HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION

2023 MOCK EXAMINATION

PHYSICS PAPER 1

8.30 am – 11.00 am (2 hours 30 minutes)

This paper must be answered in English

GENERAL INSTRUCTIONS

1. There are **TWO** sections, A and B, in this Paper. You are advised to finish Section A in about 50 minutes.

2. Section A consists of multiple-choice questions in this question paper, while Section B contains conventional questions printed separately in Question-Answer Book **B**.

3. Answers to Section A should be marked on the Multiple-choice Answer Sheet while answers to Section B should be written in the spaces provided in Question-Answer Book **B**. **The Answer Sheet for Section A and the Question-Answer Book for Section B will be collected separately at the end of the examination.**

4. The diagrams in this paper are **NOT** necessarily drawn to scale.

5. The last pages of this question paper contain a list of data, formulae and relationships which you may find useful.

INSTRUCTIONS FOR SECTION A (MULTIPLE-CHOICE QUESTIONS)

1. Read carefully the instructions on the Answer Sheet. After the announcement of the start of the examination, you should first stick a barcode label and insert the information required in the spaces provided. No extra time will be given for sticking on the barcode label after the 'Time is up' announcement.

2. When told to open this book, you should check that all the questions are there. Look for the words **'END OF SECTION A'** after the last question.

3. All questions carry equal marks.

4. **ANSWER ALL QUESTIONS**. You are advised to use an HB pencil to mark all the answers on Answer Sheet, so that wrong marks can be completely erased with a certain rubber. You must mark the answers clearly, otherwise you will lose marks if the answers cannot be captured.

5. You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARKS** for that question.

6. No marks will be deducted for wrong answers.

Section A

There are 33 questions.

1. A polystyrene cup contains equal mass of melting ice and water at 0 °C. An immersion heater takes 2.5 minutes to melt all the ice. What is the time further required for the water to reach the boiling point ?
Neglect the heat loss to the surroundings.

(Given : Specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$; specific latent heat of fusion of ice = 334 000 J kg^{-1}.)

A. 3.2 minutes
B. 6.3 minutes
C. 9.5 minutes
D. Insufficient information

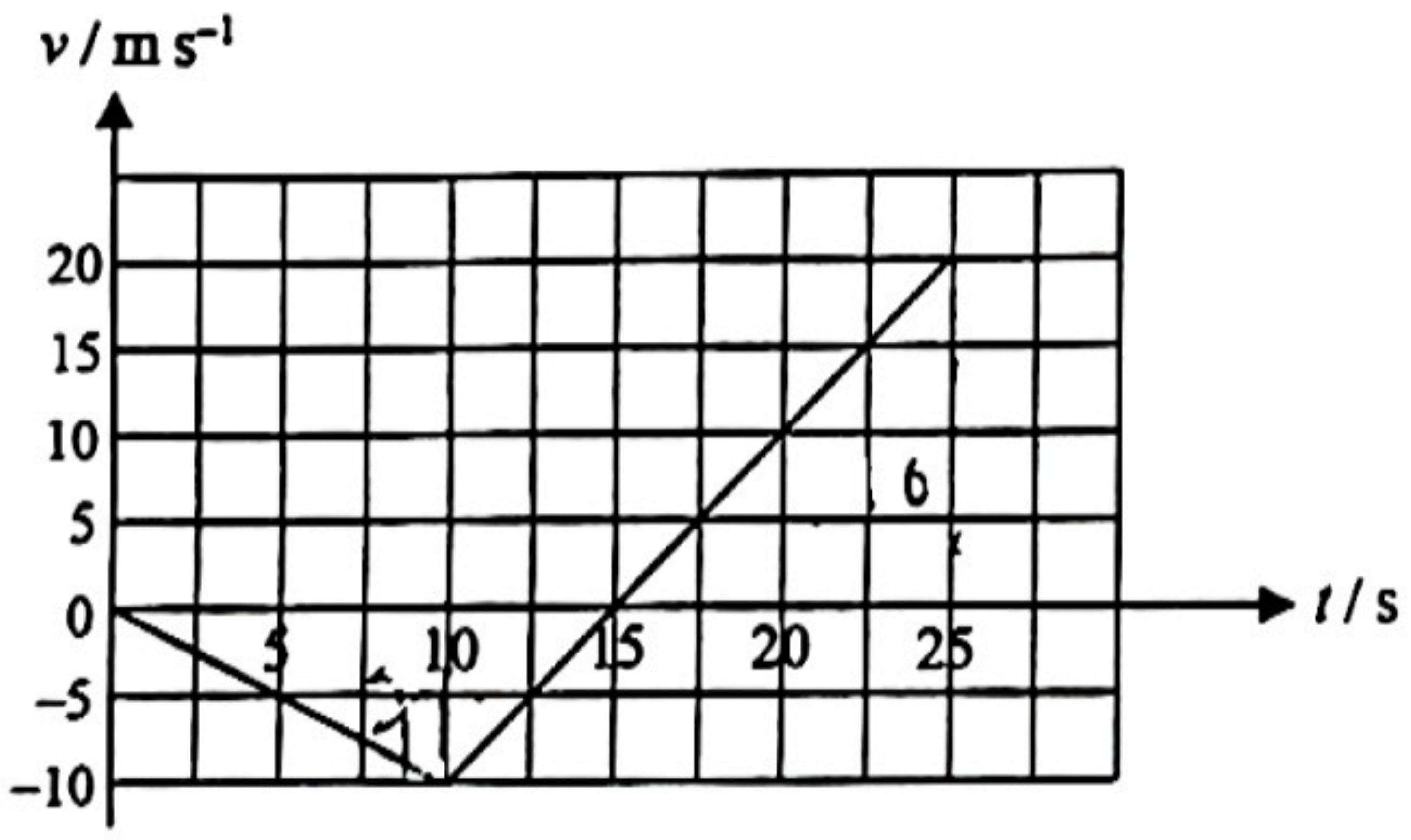
2. A closed container of volume 2 m^3 contains an ideal gas. The temperature of the gas is 25 °C and the pressure of the gas is 1.35×10^5 Pa. Calculate the number of gas molecules in the container.

