peaks in the spectrum.

.....  
 .....  
 .....  
 .....  
 ..... [2]

(b) (i) Calculate the energy of a  $K_{\alpha}$  photon.

energy = ..... eV [1]

(ii)  $L_{\alpha}$  photons are emitted when inner shell electrons de-excite from the M shell to the L shell. Calculate the wavelength of the  $L_{\alpha}$  photon.

wavelength = ..... nm [2]

(c) The minimum wavelength  $\lambda_{\min}$  observed in the continuous spectrum depends on the accelerating voltage  $V$  applied to the electrons. If the accelerating voltage is 30 kV, calculate  $\lambda_{\min}$ .

Explain your working.

$\lambda_{\min}$  = ..... nm [2]

(d) Explain why knowledge of the X-ray spectra of elements like copper can be used to identify the existence of these atoms in materials.

.....  
.....  
.....[1]

[Total: 10]

- 8 Wind energy is a renewable source of energy, harnessed from the kinetic energy of moving air. Since the late 1800s, windmills like the one shown in Fig. 8.1 have been used for milling grains.

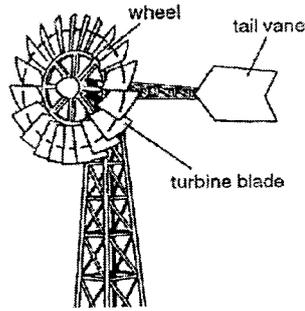


Fig. 8.1

Fig. 8.2 shows how the output power of these windmills varies with the overall diameter of the wheel for different wind speeds. The density of air is  $1.3 \text{ kg m}^{-3}$ .

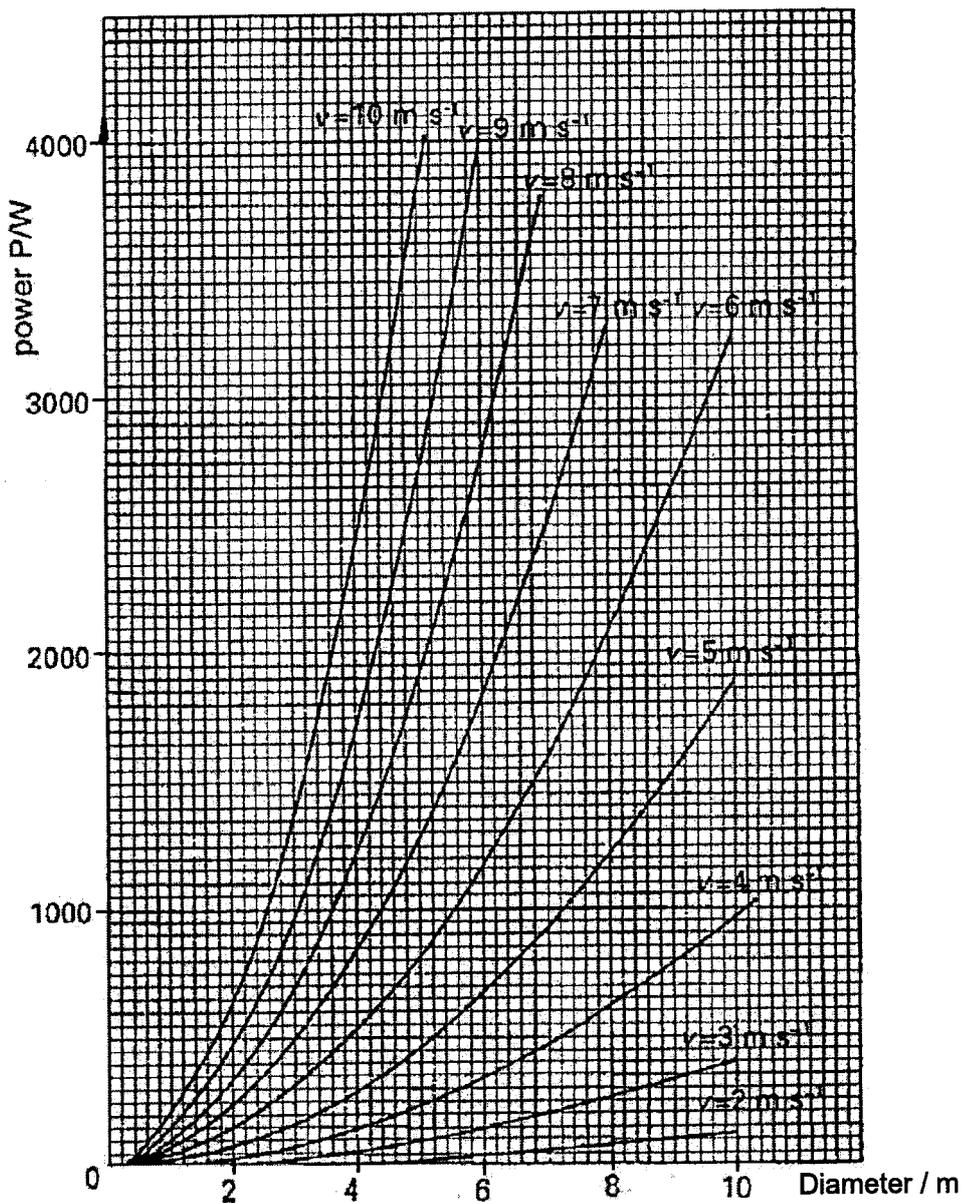
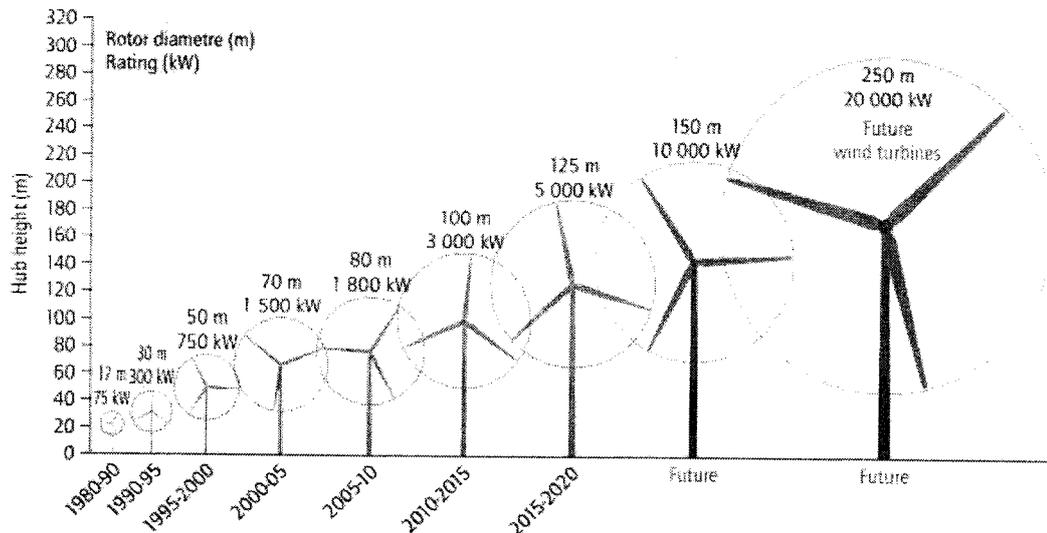


