

**HWA CHONG INSTITUTION**  
**JC2 Preliminary Examinations**  
**Higher 2**

**CANDIDATE  
NAME**

**CT GROUP**

**24S**

**CENTRE  
NUMBER**

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**INDEX  
NUMBER**

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**PHYSICS**

**9749/01**

**Paper 1 Multiple Choice**

**23 September 2025**

**1 hour**

Additional Materials: Optical Mark Sheet

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**INSTRUCTIONS TO CANDIDATES**

Write in soft pencil.

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

Write your name, CT, NRIC or FIN number on the optical mark sheet (OMS). Shade your NRIC or FIN in the spaces provided.

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 OMS.

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

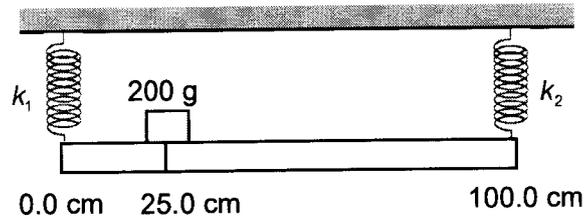
Any rough working should be done in this booklet.

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

Data	Formulae	
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion	$s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas	$W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure	$p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	gravitational potential	$\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	pressure of an ideal gas	$P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2} kT$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	electric current	$I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in series	$R = R_1 + R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$



- 4 A metre rule of mass 50 g is suspended horizontally from the ceiling by two springs at its ends, as shown.



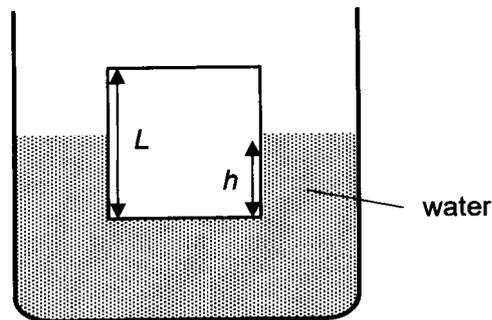
The spring at the 0.0 cm mark has spring constant  $k_1$ , while the spring at the 100 cm mark has spring constant  $k_2$ .

The springs have the same length when they are unstretched.

A 200 g mass is placed at the 25.0 cm mark.

What is the ratio  $\frac{k_2}{k_1}$  such that the ruler is horizontal?

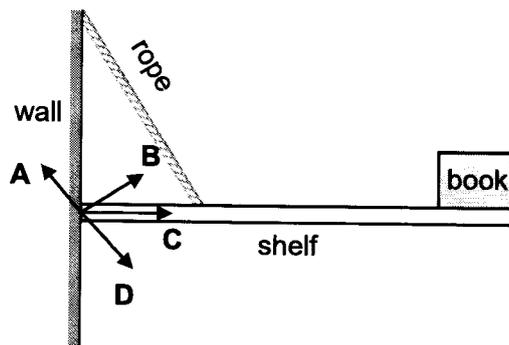
- A 0.33                      B 0.43                      C 2.3                      D 3.0
- 5 A cube of density  $\rho_0$  of side  $L$  floats in a beaker of water of density  $\rho_1$ . The depth of the cube submerged in water is  $h$ .



What is the magnitude of the upthrust on the cube?

- A  $\rho_0gh$                       B  $\rho_1gh$                       C  $\rho_0gL^3$                       D  $\rho_1gL^3$

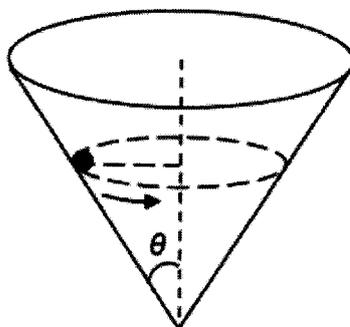
- 6 The figure below shows a light shelf attached to the wall by a rope. A heavy book is on the shelf at the position shown. What is the direction of the force of the wall on the shelf?



- 7 The potential energy of a body when it is at point P a distance  $x$  from a reference point O is given by  $U = kx^2$ , where  $k$  is a constant.  
What is the force acting on the body when it is at P?

- A magnitude of  $2kx$  from O to P
- B magnitude of  $kx$  from O to P
- C magnitude of  $kx$  from P to O
- D magnitude of  $2kx$  from P to O

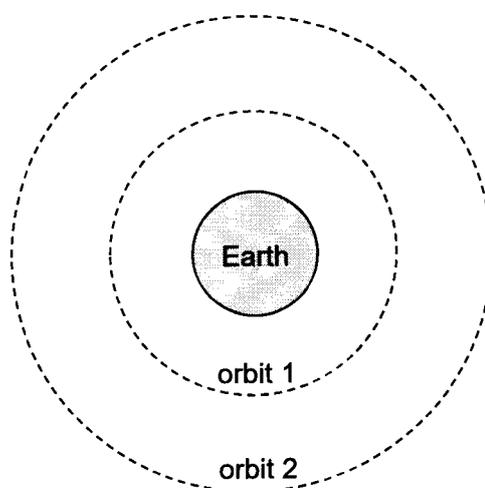
- 8 A small sphere is set into circular motion in a horizontal plane within a smooth cone as shown.



If the sphere is moving with a centripetal acceleration of  $0.8g$ , what is the angle  $\theta$ ?

- A  $37^\circ$
- B  $39^\circ$
- C  $51^\circ$
- D  $53^\circ$

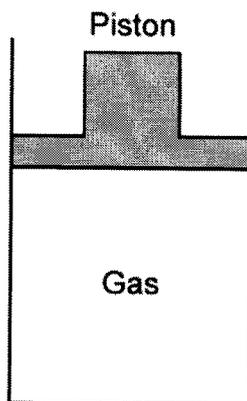
- 9 Which of the following statements regarding the gravitational field strength and acceleration of free fall at the surface of the Earth is true?
- A The gravitational field strength and the acceleration of free fall are always exactly equal at the Earth's surface, approximately  $9.8 \text{ m s}^{-2}$ , regardless of location.
- B The acceleration of free fall is larger at the Equator than at the North and South Poles.
- C The gravitational field strength varies significantly from the Poles to the Equator, while the acceleration of free fall is constant across the Earth's surface.
- D The gravitational field strength is numerically greater than or equal to the acceleration of free fall.
- 10 The diagram shows two circular orbits around the Earth.



How would the kinetic energy and gravitational potential energy of a satellite change if it is moved from orbit 1 to orbit 2?

	kinetic energy	gravitational potential energy
A	increase	increase
B	increase	decrease
C	decrease	decrease
D	decrease	increase

- 11 Two vessels Y and Z are of the same volume.  
Vessel Y contains 8 moles of hydrogen gas molecules of molar mass  $2 \text{ g mol}^{-1}$  while vessel Z contains 8 moles of oxygen gas molecules of molar mass  $32 \text{ g mol}^{-1}$ .  
The gas pressure is the same in both vessels.  
What is the ratio of the root-mean-square speed of the gas molecules in vessel Y to that in vessel Z?
- A 256                      B 16                      C 4                      D 1
- 12 Which statement about internal energy is correct?
- A The internal energy of a system can be decreased without transfer of energy by cooling.  
B When the internal energy of a system is decreased, its temperature always drops.  
C When two systems have the same internal energy, they must be at the same temperature.  
D The internal energy of a system is the summation of microscopic kinetic energy due to random motion of the molecules of the system.
- 13 A chamber containing gas is sealed by a movable piston of mass  $0.75 \text{ kg}$ .

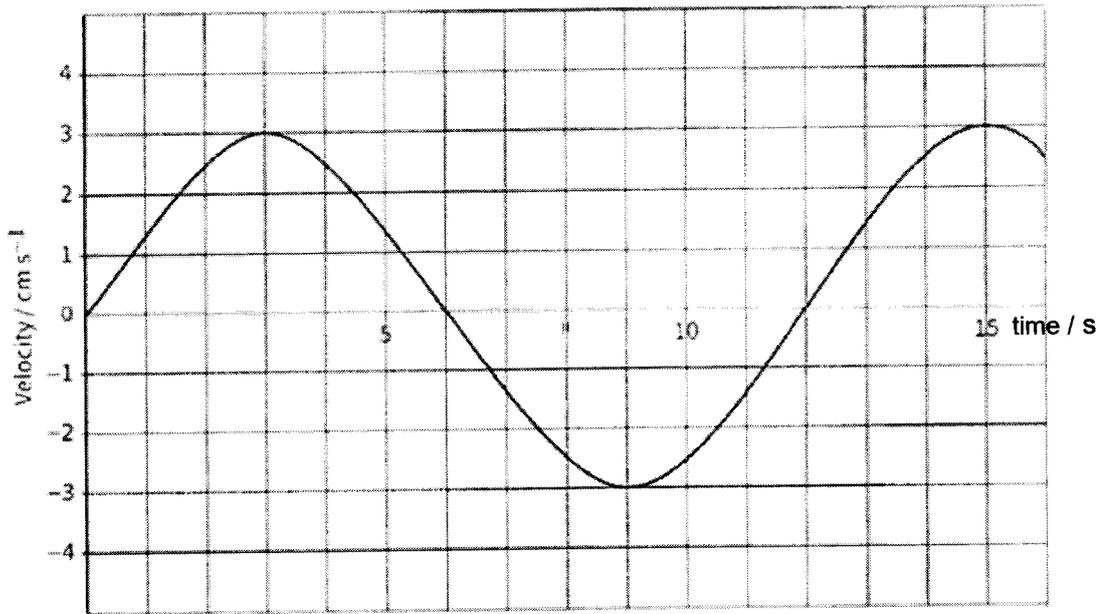


When the gas is heated, there is a short period in which the piston experiences an average upward acceleration of  $3.5 \text{ m s}^{-2}$  over a distance of  $12 \text{ cm}$ .

Calculate the work done by the gas during this period.

- A 0.315 J                      B 1.20 J                      C 2.18 J                      D 32.4 kJ

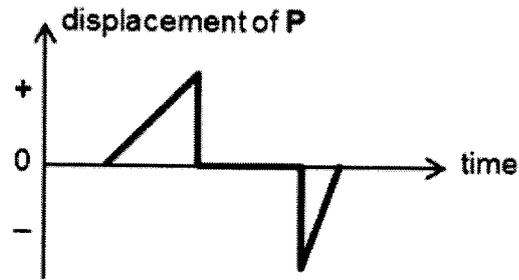
- 14 The graph below shows the variation with time of the velocity of a 3.0 kg mass oscillating in simple harmonic motion.



What is the maximum restoring force acting on the mass as it oscillates?

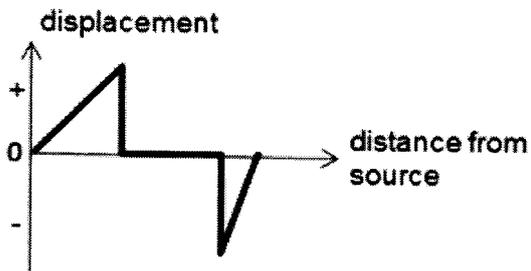
- A** 0.025 N      **B** 0.047 N      **C** 0.057 N      **D** 0.090 N

- 15 A wave pulse travels through a medium from left to right. The graph below shows the variation with time of the displacement of a particle P as the pulse passes it.

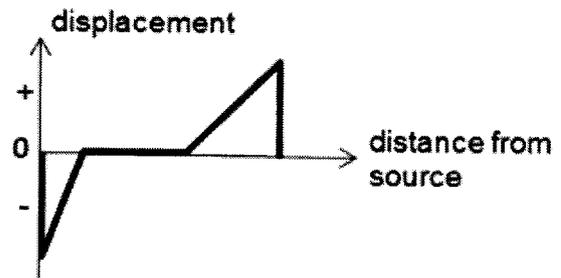


Which one of the following graphs best represents the variation of the displacement with positions of the particles along the path of the wave pulse at a certain instant?

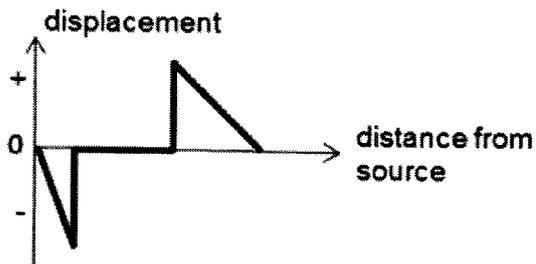
A



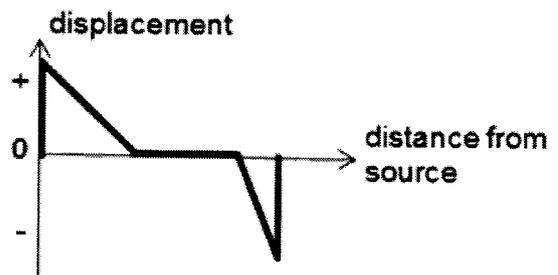
B



C



D



- 16 Unpolarised light of intensity  $I_0$  is incident on the first of two polarising sheets. Initially the axis of polarisation of the sheets are perpendicular to each other.

Which of the following should be done so that light intensity of  $0.25I_0$  can emerge from the second polarising sheet?