Fig. 8.2

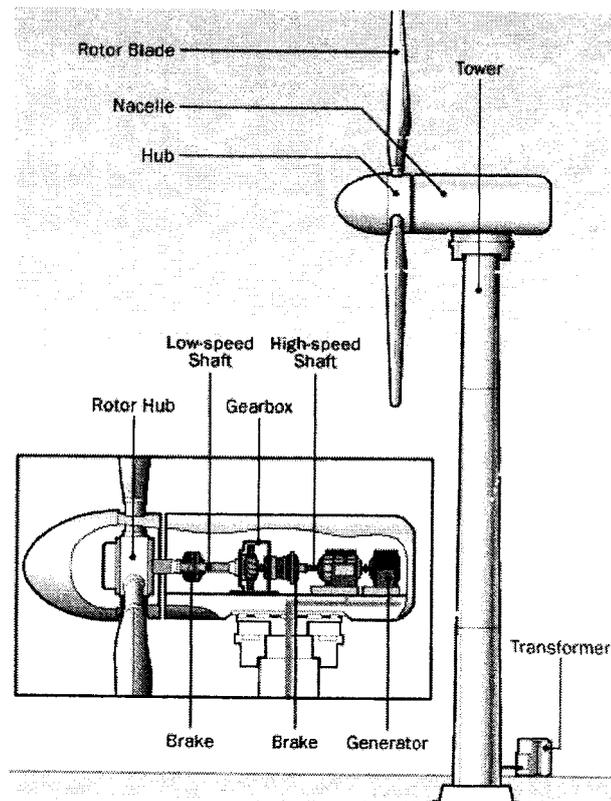
Wind turbines are the modern evolutions of windmills. They have evolved from their multi-bladed predecessors to the modern 3-bladed version. Wind turbines have also increased in hub height and rotor diameter size in the last 45 years as shown in Fig. 8.3.