- A Rotate either sheet by  $45^\circ$ .  
 B Rotate either sheet by  $60^\circ$ .  
 C Add a third sheet in between with same plane of polarisation as the first sheet.  
 D Remove one of the 2 sheets.
- 17 A telescope with an aperture of 45 cm receives light of wavelength 630 nm from a binary star system which can just be resolved by the telescope.

The two stars are  $5.9 \times 10^{16}$  m from the telescope.

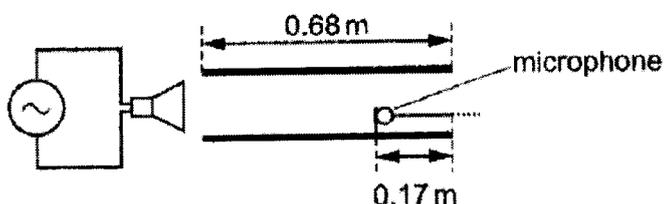
How far apart are the two stars?

- A  $2.4 \times 10^{10}$  m      B  $8.3 \times 10^{10}$  m      C  $2.4 \times 10^{13}$  m      D  $8.3 \times 10^{13}$  m

- 18 A stationary sound wave is formed inside an open tube of length 0.68 m.

A small microphone is inserted into the tube. It detects the first node at a distance of 0.17 m from the end. The microphone is then fixed in this position.

The speed of sound in the tube is  $340 \text{ m s}^{-1}$ .

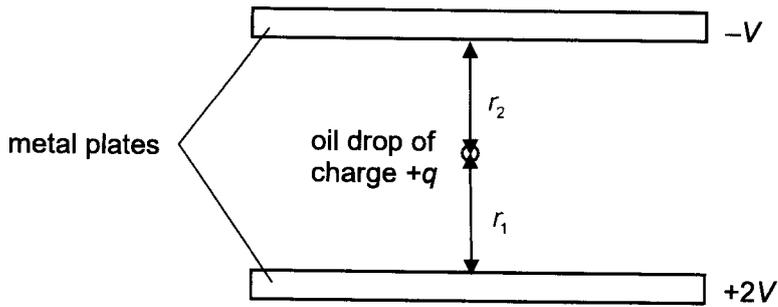


The frequency of the signal generator is now increased until the microphone again detects a node.

Which of the following is **not** one of such frequencies?

- A 2500 Hz      B 3000 Hz      C 3500 Hz      D 5500 Hz

- 19 A small oil drop of charge  $+q$  is suspended between two metal plates, as shown below.



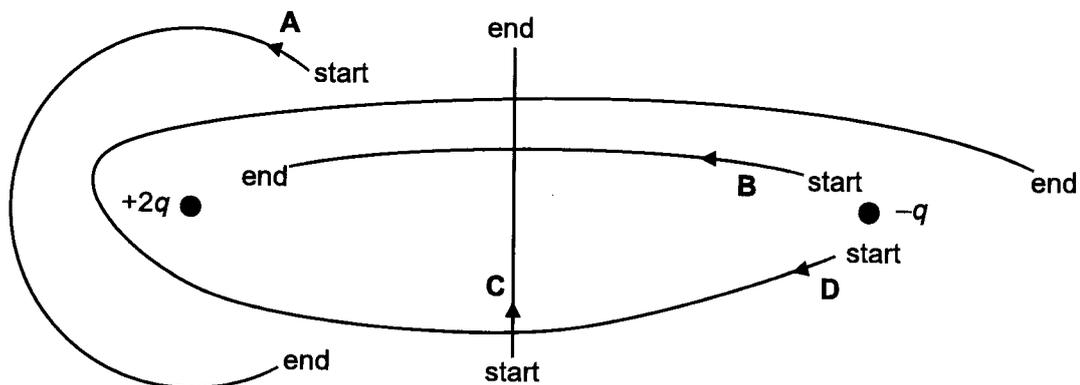
The small oil drop is a distance  $r_1$  from the lower plate and  $r_2$  from the upper plate. The lower plate has a charge  $Q_1$  and is held at a potential of  $+2V$ , while the upper plate has charge  $Q_2$  and is held at a potential of  $-V$ .

What one of the expressions gives the magnitude of the electric force on the oil drop?

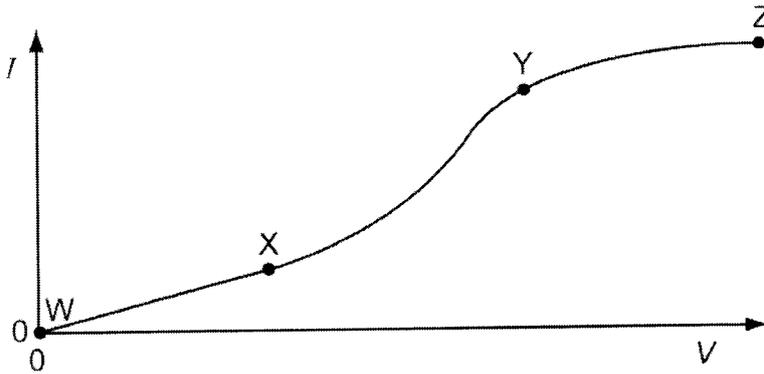
- A  $\frac{Q_1 q}{4\pi\epsilon_0 r_1^2} - \frac{Q_2 q}{4\pi\epsilon_0 r_2^2}$       B  $\frac{Q_1 q}{4\pi\epsilon_0 r_1^2} + \frac{Q_2 q}{4\pi\epsilon_0 r_2^2}$       C  $\frac{2Vq}{r_1} + \frac{Vq}{r_2}$       D  $\frac{3Vq}{r_1 + r_2}$

- 20 Two point charges  $+2q$  and  $-q$  are arranged as shown below. An external force moves a third point charge  $+q$  along the paths shown, without any change in kinetic energy.

Along which path is the net work done on the third charge by the external force the greatest?



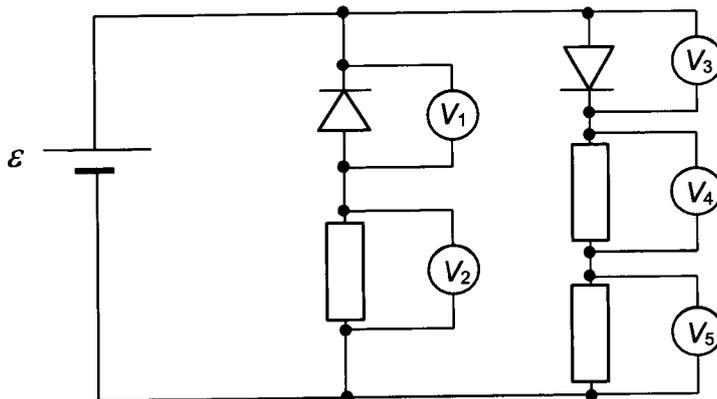
- 21 An electrical component has a potential difference  $V$  across it and a current  $I$  through it. A graph of  $I$  against  $V$  is drawn and is marked in three sections WX, XY and YZ.



Which one of the options below correctly indicates the variation of the resistance of the component within each of the three sections of the  $I$ - $V$  graph?

	WX	XY	YZ
A	constant	decreases	increases
B	constant	increases	increases
C	increases	decreases	constant
D	increases	increases	decreases

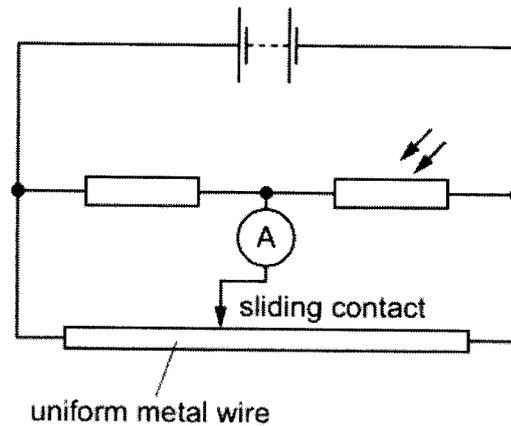
- 22 A circuit consisting of a battery, two ideal diodes and three identical resistors is shown below. The potential difference across each component is measured using ideal voltmeters.



Which statement is correct?

- A The reading in  $V_1$  is zero.  
 B The reading in  $V_2$  is equal to the sum of the readings in  $V_4$  and  $V_5$ .  
 C The readings in  $V_2$  and  $V_3$  are the same.  
 D The readings in  $V_3$ ,  $V_4$  and  $V_5$  are the same.

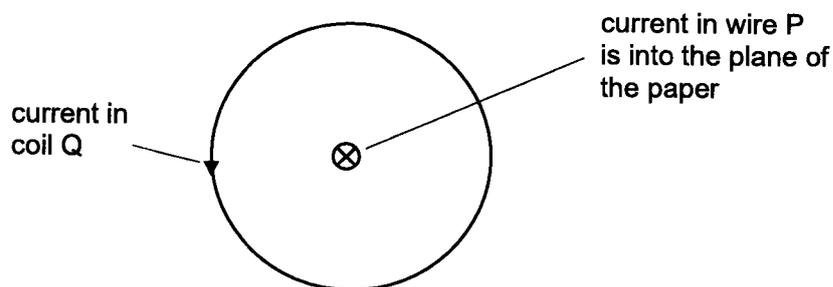
- 23 In the potentiometer circuit shown, the reading on the ammeter is initially zero.



The light-dependent resistor (LDR) is then covered up and the ammeter gives a non-zero reading.

Which change could return the ammeter reading to zero?

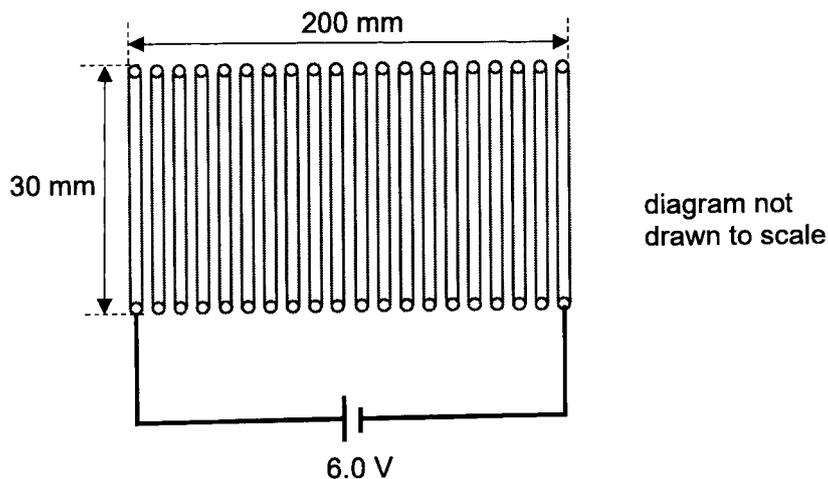
- A Move the sliding contact to the left.
  - B Move the sliding contact to the right.
  - C Increase the supply voltage.
  - D Decrease the supply voltage.
- 24 A long straight wire P is placed along the central axis of a flat circular coil Q. The wire and coil each carry a current as shown.



Which statement about the force acting on each part of coil Q due to the current in wire P is correct?

- A The force is towards wire P
- B The force is away from wire P
- C The force is perpendicular to the plane of coil Q
- D There is no force in all directions

- 25 A wire is tightly wound in a single layer to form a hollow solenoid of 4000 turns and resistance of  $3.26 \text{ k}\Omega$ . The resulting solenoid resembles a tube of length  $200 \text{ mm}$  and diameter  $30 \text{ mm}$ . The solenoid is connected in series to a battery of e.m.f.  $6.0 \text{ V}$  and has negligible internal resistance.