Source: adapted from EWEA, 2009.

**Fig. 8.3**

Wind turbines have rotor hubs that can change the angle of attack of the rotor blades, which allows it to vary the amount of wind it catches. The nacelle houses a low-speed shaft that is connected to a gearbox which is in turn connected to a high-speed shaft before being connected to a generator. Parts of the wind turbine are shown in Fig. 8.4 below.



**Fig. 8.4**

The choice of location of wind turbines is an important factor to consider when building wind turbines. A table of average wind speed at various heights and locations are shown in Fig. 8.5.

Height above ground / m	Wind speed / m s <sup>-1</sup>	
	On land	Offshore
20	2.43	3.52
50	3.86	4.51
80	4.11	5.96
100	5.29	7.27
120	6.43	9.51

**Fig. 8.5**

- (a) The windmill is most efficient when the wheel and turbine faces the oncoming wind head-on. With reference to Fig. 8.1, explain how the tail vane works.

.....  
 .....[1]

- (b) By considering the kinetic energy possessed by a cylindrical volume of air, prove that the input power  $P$  that can be harnessed by a windmill of cross-sectional area  $A$  is given by

$$P = \frac{1}{2} \rho A v^3,$$

where  $\rho$  is the density of air and  $v$  is the velocity of air. Explain your working.

[3]

- (c) (i) For a windmill of diameter 9.0 m, state the power produced by the windmill when the wind speed is  $6.0 \text{ m s}^{-1}$ .

power = ..... W [1]

- (ii) Calculate the efficiency of a windmill of diameter 9.0 m when the wind speed is  $6.0 \text{ m s}^{-1}$ .

efficiency = ..... % [2]

- (iii) Suggest one reason for the loss in efficiency.

.....  
 ..... [1]

- (d) (i) For the 3-bladed wind turbines built between 2010 to 2015, each typical rotor blade has an effective area of  $120 \text{ m}^2$  that faces the wind head on. The dynamic wind pressure  $p$  is given by

$$p = \frac{1}{2} \rho v^2$$

where  $\rho$  is the density of air and  $v$  is the speed of air.

1. State the hub height of a typical wind turbine built on land between 2010 to 2015.

hub height = ..... m [1]

2. By considering the wind speed at the hub height in your answer in (d)(i)1., estimate the moments acting on the wind turbine taken about the base of the tower when built on land.

moment = ..... N m [2]

3. Hence suggest why modern wind turbines typically have only 3 blades even though a multi-bladed windmill ensures that more wind energy is harnessed.

.....  
.....  
.....[1]

(e) Explain how an increase in hub height and rotor diameter of wind turbines improves energy production.

.....  
.....  
.....  
.....[2]

(f) (i) Wind turbines typically spin at a rate of 10 to 20 rounds per minute. For a wind turbine with a rotor diameter of 250 m, calculate the speed at the tip of the blade if it were to spin at 30 rounds per minute.

speed = ..... m s<sup>-1</sup> [2]

(ii) Suggest why this rate of rotation is undesirable.

.....  
.....[1]

(g) Explain, using the laws of electromagnetic induction, why there is a need to convert the rate of rotation of the shaft to a high rate before connecting to the generator.

.....  
.....  
.....[2]

[Total: 19]



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
<b>Total</b>	<b>/ 80</b>

This document consists of **23** printed pages.

**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

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$$

$$(1 / (36\pi)) \times 10^{-9} \text{ F m}^{-1}$$

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

$$g = 9.81 \text{ m s}^{-2}$$

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2}at^2$$

work done on / by a gas

$$v^2 = u^2 + 2as$$

hydrostatic pressure

$$W = p\Delta V$$

gravitational potential

$$p = \rho gh$$

temperature

$$\phi = -Gm/r$$

pressure of an ideal gas

$$T / K = T / ^\circ C + 273.15$$

mean translational kinetic energy of an ideal molecule

$$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$$

displacement of particle in s.h.m.

$$E = \frac{3}{2} kT$$

velocity of particle in s.h.m.