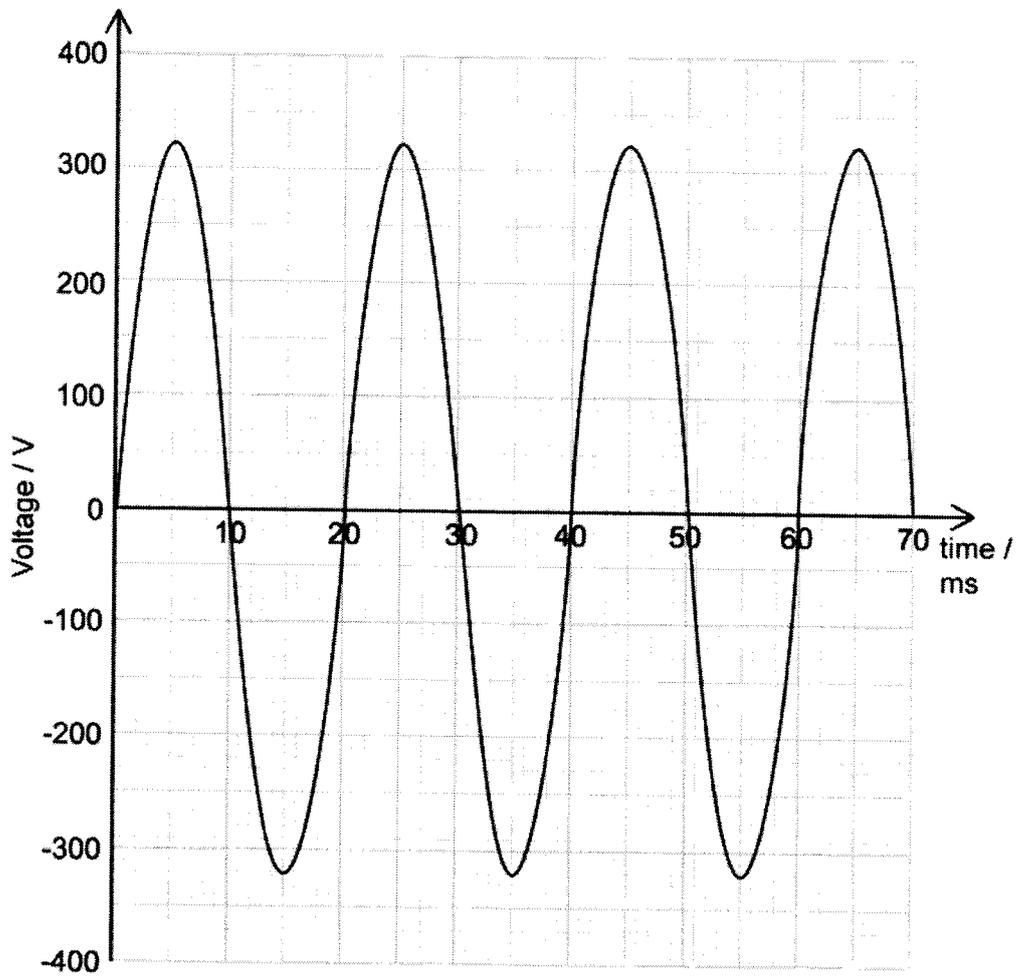
Determine the largest possible magnetic flux density at the center of the solenoid due to the current through the solenoid.

- A  $4.6 \times 10^{-2} \text{ T}$   
 B  $4.6 \times 10^{-5} \text{ T}$   
 C  $9.3 \times 10^{-3} \text{ T}$   
 D  $9.3 \times 10^{-6} \text{ T}$
- 26 A circular loop of wire is placed in a uniform magnetic field of  $1.2 \text{ T}$  that is normal to the plane of the loop. The loop shrinks from a radius of  $0.2 \text{ m}$  to a radius of  $0.1 \text{ m}$  in  $0.1 \text{ s}$ , at a rate which generates a steady e.m.f..

Which one of the following gives the induced e.m.f.?

- A  $1.2 \times \pi(0.2 - 0.1)^2 \times 10 \text{ V}$   
 B  $1.2 \times \pi(0.2)^2 \times 10 \text{ V}$   
 C  $1.2 \times 2\pi(0.2 - 0.1) \times 10 \text{ V}$   
 D  $1.2 \times \pi(0.04 - 0.01) \times 10 \text{ V}$

27 This is a graph of the voltage against time for a power supply.

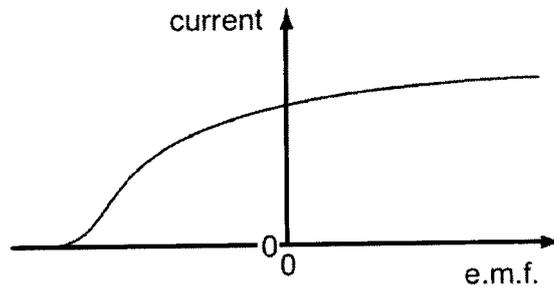


What is the d.c. voltage that gives the same mean power as produced by the alternating waveform of the power supply?

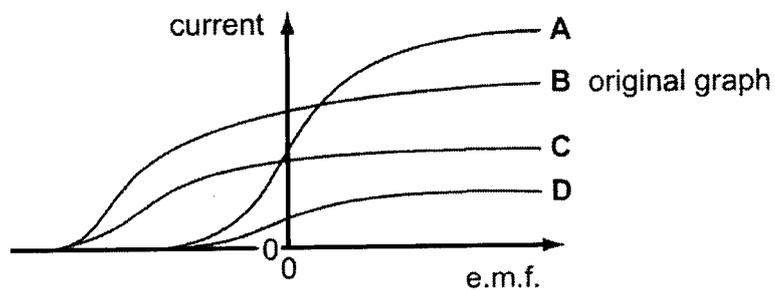
- A 160 V
- B 230 V
- C 320 V
- D 640 V

- 28 A photocell is connected in a series circuit with a variable d.c. power supply and a sensitive ammeter.

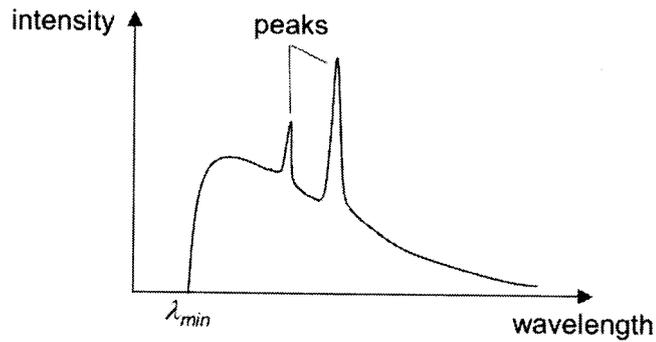
The photocell is illuminated with ultra-violet radiation and photoelectrons are emitted. The electromotive force (e.m.f.) of the supply is then reduced and reversed and a graph is plotted of current against e.m.f. as shown.



Which graph is obtained if the experiment is repeated with a lower intensity of the same ultra-violet source?



- 29 The following graph shows the spectrum of X-rays emitted from an X-ray tube.



If the potential difference between the target and cathode is decreased, which one of the following combinations represents a possible change in the minimum wavelength,  $\lambda_{min}$ , and the intensity of the peaks?

	Minimum Wavelength ( $\lambda_{min}$ )	Intensity
A	increase	decrease
B	increase	remain the same
C	decrease	decrease
D	decrease	remain the same

- 30 What is the decay constant of a radioactive substance?
- A The number of disintegrations of nuclei in the substance occurring in one half-life of the substance.
  - B The number of disintegrations of nuclei in the substance occurring per unit time
  - C The average time taken for half the nuclei initially present in the substance to decay
  - D The constant proportionality in the equation relating the rate of decay of nuclei in the substance to the number of undecayed nuclei

**END OF PAPER**



**HWA CHONG INSTITUTION**  
**JC2 Preliminary Examination**  
**Higher 2**

**CANDIDATE NAME**

**CT GROUP**

**24S**

**CENTRE NUMBER**

**INDEX NUMBER**

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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.

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**READ THESE INSTRUCTIONS FIRST**

Write your Centre Number, Index Number, Name and CT 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 a soft 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.

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

You are reminded of the need for good English and clear presentation in your answers.

<b>For Examiner's Use</b>		
<b>Paper 2</b>		
<b>1</b>		<b>7</b>
<b>2</b>		<b>8</b>
<b>3</b>		<b>12</b>
<b>4</b>		<b>7</b>
<b>5</b>		<b>9</b>
<b>6</b>		<b>8</b>
<b>7</b>		<b>8</b>
<b>8</b>		<b>21</b>
<b>Deductions</b>		
<b>Total</b>		<b>80</b>

Data	Formulae	
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion	$s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas	$W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure	$p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	gravitational potential	$\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	temperature	$T/\text{K} = T/^\circ\text{C} + 273.15$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	pressure of an ideal gas	$P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2} kT$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	electric current	$I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in series	$R = R_1 + R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	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 (a) Fig 1.1 shows a fluid of density  $\rho$  in a rectangular container. The height of the liquid is  $h$ .

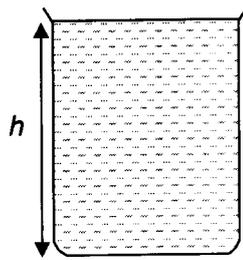


Fig 1.1

Show that the pressure  $P$  at the bottom of the container due to the fluid is given by

$$P = \rho gh$$

- (b) (i) An object of mass  $m$  and density  $d$  is surrounded by air of density  $\rho$ .

[2]

Show that the resultant force  $F$  acting downward on the object is given by

$$F = mg \left( 1 - \frac{\rho}{d} \right)$$

[2]

- (ii) A chemist uses an accurate balance to weigh a sample as shown in Fig. 1.2.

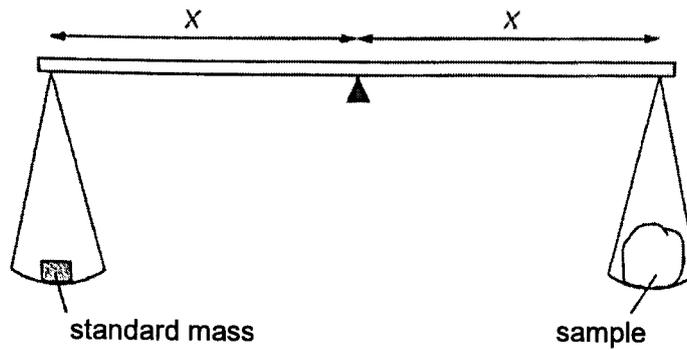


Fig. 1.2

The mass of the standard mass is 0.17851 kg. The density of the sample is  $940.0 \text{ kg m}^{-3}$ , the density of the standard mass is  $8493 \text{ kg m}^{-3}$ , and the density of air is  $1.29 \text{ kg m}^{-3}$ .

Using your answer in (b)(i), calculate the mass of the sample.

Leave your answer to 5 decimal places.

mass = ..... kg [3]

[Total: 7 marks]

- 2 An object of mass  $m$  of 0.42 kg is attached to a spring S and the system is made to oscillate with simple harmonic motion on a horizontal, frictionless surface, as shown in Fig 2.1. The mass passes through the equilibrium position at P 200 times per minute.

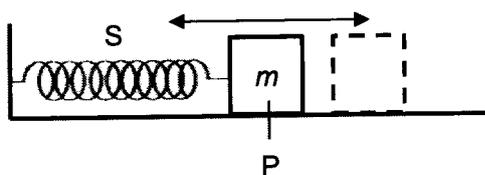


Fig 2.1

The kinetic energy of the mass as it passes through the equilibrium position is 500 mJ.

- (a) (i) Determine the period of the oscillation.

period = ..... s [1]

- (ii) Show that the amplitude of the oscillation is approximately 15 cm.

[3]

- (iii) Sketch in Fig 2.2 the variation with time of the velocity of the mass for 2 cycles. Label the axes with appropriate values.

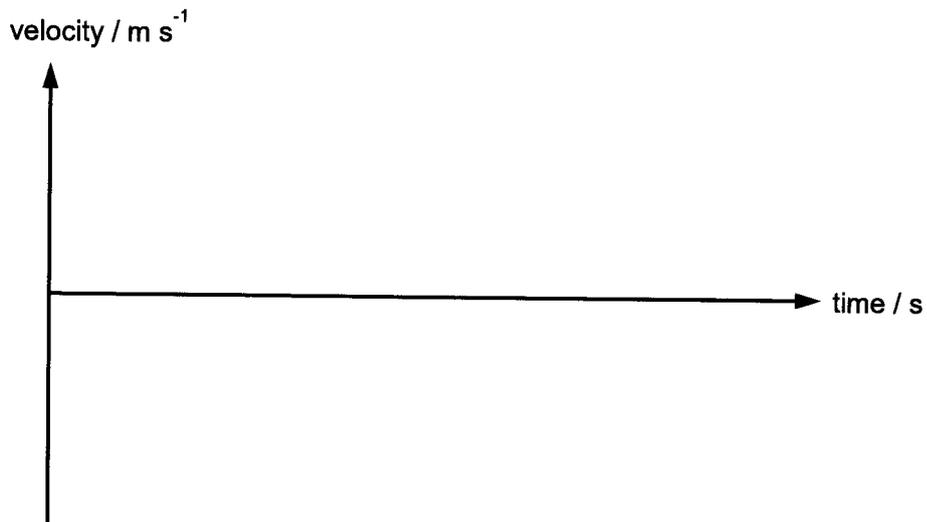


Fig 2.2 [2]

- (b) Deduce the change, if any, to the frequency of the oscillation if the following modifications are made separately to the experiment:

- (i) the experiment is done on Mars instead of the Earth,

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

- (ii) another spring identical to S is connected in parallel, as shown in Fig 2.3.

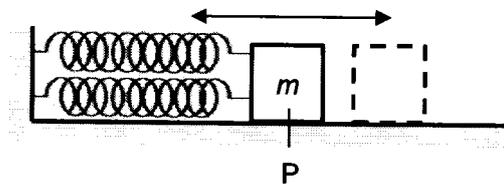


Fig 2.3

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

[Total: 8 marks]

3 (a) Define *gravitational potential* at a point.

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

(b) The neutral point is the point where the gravitational field strength due to Earth is equal in magnitude and opposite in direction to the gravitational field strength due to the Moon.

The gravitational potentials at the Earth's and Moon's surfaces are  $-62.3 \times 10^6 \text{ J kg}^{-1}$  and  $-3.90 \times 10^6 \text{ J kg}^{-1}$  respectively.