$$x = x_0 \sin \omega t$$

electric current

$$v = v_0 \cos \omega t$$

resistors in series

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

resistors in parallel

$$I = Anvq$$

electric potential

$$R = R_1 + R_2 + \dots$$

alternating current/voltage

$$1/R = 1/R_1 + 1/R_2 + \dots$$

magnetic flux density due to a long straight wire

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

magnetic flux density due to a flat circular coil

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long solenoid

$$B = \frac{\mu_0 I}{2\pi d}$$

radioactive decay

$$B = \frac{\mu_0 NI}{2r}$$

decay constant

$$B = \mu_0 nI$$

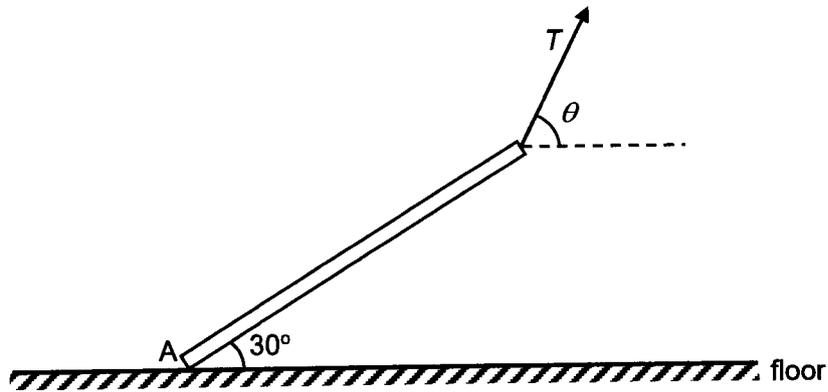
$$x = x_0 \exp(-\lambda t)$$

$$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$$

**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  $\theta$  is  $70^\circ$ , determine force  $T$ .

force  $T = \dots\dots\dots$  N [3]

[Total: 7]

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

$g = \dots\dots\dots \text{N kg}^{-1}$  [2]

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

$a_c = \dots\dots\dots \text{m s}^{-2}$  [1]

(iii) The speed of the ISS in its orbit is  $7.7 \text{ km s}^{-1}$ . 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  $2500 \text{ m}^2$ . The intensity of solar radiation at the orbit of the ISS is  $1.4 \text{ kW m}^{-2}$  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.

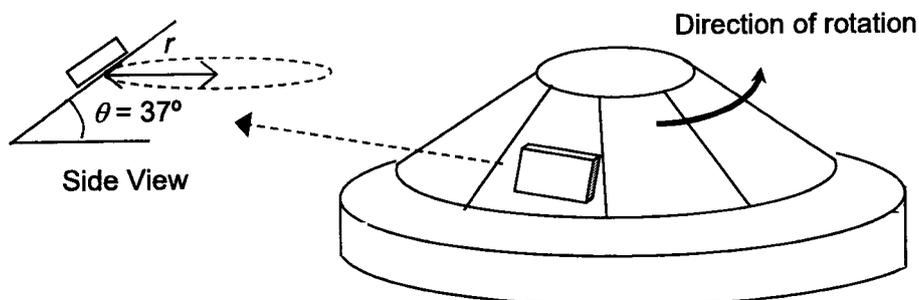


Fig. 3.1

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  $\theta$  that the slanted surface makes with the horizontal is  $37^\circ$ . 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  $10.0 \times 10^{-4} \text{ m}^3$  and  $3.0 \times 10^{-4} \text{ m}^3$  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  $\frac{\text{number of moles of gas in X}}{\text{number of moles of gas in Y}}$ .

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.

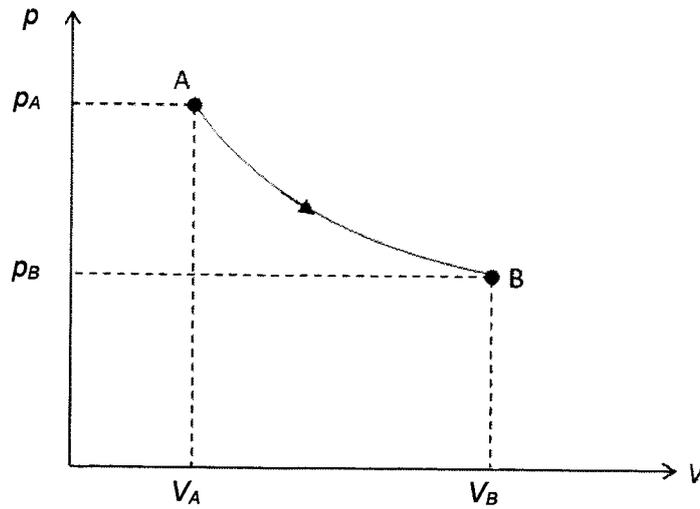


Fig. 4.1

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.