A 10.0 kg mass projected from the Earth's surface needs  $6.10 \times 10^8 \text{ J}$  of kinetic energy to just reach the neutral point from the Earth. The effects of air resistance may be neglected.

(i) Determine the gravitational potential at the neutral point.

gravitational potential = .....  $\text{J kg}^{-1}$  [2]

(ii) Determine the minimum kinetic energy needed to send a 1.4 kg rock from the surface of the Moon to the surface of the Earth.

minimum kinetic energy = ..... J [3]

- (c) Two stars of mass  $M$  and  $2M$ , a distance of  $3R$  apart, rotate in circles about their common centre of mass  $O$ .

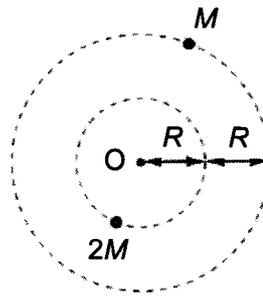


Fig 3.1

The period of this binary star system is  $3.42 \times 10^5$  s. The value of  $M$  is  $3.14 \times 10^{30}$  kg.

- (i) Explain why the two stars experience the same magnitude of centripetal force.

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

- (ii) Determine the distance  $R$ .

$R = \dots\dots\dots$  m [3]

[Total: 12 marks]

- 4 (a) Waves from a point source pass through an area that is 1.6 cm wide, as shown in Fig. 4.1.

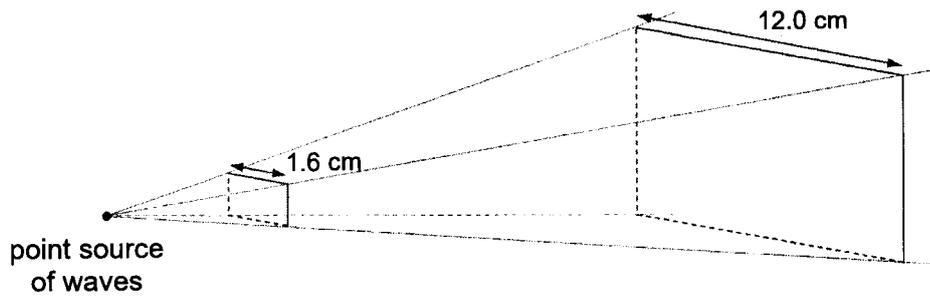


Fig. 4.1

Within this area, the intensity of the waves is  $I_0$  and their amplitude is  $A_0$ . The waves reach a second area of width 12.0 cm.

Determine the amplitude of the waves when they reach the second area in terms of  $A_0$ .

Show your working clearly.

amplitude = ..... [2]

(b) A stationary wave is formed on a stretched string between two fixed points A and B.

The variation of the displacement  $y$  of particles of the string with distance  $x$  along the string for the wave at time  $t = 0$  is shown on Fig. 4.2.

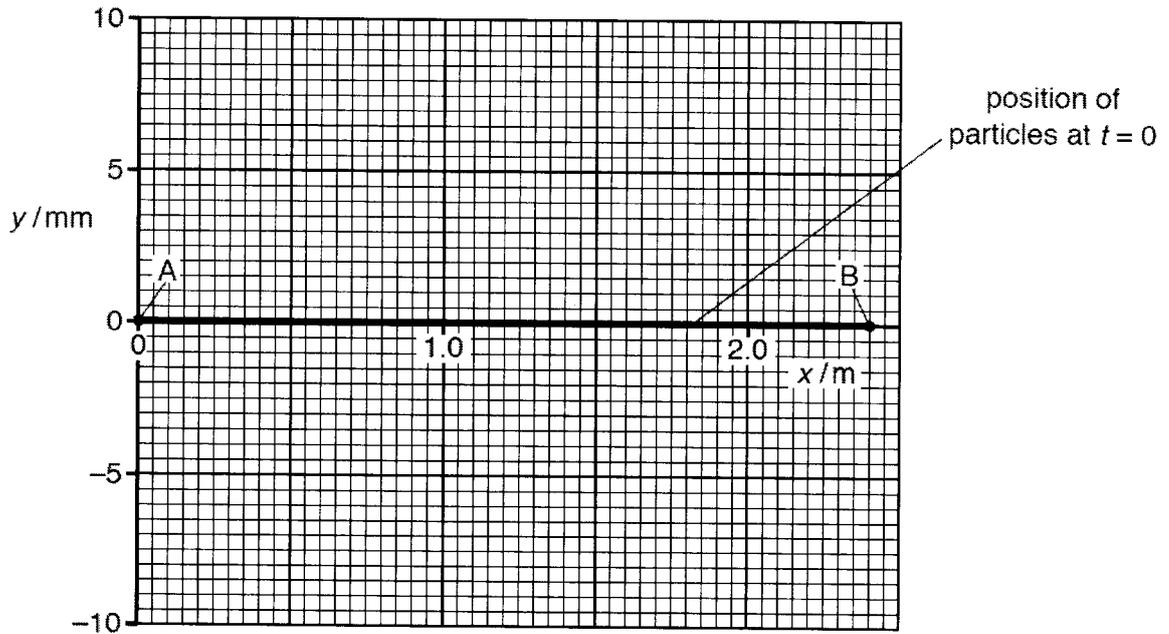


Fig. 4.2

The wave has a period of 20 ms and a wavelength of 1.2 m. The maximum amplitude of the particles of the string is 5.0 mm.

- (i) On Fig. 4.2, sketch the variation with position of the displacement of the string at
  - 1.  $t = 12.5$  ms (label this Y) [2]
  - 2.  $t = 5.0$  ms (label this Z) [2]
- (ii) State the phase difference between the particles of the string at  $x = 0.40$  m and at  $x = 0.80$  m.

phase difference = ..... [1]

[Total: 7 marks]

- 5 Two charged metal spheres A and B of diameters 18.0 cm and 12.0 cm respectively, are isolated in space, as shown in Fig. 5.1.

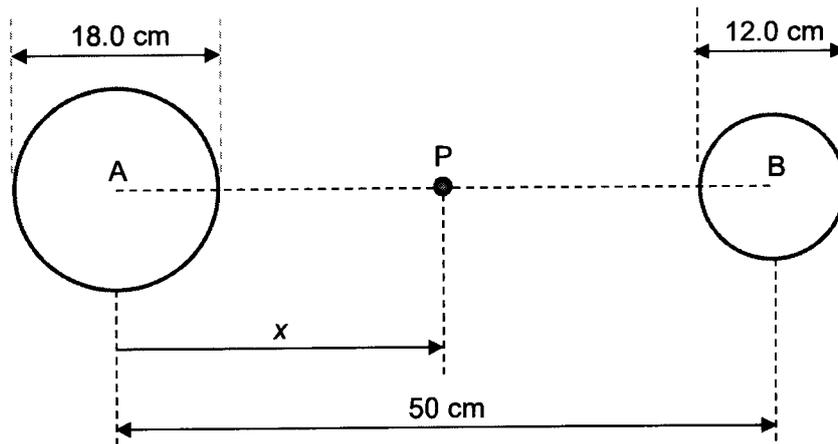


Fig. 5.1

The centres of the spheres are separated by a distance of 50.0 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. 5.2.

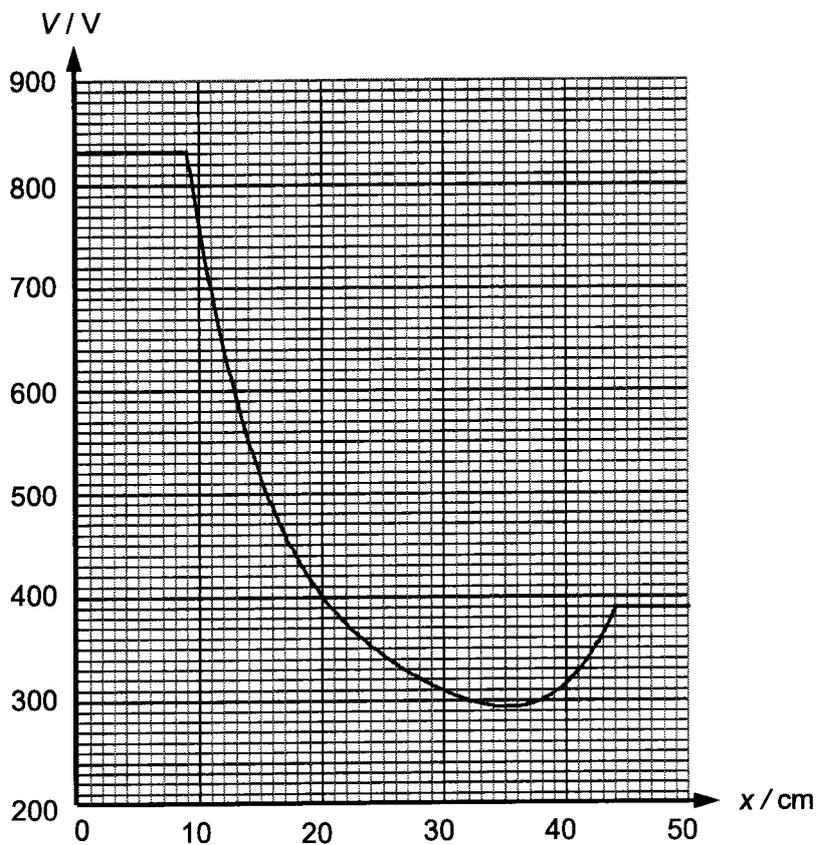


Fig. 5.2

(a) (i) State and explain the direction of the electric field at the point P when  $x = 25.0$  cm.

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

(ii) Use Fig. 5.2 to determine the magnitude of the electric field strength on an electron placed at point P when  $x = 25.0$  cm

electric field strength = .....  $\text{V cm}^{-1}$  [3]

(iii) By making reference to electric fields, explain why the potential is constant between  $x = 0.0$  cm and  $x = 9.0$  cm.

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

(b) A positively-charged ion is released from rest at  $x = 25.0$  cm.

Describe the subsequent motion of the ion.

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

[Total: 9 marks]

6 In a metallic conductor, conduction electrons do not travel in a straight line through the conductor.

Fig. 6.1 shows some of the conduction electrons in a copper wire. The arrows represent the velocities of these electrons.

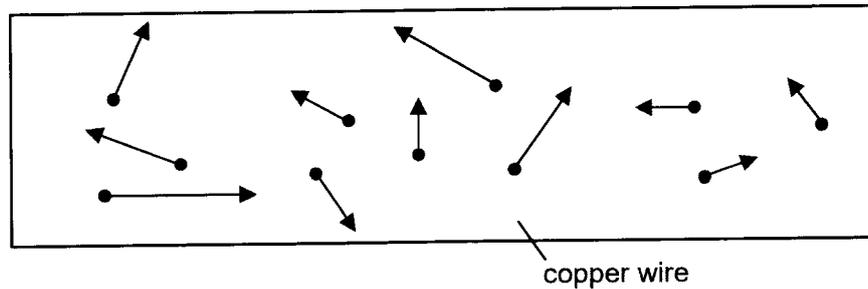


Fig. 6.1

(a) Explain, by reference to the motion of the electrons, why there is no current in the wire.

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

(b) An electric field is established inside the copper wire directed as shown in Fig. 6.2.

The dots represent electrons. The velocities of the electrons are not shown.

The average velocity that an electron travels along the conductor is called the drift velocity.

Draw on Fig. 6.2 an arrow to indicate the direction of the drift velocity of the electrons.

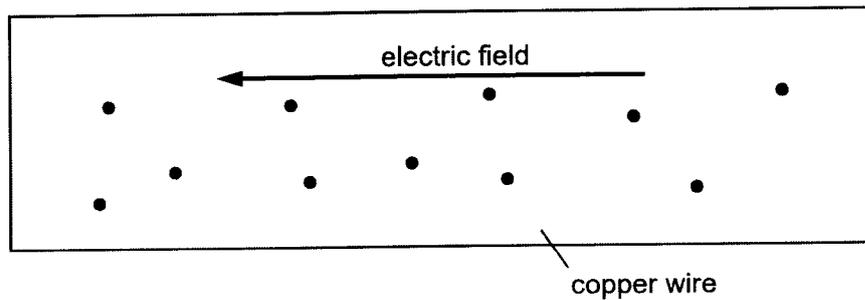


Fig. 6.2

[1]

- (c) In the circuit in Fig. 6.3, the length of the copper wire joining the negative terminal of the battery to the lamp is 0.50 m and has a radius of 0.40 mm. There are  $8.5 \times 10^{28}$  mobile electrons per cubic metre in copper.

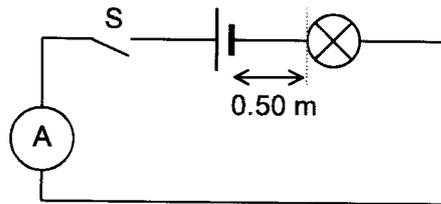


Fig. 6.3

- (i) When the switch S is closed, the ammeter reads 2.0 A. Calculate the average time it would take for an electron to move from the negative terminal of the battery to the lamp.

average time = ..... s [2]

- (ii) The lamp lights up in a much shorter time than that calculated in (c)(i). Explain this observation.

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

- (iii) The circuit is now connected with two copper wires of different thickness as shown in Fig. 6.4.

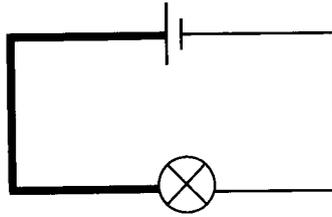


Fig 6.4

State and explain whether the drift velocity of electrons in the thicker wire is smaller than, equal to, or larger than that in the thinner wire.

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

[Total: 8 marks]

7 (a) State experimental evidence to suggest that the process of radioactive decay is

(i) random

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

(ii) spontaneous

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

(b) A student determines the half-life of the radioactive isotope of phosphorous-32. Phosphorous-32 decays by beta emission to form sulfur-32 which is stable.

The student measures the average count-rate from a sample of phosphorous-32 at various times  $t$ . The background-subtracted count rate,  $R$ , is shown in Fig. 7.1.

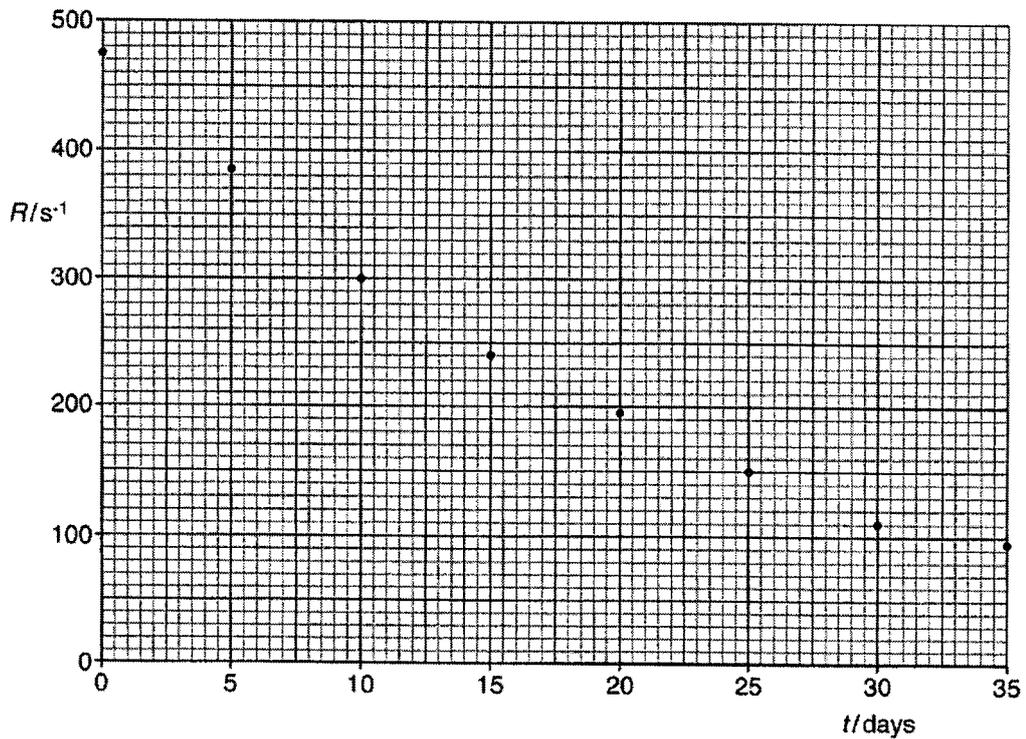


Fig. 7.1

(i) Use Fig. 7.1 to determine a value for the half-life of phosphorous-32. Show your working clearly.

half-life = ..... days [3]

- (ii) Explain why, although the count rates are too low for the radiation to cause immediate symptoms in the student, careful shielding of the source is necessary.

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

- (iii) Suggest why the determination of the half-life of phosphorus-32 by this method requires that the product of the decay is stable.

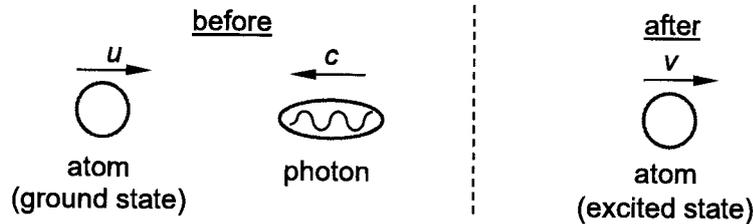
.....  
.....  
..... [1]

[Total: 8 marks]

8 Read the passage and answer the questions that follow.

### Laser cooling of atoms

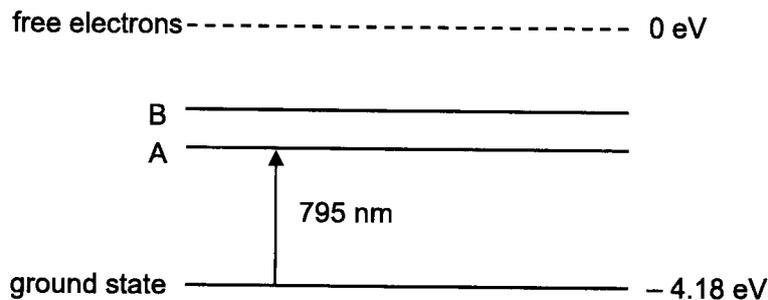
Atoms in a gas are always in motion. The temperature of a gas is related to the average kinetic energy of its atoms—the faster they move, the higher the temperature. Physicists have found ways to slow atoms down using laser light, and in doing so, cool the atoms to extremely low temperatures. This process is called laser cooling, illustrated in Fig. 8.1.



**Fig. 8.1**

Each photon has a small momentum. When the energy of the photon is just right, it can be absorbed by an atom, bringing it into an excited state. To slow an atom down, scientists shine light in the opposite direction that the atom is moving, so the atom absorbs photons, reducing its speed. Of course, after a short time, the atom will de-excite, emitting another photon – but this is in a random direction, rarely in the same direction as the first photon, and so generally the net effect is still that the atom's velocity in that axis is decreased.

Laser cooling experiments are often performed on rubidium (Rb) atoms. A simplified energy level diagram of the  $^{87}\text{Rb}$  atom is shown in Fig. 8.2, showing the ground state, the first two excited states (labelled A and B), and their energies.



**Fig. 8.2 (not to scale)**

When an  $^{87}\text{Rb}$  atom absorbs a photon of wavelength 795 nm, it transitions from the ground state to state A.

Table 8 shows some data about rubidium-87 ( $^{87}\text{Rb}$ ).

atomic number	37
nucleon number	87
atomic mass	86.9 u
melting point at 1 atm	39.3 °C
boiling point at 1 atm	688 °C
lifetime of state A	27.6 ns
lifetime of state B	26.2 ns
emission wavelength from state A	795 nm
emission wavelength from state B	780 nm

**Table 8**

The setup of a laser cooling experiment is shown in Fig. 8.3 below.

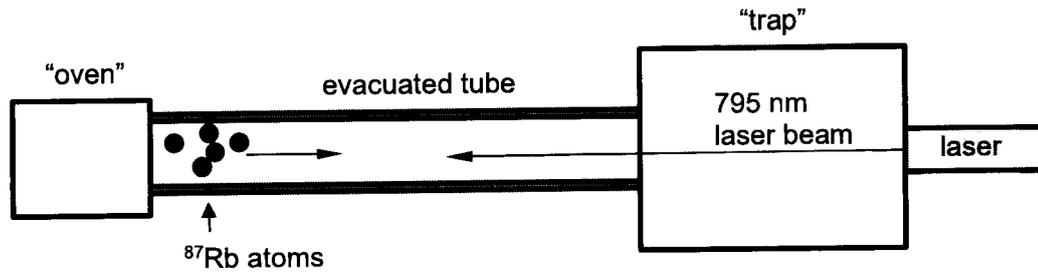


Fig. 8.3

A hot “oven” serves as a source of  $^{87}\text{Rb}$  atoms, which travel through the evacuated tube towards the “trap”. A laser is directed in the opposite direction to the atoms’ motion, slowing them down significantly. When they reach the “trap”, they are slowed and cooled even further using other methods.

Laser cooling and other trapping methods have allowed physicists to make exciting discoveries, such as the first-ever creation of a Bose-Einstein Condensate in 1995 by Eric Cornell and Carl Wieman. A Bose-Einstein Condensate (BEC) is a new state of matter. In 1925, Bose and Einstein theorized that, as a consequence of wave-particle duality, at very low temperatures, the matter wave of atoms could have a wavelength  $\lambda$  greater than the average separation  $d$  between the atoms. When this happens, the matter waves of the individual atoms overlap to form a single wave, allowing the atoms to seemingly occupy the same space!

Of interest is the critical temperature  $T_c$  at which a BEC is formed, which depends on several factors, including the separation  $d$  between the atoms. This can be estimated using the relationship:

$$d \approx \frac{1}{\sqrt[3]{n}}$$

where  $n$  is the number of particles per unit volume.

Fig. 8.4 shows data from a laser cooling experiment when the temperature  $T$  of the cloud of atoms is  $T > T_c$ ,  $T \approx T_c$ , and  $T < T_c$ .

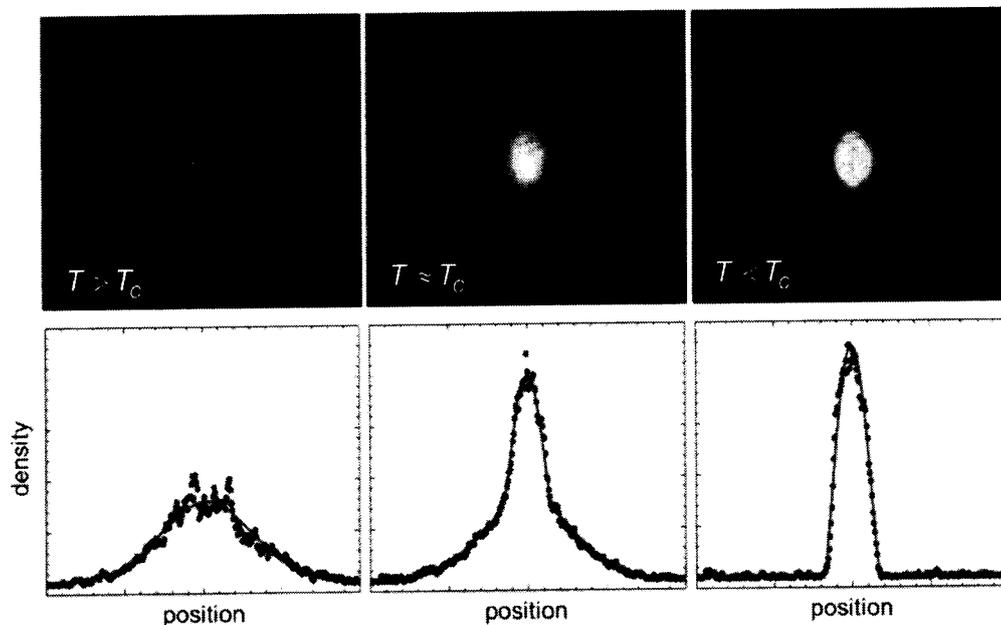


Fig. 8.4

- (a) (i) With reference to Fig. 8.2, explain why rubidium-87 atoms ( $^{87}\text{Rb}$ ) only absorb photons of certain frequencies.

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

- (ii) With reference to Fig. 8.2, determine the energy of state A in electron-volts.

energy = ..... eV [3]

- (iii) When an  $^{87}\text{Rb}$  atom transitions from state A to the ground state, a photon is released. Suggest why this photon is difficult to observe with the naked eye.

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

- (b) A collection of  $^{87}\text{Rb}$  atoms in the gaseous state emerge from the "oven" at a temperature of 1000 K.

Treating the  $^{87}\text{Rb}$  atoms as an ideal gas, determine the average speed of an  $^{87}\text{Rb}$  atom.

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

(c) Suggest what is meant by the “lifetime” of state A and state B in Table 8.

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

(d) (i) Using the principle of conservation of linear momentum, determine the magnitude of the change in momentum of an  $^{87}\text{Rb}$  atom after it absorbs a photon from the laser, as in Fig. 8.1.

**Show your working clearly.**

change in momentum = .....  $\text{kg m s}^{-1}$  [3]

(ii) Explain why, when an excited  $^{87}\text{Rb}$  atom de-excites and emits a photon, the average change in momentum of the  $^{87}\text{Rb}$  atom over many such emissions is zero.

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

(iii) Hence, using data from Table 8, determine the average force on the  $^{87}\text{Rb}$  atom through the entire process of absorbing and emitting a photon.

force = ..... N [2]

(iv) Give one reason why the  $^{87}\text{Rb}$  atoms could be cooled faster if the laser emitted photons that excite the atoms to state B instead of state A.

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

- (e) State how Fig. 8.4 shows that a Bose-Einstein Condensate forms when the temperature  $T$  of the cloud of atoms is equal to or below the critical temperature  $T_c$ .