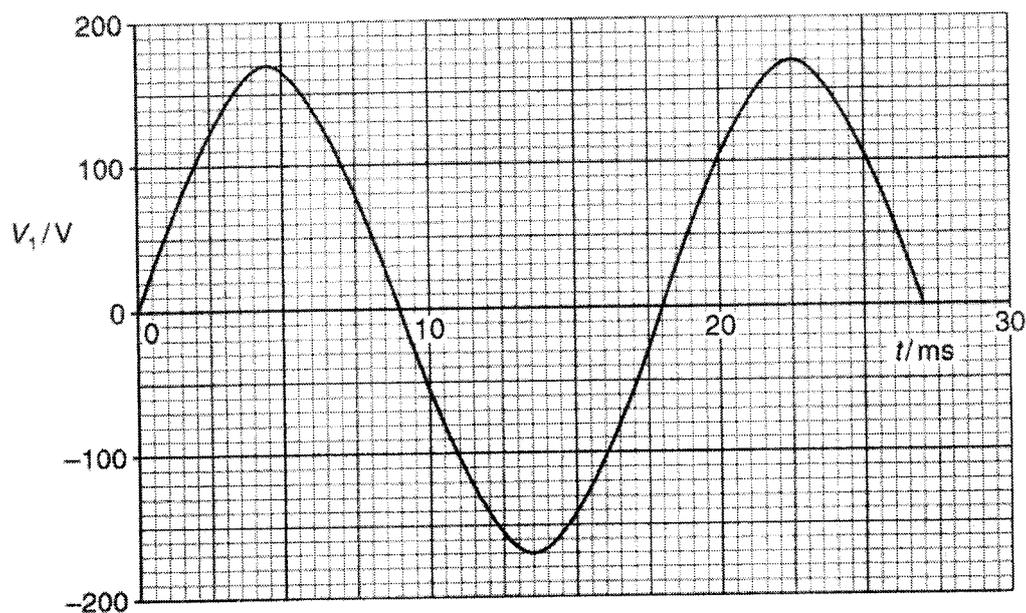


Fig. 5.1

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  $15 \Omega$  resistor.

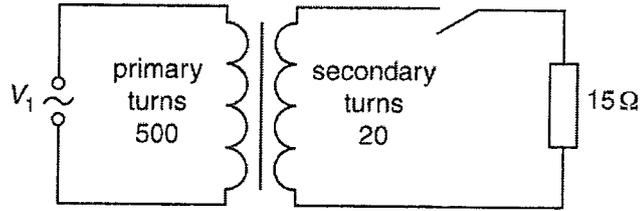


Fig. 5.2

The switch in the secondary circuit is now closed.

Determine

- (i) the peak current in the  $15 \Omega$  resistor,

peak current = ..... A [2]

- (ii) the mean power dissipated in the  $15 \Omega$  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  $\omega$  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.

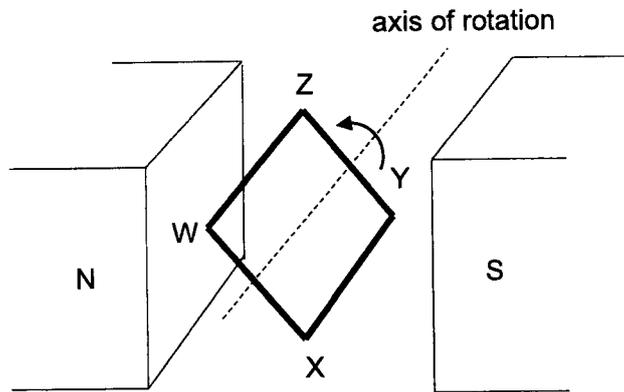


Fig. 6.1

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

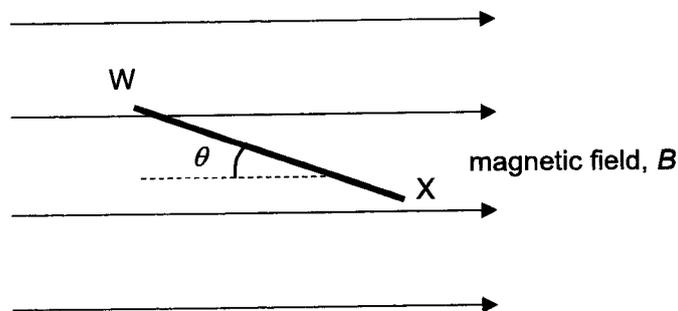


Fig. 6.2

- (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  $B$ ,  $\theta$  and  $L$ .

[1]

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

[2]

- (d) The resistance of the frame is  $5.0 \Omega$  and the length  $L$  of the square frame is  $0.20 \text{ m}$ . The frame is rotated in the magnetic field of flux density  $1.0 \text{ T}$  at an angular frequency of  $10 \text{ rad s}^{-1}$ . 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.