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

- (f) The momentum of an  $^{87}\text{Rb}$  atom in the "trap" is given by:

$$p = \sqrt{3mkT}$$

where  $m$  is the mass of an  $^{87}\text{Rb}$  atom,  $T$  is the thermodynamic temperature of the collection of atoms, and  $k$  is the Boltzmann constant.

Using the de Broglie relation, calculate the critical temperature  $T_c$  at which a collection of  $^{87}\text{Rb}$  atoms forms a BEC in a "trap" where  $n = 1.00 \times 10^{19} \text{ m}^{-3}$ .

$$T_c = \dots\dots\dots \text{K} \quad [4]$$

[Total: 21 marks]

**End of paper**

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**Copyright Acknowledgements:**

A. Steck, "Rubidium 87 D Line Data," available online at <http://steck.us/alkalidata> (revision 2.3.3, 28 May 2024) (Table 8)

Fallani, L. & Kastberg, A.. (2015). Cold atoms: A field enabled by light. EPL (Europhysics Letters). 110. 53001. 10.1209/0295-5075/110/53001. (Fig. 8.4)



CANDIDATE NAME

CT GROUP

CENTRE NUMBER

INDEX NUMBER

**PHYSICS**

**9749/03**

**Paper 3 Longer Structured Questions**

**19 September 2025**

Candidates answer on the Question Paper.

**2 hours**

No Additional Materials are required.

**INSTRUCTIONS TO CANDIDATES**

Write your **Centre number, index number, name and CT class** clearly on all work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs or rough working.

Do not use staples, paperclips, glue or correction fluid.

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

**Section A**

Answer **all** questions.

**Section B**

Answer **one** question only. **Circle** the question number on the cover page.

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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
<b>Section A</b>		
<b>1</b>		<b>8</b>
<b>2</b>		<b>6</b>
<b>3</b>		<b>8</b>
<b>4</b>		<b>8</b>
<b>5</b>		<b>10</b>
<b>6</b>		<b>10</b>
<b>7</b>		<b>10</b>
<b>Section B (choose ONE)</b>		
<b>8</b>		<b>20</b>
<b>9</b>		<b>20</b>
<b>Deductions</b>		
<b>Total</b>		<b>80</b>

Data	Formulae
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas $W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure $p = \rho gh$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	gravitational potential $\phi = -\frac{Gm}{r}$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	temperature $T/\text{K} = T/^\circ\text{C} + 273.15$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	pressure of an ideal gas $P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	mean kinetic energy of a molecule of an ideal gas $E = \frac{3}{2} kT$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m. $x = x_0 \sin \omega t$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	velocity of particle in s.h.m. $v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	electric current $I = Anvq$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	resistors in series $R = R_1 + R_2 + \dots$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	resistors in parallel $1/R = 1/R_1 + 1/R_2 + \dots$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	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 $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

## Section A

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

- 1 A ball is thrown from point S, as shown in Fig. 1.1.

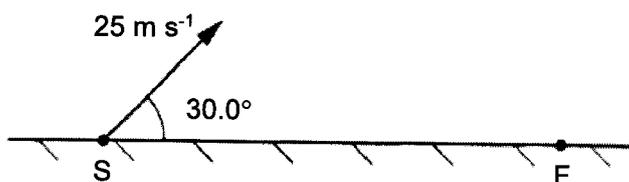


Fig. 1.1

The initial velocity of the ball is  $25 \text{ m s}^{-1}$  at an angle to the horizontal of  $30.0^\circ$ .

The ball lands at point F. The points S and F are at the same horizontal level.

- (a) (i) Calculate the vertical component of the ball's initial velocity.

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

- (ii) Show that the maximum height reached by the ball is 8.0 m, assuming air resistance is negligible.

[1]

- (iii) The kinetic energy of the ball at S is  $K$ . Calculate the kinetic energy and the potential energy of the ball in terms of  $K$  at a height of 8.0 m,

kinetic energy = .....

potential energy = .....

[3]

- (b) The horizontal distance from S to F is  $x$ .

On Fig. 1.2, sketch the variation with the horizontal distance of

- (i) the potential energy of the ball and label the graph as  $E_p$ .  
 (ii) the kinetic energy of the ball and label the graph as  $E_k$ . [3]



Fig. 1.2

[Total: 8 marks]

- 2 (a) The drag force  $F_d$  on a car moving through air is given by the formula:

$$F_d = \frac{1}{2} \rho C_d A v^2$$

where  $\rho$  is the air density,

$C_d$  is the unitless drag coefficient,

$A$  is the frontal area of the car, and

$v$  is the velocity of the car.

Table 2.1 shows the data measured for car A.

**Table 2.1**

$\rho / \text{kg m}^{-3}$	$1.20 \pm 0.05$
$C_d$	$0.30 \pm 0.02$
$A / \text{m}^2$	$2.50 \pm 0.05$
$v / \text{km h}^{-1}$	$108 \pm 2$

Use this data to calculate the drag force  $F_d$  on car A and its associated uncertainty.

$$F_d \pm \Delta F_d = \dots\dots\dots \text{ N [3]}$$

(b) Cars A and B approach a junction as shown in Fig. 2.2.

Car A travels east at a constant speed of  $40.0 \text{ km h}^{-1}$  while car B travels northwest at a constant speed of  $50.0 \text{ km h}^{-1}$ .

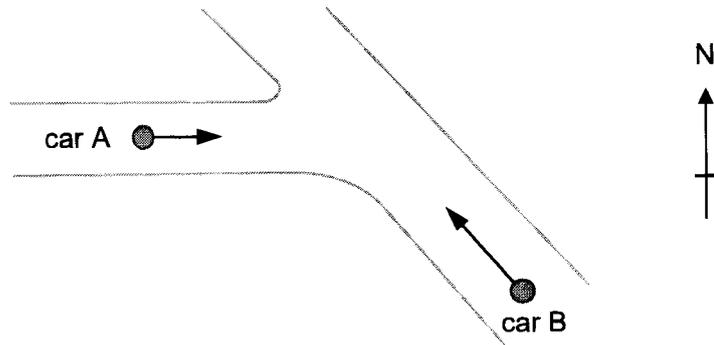


Fig. 2.2

With the aid of a vector diagram, determine the velocity of car A relative to car B.

velocity of car A relative to car B = .....  $\text{km h}^{-1}$

direction: .....

[3]

[Total: 6 marks]

- 3 Planet Z is spherical and has a uniform density. It has only argon in its atmosphere.
- (a) The escape velocity is the minimum velocity required to escape the gravitational pull of a celestial body.

Show that the escape velocity  $v$  of Planet Z is given by

$$v = \sqrt{\frac{8}{3} G \pi \rho r^2}$$

where  $r$  is the radius, and  $\rho$  is the density of Planet Z.

[2]

- (b) Given that Planet Z has a mean density of  $5500 \text{ kg m}^{-3}$  and radius of 413 km, calculate the escape velocity of the argon gas molecules at its surface.

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

- (c) Argon gas behaves as an ideal monatomic gas on Planet Z, and it has a molar mass of  $40 \text{ g mol}^{-1}$ .

Assume that the root-mean-square speed of the argon molecules is equal to the escape velocity.

Using Kinetic Theory, determine the absolute temperature of the atmosphere on Planet Z.

absolute temperature = ..... K [3]

- (d) Suppose the atmosphere of Planet Z is 100 K lower than the temperature calculated in (c). Suggest a reason whether argon gas molecules would be able to escape from the atmosphere of Planet Z.

.....

.....

..... [2]

[Total: 8 marks]

- 4 A beam of monochromatic light of wavelength 633 nm is incident normally on a double slit. A screen is placed parallel to the plane of the double slit at a distance 98.0 cm from the slits. P is the point on the screen that is equidistant from the two slits, as illustrated in Fig. 4.1.

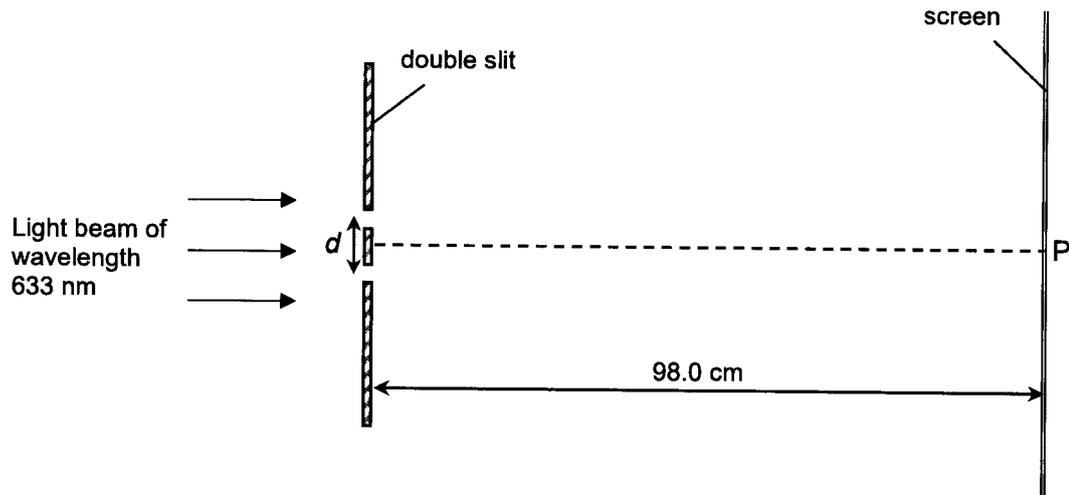


Fig. 4.1 (not to scale)

Fig. 4.2 shows the variation with distance from P of the intensity  $I$  of the light on the screen.

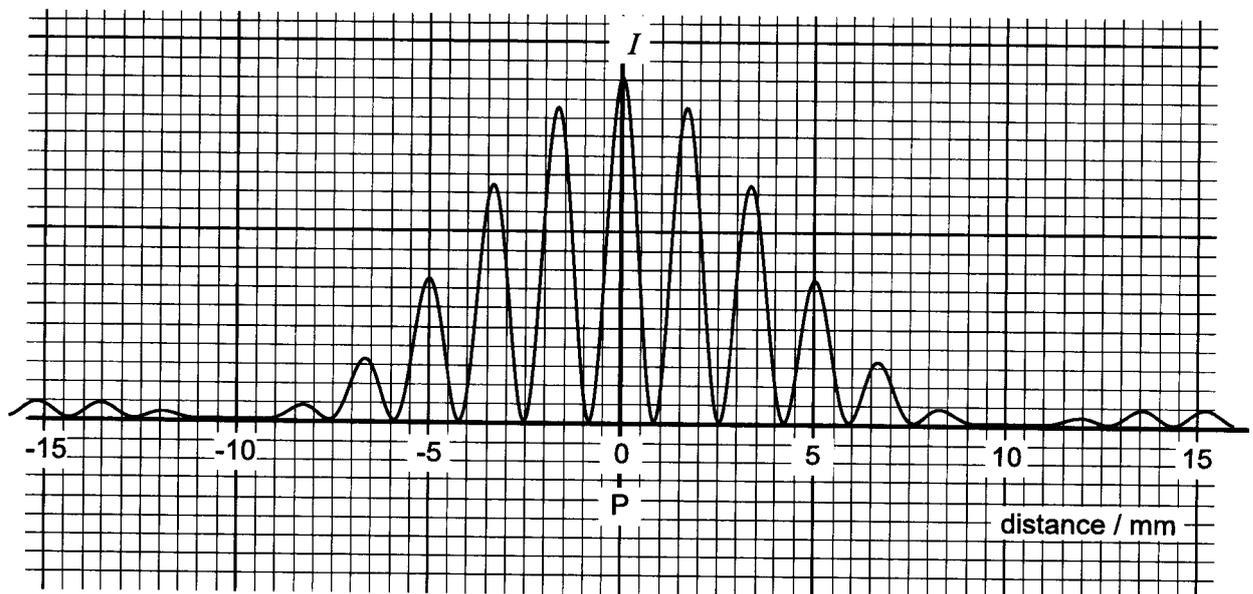


Fig. 4.2

(a) Using Fig. 4.2, show that the slit separation  $d$  is  $3.7 \times 10^{-4}$  m.

[2]

(b) Estimate the slit width  $b$  of each slit.

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

(c) State with a reason the change to be made to the double slit to achieve each of the following interference patterns on the screen.

(i) The interference pattern spreads out more on the screen.

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

(ii) The bright fringes have nearly uniform intensity across the pattern.

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

[Total: 8 marks]

- 5 (a) An electron moves in a vacuum at an angle of  $20^\circ$  to a magnetic field of magnetic flux density  $0.088 \text{ T}$ , as shown in Fig. 5.1.

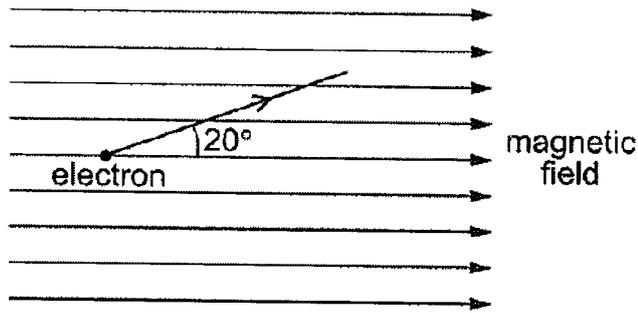


Fig. 5.1

The force on the electron is  $4.3 \times 10^{-14} \text{ N}$ .