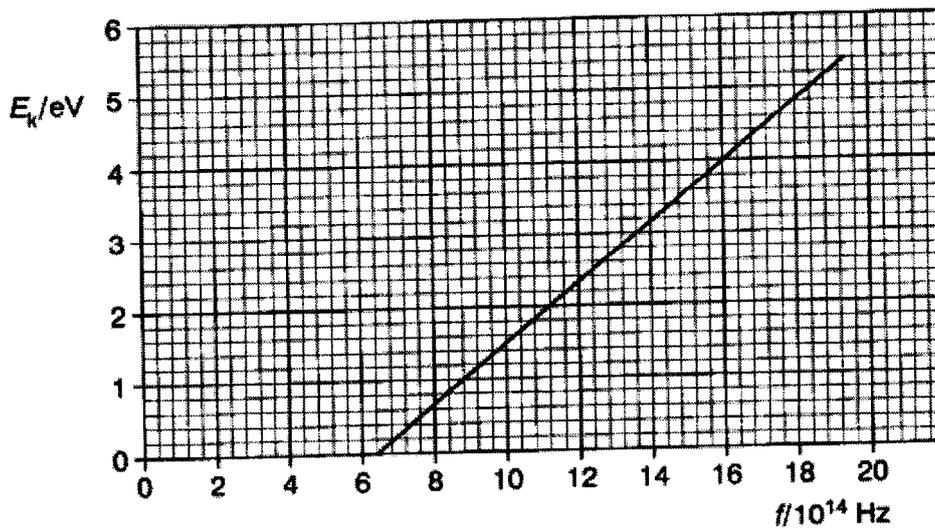


Fig. 7.1

(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  $18.0 \times 10^{14}$  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.

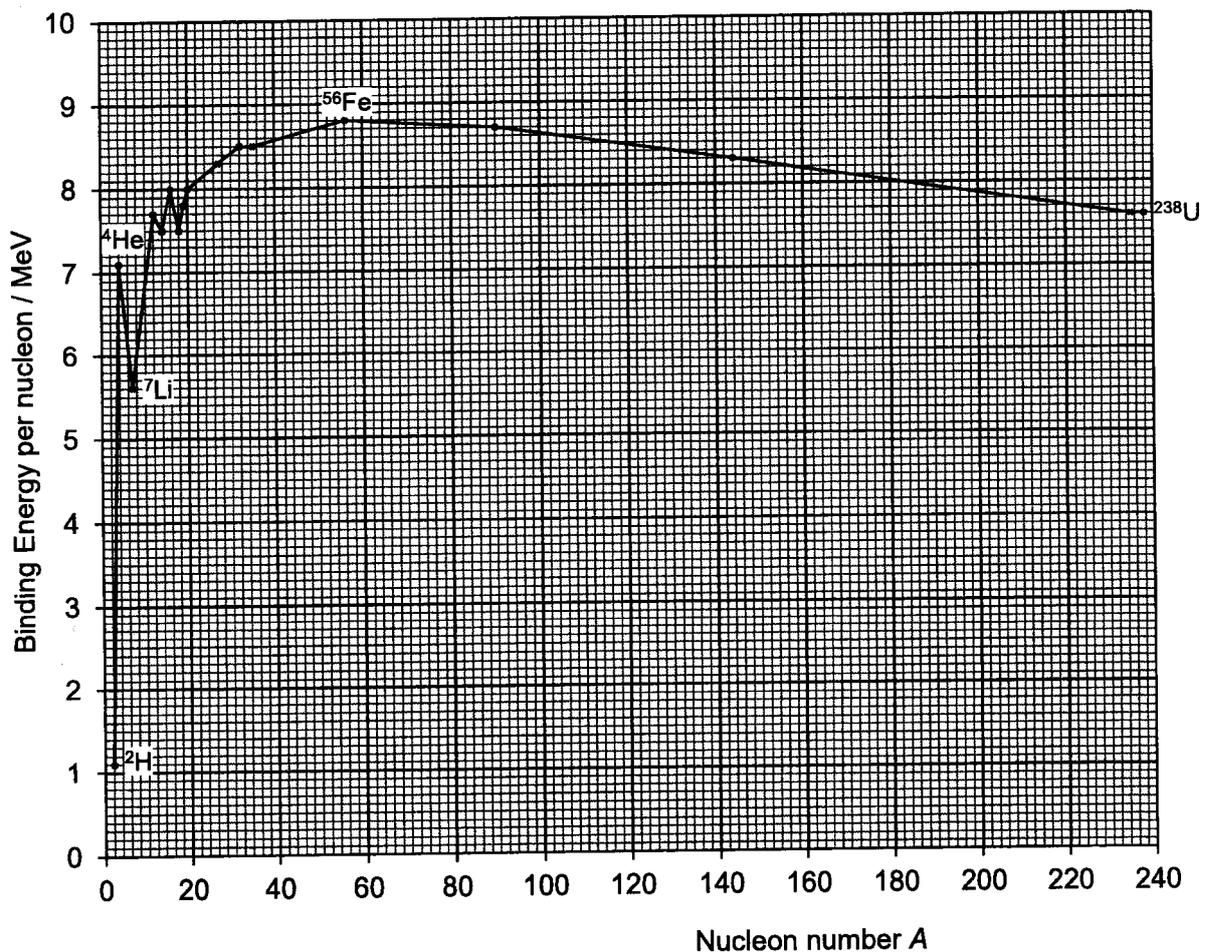
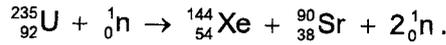