- (i) Explain why the electron follows a helical path in the magnetic field.

.....

.....

.....

.....

..... [2]

- (ii) Calculate the speed of the electron.

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

(iii)

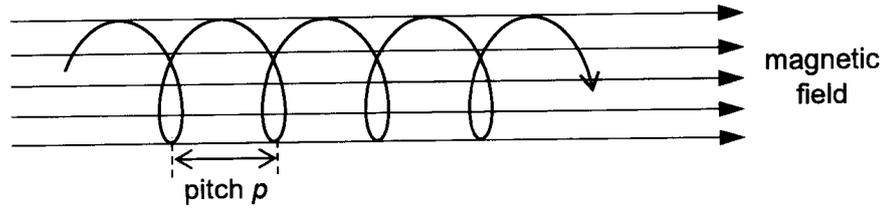


Fig. 5.2

Fig. 5.2 shows the pitch  $p$  of the helical path taken by the electron, which is given by the product of the period of the circular motion and the velocity component of the electron parallel to the magnetic field.

Calculate the pitch  $p$ .

$$p = \dots\dots\dots \text{ m [4]}$$

(b) Fig. 5.3 shows the coil of a simple electric motor between the poles of a magnet.

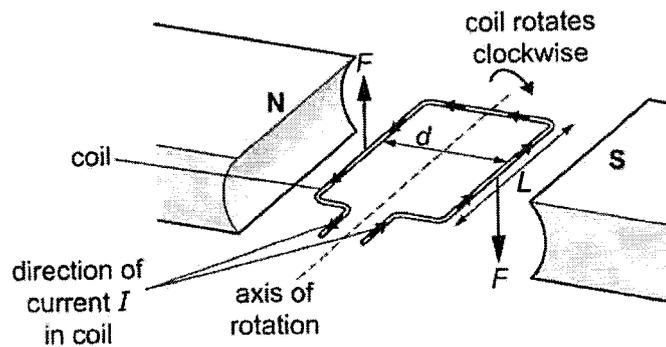


Fig. 5.3

The coil has length  $L$  and width  $d$ . The entire coil lies within the magnetic field. The magnetic flux density between the poles of the magnet is  $B$ . There is a current  $I$  in the coil.

Two forces, each of magnitude  $F$ , act in opposite directions on the two sides of the coil, as shown in Fig. 5.3. This produces a torque that causes the coil to rotate.

The current  $I$  in the coil is 96 A. The area of the rectangular coil in the magnetic field of the magnet is  $6.1 \times 10^{-3} \text{ m}^2$  and the coil contains 1200 turns. The maximum output torque given to the coil is 395 Nm.

Calculate the magnetic flux density  $B$  needed to produce the maximum output torque.

$$B = \dots\dots\dots \text{ T [2]}$$

[Total: 10 marks]

- 6 Light of frequency  $f$  and wavelength  $\lambda$  is incident on a metal surface of work function energy  $\Phi$ . Electrons are emitted from the surface with maximum kinetic energy  $E_{MAX}$ .

Conservation of energy for this effect may be expressed as

$$E_{MAX} = hf - \Phi$$

where  $h$  is the Planck constant.

- (a) (i) Explain what is meant by threshold frequency.

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

- (ii) Light at the threshold frequency for the metal surface has a wavelength  $\lambda_0$ .

Show that

$$E_{MAX} = hc \left( \frac{1}{\lambda} - \frac{1}{\lambda_0} \right)$$

where  $c$  is the speed of light.

[1]

(b) The variation with  $\frac{1}{\lambda}$  of  $E_{MAX}$  is shown in Fig. 6.1.

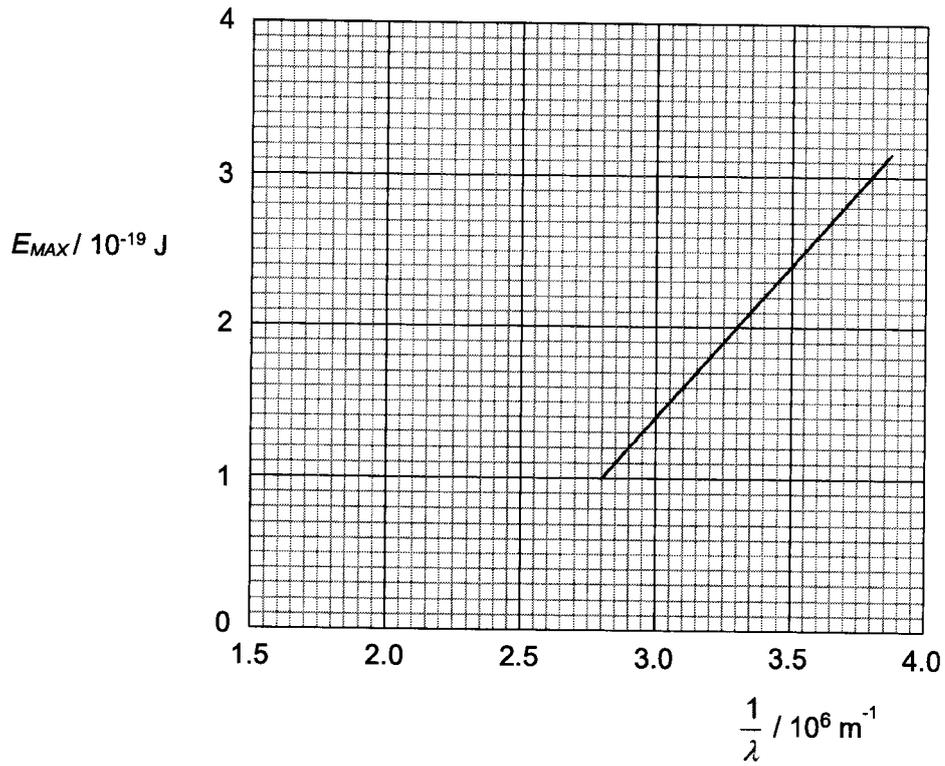


Fig. 6.1

Use Fig 6.1 and the expression in (a)(ii) to determine

- (i) the maximum wavelength  $\lambda_0$  at which emission of electrons occurs, without using any value of  $h$ ,

$\lambda_0 = \dots\dots\dots \text{ m [2]}$

- (ii) the Plank constant  $h$  using data in Fig. 6.1.

$$h = \dots\dots\dots \text{ J s [2]}$$

- (c) The metal is replaced with one that has a smaller work function.

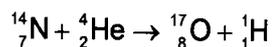
On Fig. 6.1, draw a line to show the variation with  $\frac{1}{\lambda}$  of  $E_{MAX}$  for this new metal surface. [1]

- (d) An isolated sphere of radius  $r$  made of this material is illuminated by the light of wavelength  $\lambda$ .  
By energy consideration, derive an expression of the final charge induced on the sphere in terms of  $\lambda$ ,  $\lambda_0$  and  $r$ .

[3]

[Total: 10 marks]

- 7 The discovery of the proton was credited to Ernest Rutherford. In 1917, he fired a beam of  $\alpha$  particles into pure nitrogen gas which resulted in the production of oxygen and protons. The nuclear reaction is given by the equation



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

.....

.....

.....

.....

..... [2]

- (b) Data for some masses are given in Table 7.1.

		mass / u
proton	${}^1_1\text{H}$	1.007 276
neutron	${}^1_0\text{n}$	1.008 665
nitrogen-14	${}^{14}_7\text{N}$	14.003 074

**Table 7.1**

- (i) Show that the energy equivalent of 1.00 u is 934 MeV.

[2]

- (ii) Using data from Table 7.1, show that the binding energy per nucleon of nitrogen-14 is 7.24 MeV.

[2]

- (c) The binding energy per nucleon for the other nuclides is shown in Table 7.2.

		binding energy per nucleon / MeV
helium	${}^4_2\text{He}$	6.836
oxygen-17	${}^{17}_8\text{O}$	7.530

**Table 7.2**

- (i) Use data from Table 7.2 to determine, to three significant figures, the energy released in this reaction associated with the change in mass.

energy released = ..... MeV [2]

- (ii) State and explain whether the reaction will take place if the incident  $\alpha$ -particle has a kinetic energy of 0.300 MeV. You may assume that the nitrogen-14 nucleus is at rest.

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

[Total: 10 marks]



CANDIDATE NAME

CT GROUP

CENTRE NUMBER

INDEX NUMBER

## PHYSICS

**9749/03**

### Paper 3 Longer Structured Questions

**19 September 2025**

Candidates answer on the Question Paper.

**2 hours**

No Additional Materials are required.

### INSTRUCTIONS TO CANDIDATES

Write your **Centre number, index number, name** and **CT class** clearly on all work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs or rough working.

Do not use staples, paperclips, glue or correction fluid.

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

#### Section A

Answer **all** questions.

#### Section B

Answer **one** question only. **Circle** the question number on the cover page.

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.

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
<b>Section B (Choose ONE)</b>		
8		20
9		20
<b>Deductions</b>		
<b>Total</b>		<b>80</b>

Data	Formulae
speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$	uniformly accelerated motion $s = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2as$
permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	work done on / by a gas $W = p \Delta V$
permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $\approx (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$	hydrostatic pressure $p = \rho gh$ gravitational potential $\phi = -\frac{Gm}{r}$
elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$	temperature $T/\text{K} = T/^\circ\text{C} + 273.15$ pressure of an ideal gas $P = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
the Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$	mean kinetic energy of a molecule of an ideal gas $E = \frac{3}{2} kT$
unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$	displacement of particle in s.h.m. $x = x_0 \sin \omega t$
rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$	velocity of particle in s.h.m. $v = v_0 \cos \omega t$ $= \pm \omega \sqrt{(x_0^2 - x^2)}$
rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$	electric current $I = Anvq$
molar gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$	resistors in series $R = R_1 + R_2 + \dots$
the Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$	resistors in parallel $1/R = 1/R_1 + 1/R_2 + \dots$ electric potential $V = \frac{Q}{4\pi\epsilon_0 r}$
the Boltzmann constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$	alternating current / voltage $x = x_0 \sin \omega t$
gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	magnetic flux density due to a long straight wire $B = \frac{\mu_0 I}{2\pi d}$
acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$	magnetic flux density due to a flat circular coil $B = \frac{\mu_0 NI}{2r}$
	magnetic flux density due to a long solenoid $B = \mu_0 nI$
	radioactive decay $x = x_0 \exp(-\lambda t)$
	decay constant $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

**Section B**

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

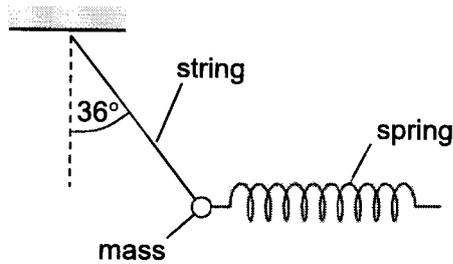
- 8 (a) State the conditions required for a body to be in equilibrium.

.....

.....

..... [2]

- (b) A pendulum bob of mass  $m$  is held in static equilibrium by a light inelastic string and a horizontal spring with an extension of 5.0 cm. The string makes an angle of  $36^\circ$  with the vertical as shown in Fig. 8.1.



**Fig. 8.1**

- (i) The tension  $T$  in the string is measured to be 2.5 N.  
Calculate the force constant  $k$  of the spring.

force constant  $k = \dots\dots\dots \text{N m}^{-1}$  [2]

(ii) Determine the mass  $m$  of the bob.

mass  $m = \dots\dots\dots$  kg [2]

(iii) Calculate the elastic potential energy stored in the spring.

elastic potential energy =  $\dots\dots\dots$  J [2]

- (c) The spring is detached from the pendulum bob.

The bob is then slightly displaced to an angular displacement  $\theta$  of  $10.0^\circ$  and released to undergo simple harmonic motion as shown in Fig. 8.2. The inelastic string is 15.0 cm in length.

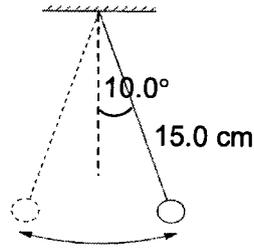


Fig. 8.2

- (i) Define simple harmonic motion.

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

- (ii) Assuming air resistance is negligible, when the bob is at the bottom of its swing,

1. show that the speed of the bob is  $0.21 \text{ m s}^{-1}$ ,

[2]

2. compare the tension  $T$  in the string with the weight  $W$  of the bob. Explain your reasoning qualitatively.

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

3. Hence or otherwise, calculate the tension in the string at the bottom of its swing.

tension = ..... N [2]

(d) Assuming **air resistance is not negligible**.

- (i) Sketch in Fig. 8.3, the variation with displacement  $x$  of the velocity  $v$  of the bob for 1 period of oscillation.

Label the axes with appropriate values.