Fig. 8.1

- (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



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 ( ${}_{38}^{90}\text{Sr}$ ). 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.



- (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.

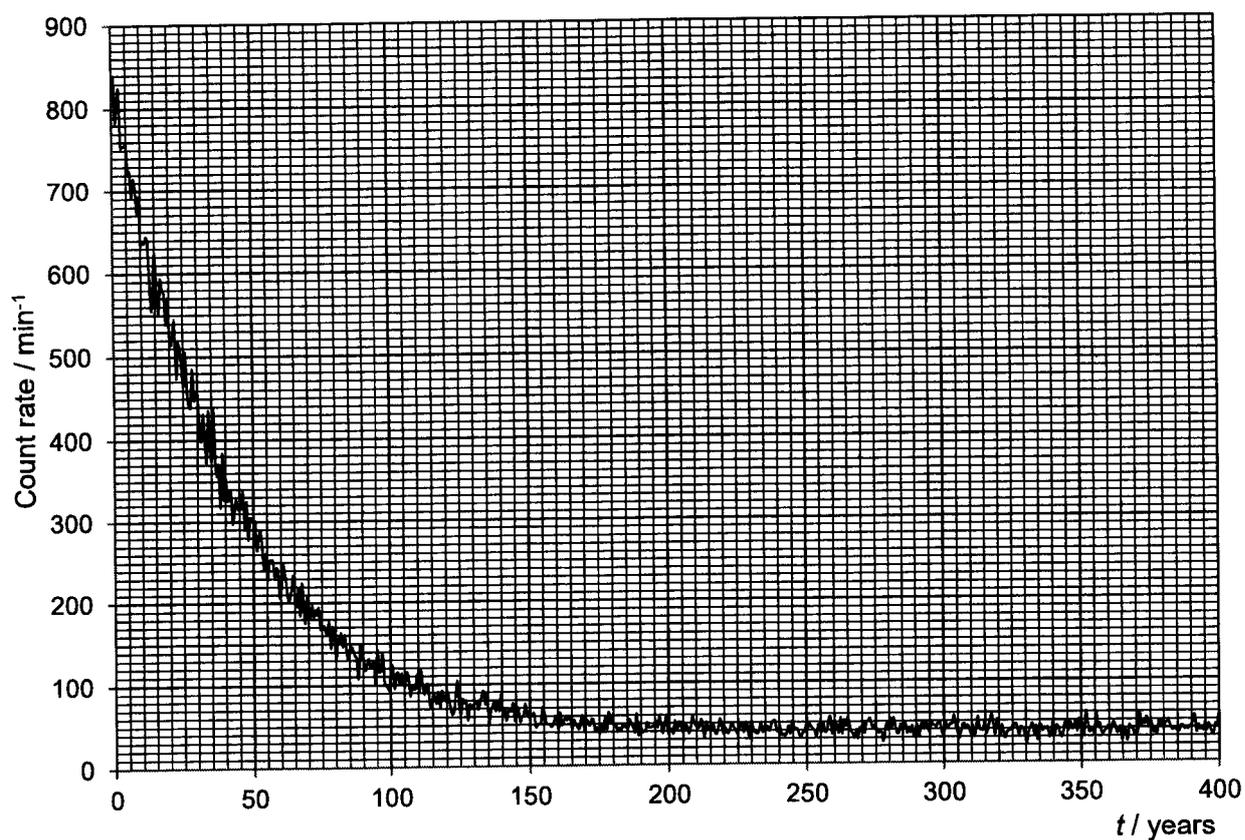


Fig. 8.2

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

.....[1]

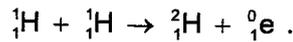
2. Use Fig. 8.2 to determine the half-life of strontium-90.