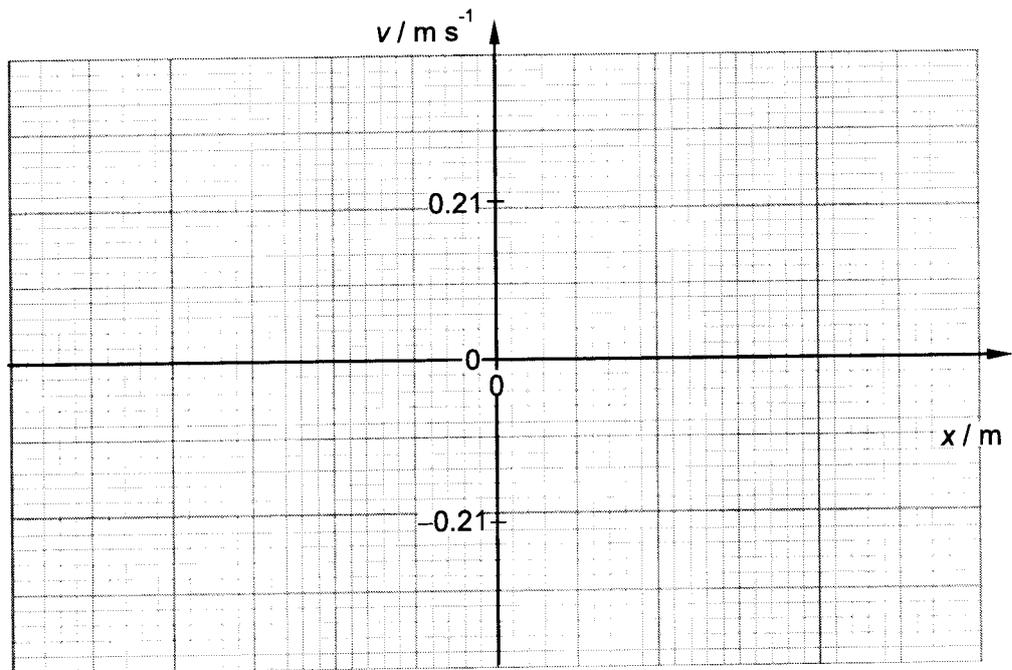


Fig. 8.3

[2]

- (ii) Sketch in Fig. 8.4, the variation with time  $t$  of
1. the potential energy (label the graph  $U$ ) and
  2. the kinetic energy (label the graph  $K$ ) of the pendulum bob for 1 period of oscillation.

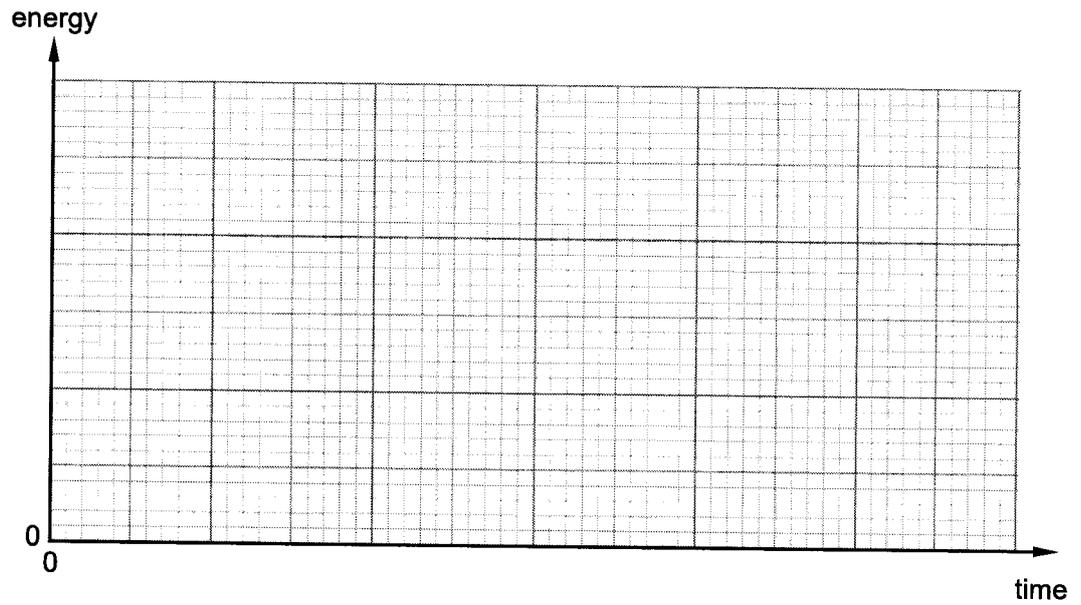


Fig. 8.4

[3]

[Total: 20 marks]

- 9 (a) The coil in a generator is situated in a uniform magnetic field as shown in Fig. 9.1.

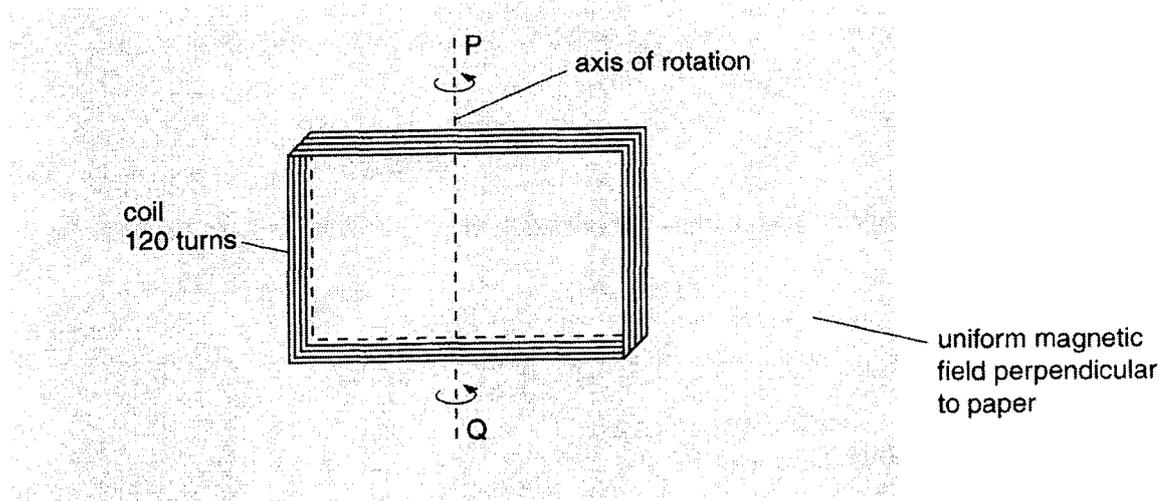


Fig. 9.1

The coil is rotated about the axis PQ as shown in Fig. 9.1. An electromotive force (e.m.f.) is induced in the coil. The e.m.f. is measured with a cathode-ray oscilloscope (c.r.o.).

The Y-plates sensitivity of the c.r.o. is  $0.050 \text{ V cm}^{-1}$  and the time-base setting is  $8.0 \text{ ms cm}^{-1}$ .

The waveform displayed on the c.r.o. is shown in Fig. 9.2.

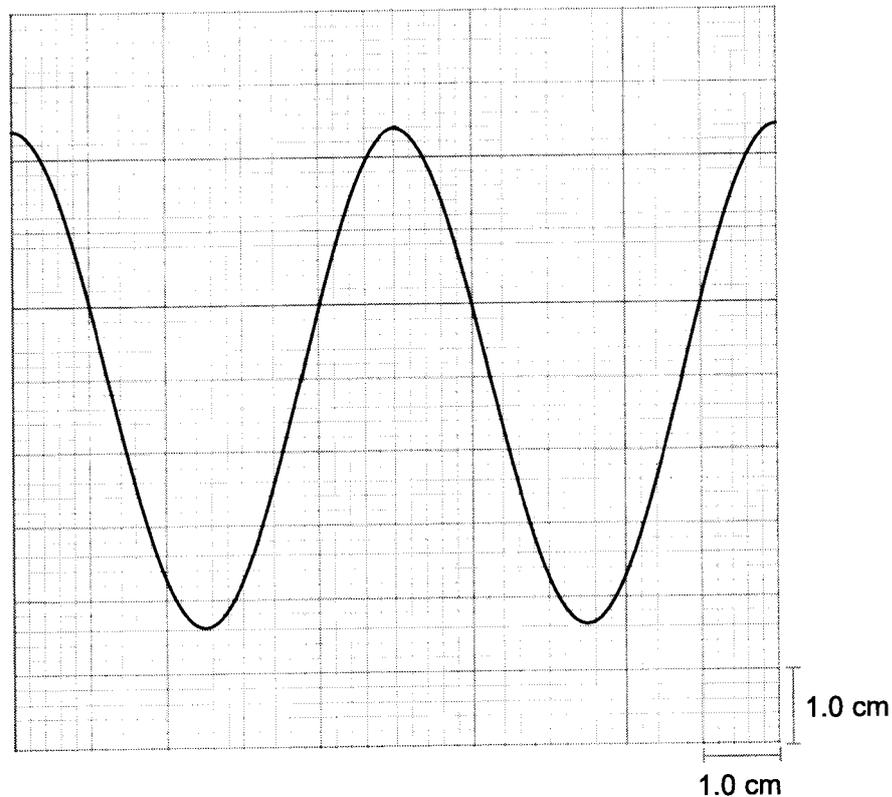


Fig. 9.2

- (i) Use Faraday's law of electromagnetic induction to explain the variation of the e.m.f. induced in the coil.

.....  
.....  
.....  
.....  
.....  
.....  
..... [3]

- (ii) Using Fig. 9.2, calculate

1. the maximum induced e.m.f.

maximum e.m.f. = ..... V [2]

2. the frequency.

frequency = ..... Hz [2]

- (iii) With reference to Fig. 9.1, state how the coil is positioned relative to the magnetic field when the induced e.m.f. in the coil is maximum.

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

- (iv) The coil has 120 turns and a cross-sectional area of  $1.3 \times 10^{-3} \text{ m}^2$ .

The maximum induced e.m.f.  $E_0$  is given by the expression

$$E_0 = \text{maximum magnetic flux linkage} \times \text{angular speed of the coil.}$$

Use this expression and your answers in (a)(ii) to calculate the magnetic flux density of the field.

magnetic flux density = ..... T [2]

- (b) An electric heater has a resistance of  $38 \Omega$  at its working temperature. The variation with time  $t$  of the supply voltage  $V$  connected between the terminals of the heater is given by

$$V = 240 \sin 377t$$

where  $V$  is measured in volts and  $t$  is in seconds.

- (i) By reference to heating effect, explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating current.

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

- (ii) Determine the frequency  $f$  of the supply voltage

$f = \dots\dots\dots$  Hz [2]

- (iii) Determine the power dissipation of the heater.

power = ..... W [3]

- (iv) On Fig. 9.3, show the variation with time  $t$  of the power  $P$  dissipated in the heater for two periods of the alternating voltage. The alternating voltage has period  $T$ .

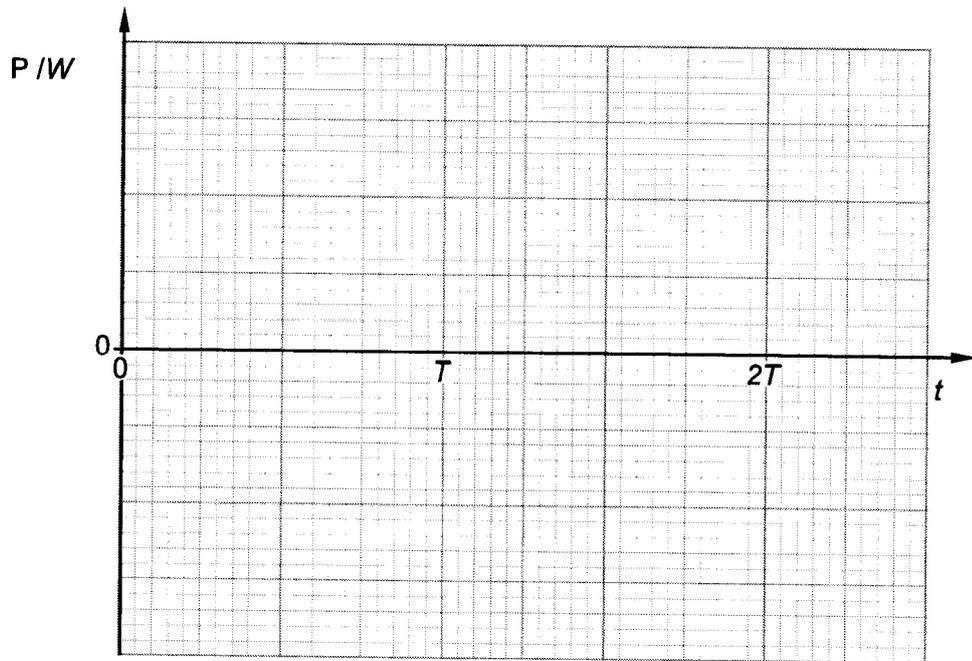


Fig. 9.3

[3]

[Total: 20 marks]

END OF PAPER