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



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  $1.2 \times 10^{-13}$  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  $1.5 \times 10^7$  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.

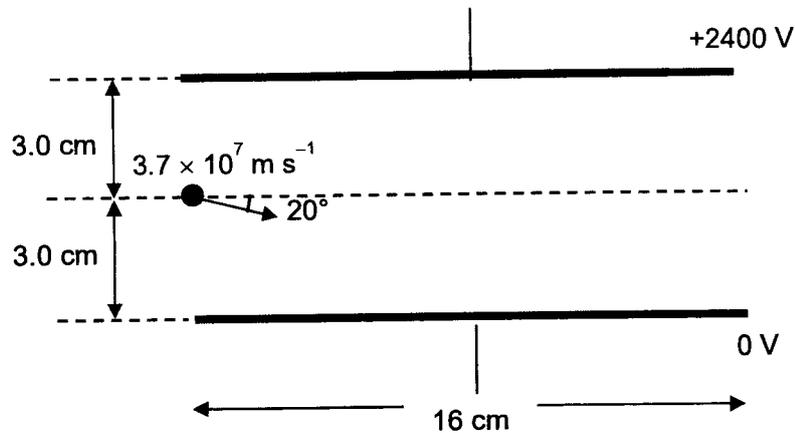


Fig. 9.1

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

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

acceleration = .....  $\text{m s}^{-2}$

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.

(iv) Hence, sketch, on Fig. 9.1, the path of the electron. [3]

(iv) Describe the path of the electron in the field. [1]

.....[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.

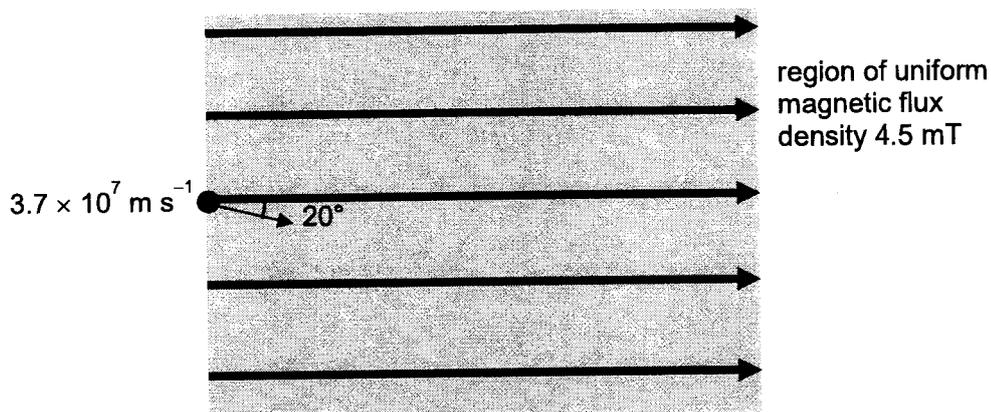


Fig. 9.2

The initial direction of the electron is at an angle of  $20^\circ$  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]

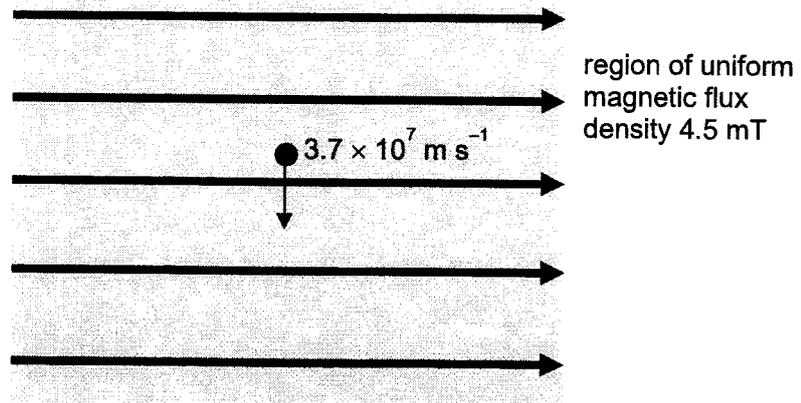
- (iii) State the magnitude of the force on the electron due to the component of its velocity along the direction of the field.

..... [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.

$$E = \dots\dots\dots \text{V m}^{-1} [2]$$

[Total: 20]