A. 2.36×10^{25}
B. 4.58×10^{25}
C. 6.56×10^{25}
D. 8.28×10^{25}

3. A container contains an ideal gas at a pressure of 150 kPa. If the root-mean-square speed of the gas molecules is 575 m s^{-1}, what is the density of the gas inside the vessel ?

A 1.36 kg m^{-3}
B. 1.72 kg m^{-3}
C 2.72 kg m^{-3}
D. 5.44 kg m^{-3}

4.



A car travels along a straight horizontal road starts from rest at $t = 0$ s from a road sign. The above figure shows the velocity-time (v-t) graph of the car during the journey of 25 s. Take the direction towards the right as positive. Which of the following descriptions are correct ?

(1) The average speed of the car is 7 m s^{-1}.
(2) The average velocity of the car is 1 m s^{-1}
(3) The greatest separation between the car and the road sign is 75 m.

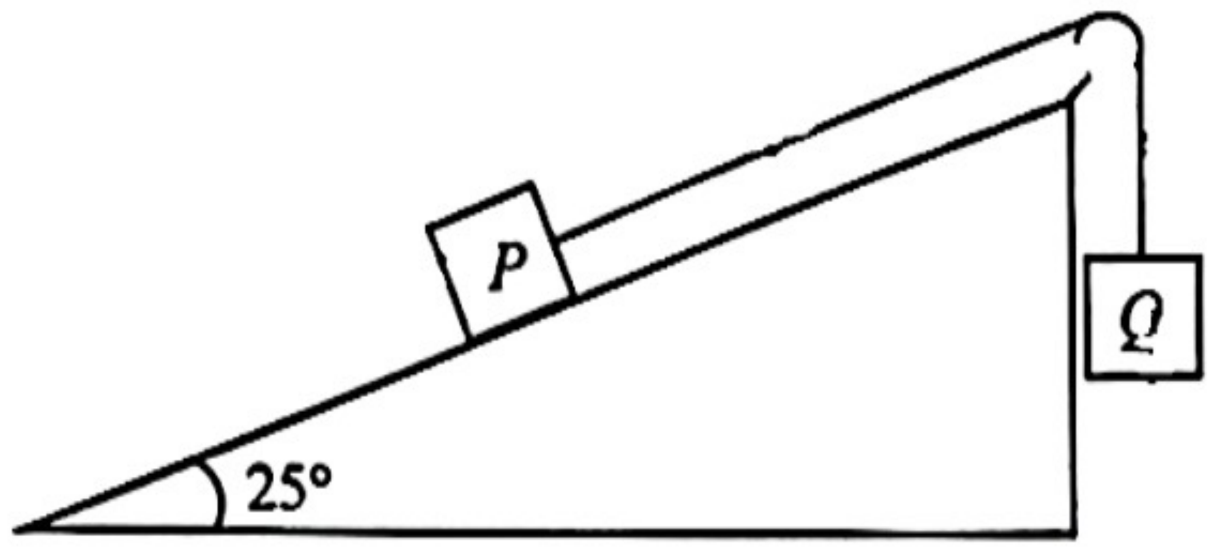
A. (1) and (2) only
B. (1) and (3) only
C (2) and (3) only
D (1), (2) and (3)

5. A man of weight W stands inside a lift which is moving downwards with a deceleration of $0.1g$, where g is the acceleration due to gravity. Which of the following statements is/are correct ?

(1) The man would feel heavier inside the lift.
(2) The weight of the man would change by 10%.
(3) The force acting on the man by the floor and the weight of the man form an action and reaction pair.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

6.



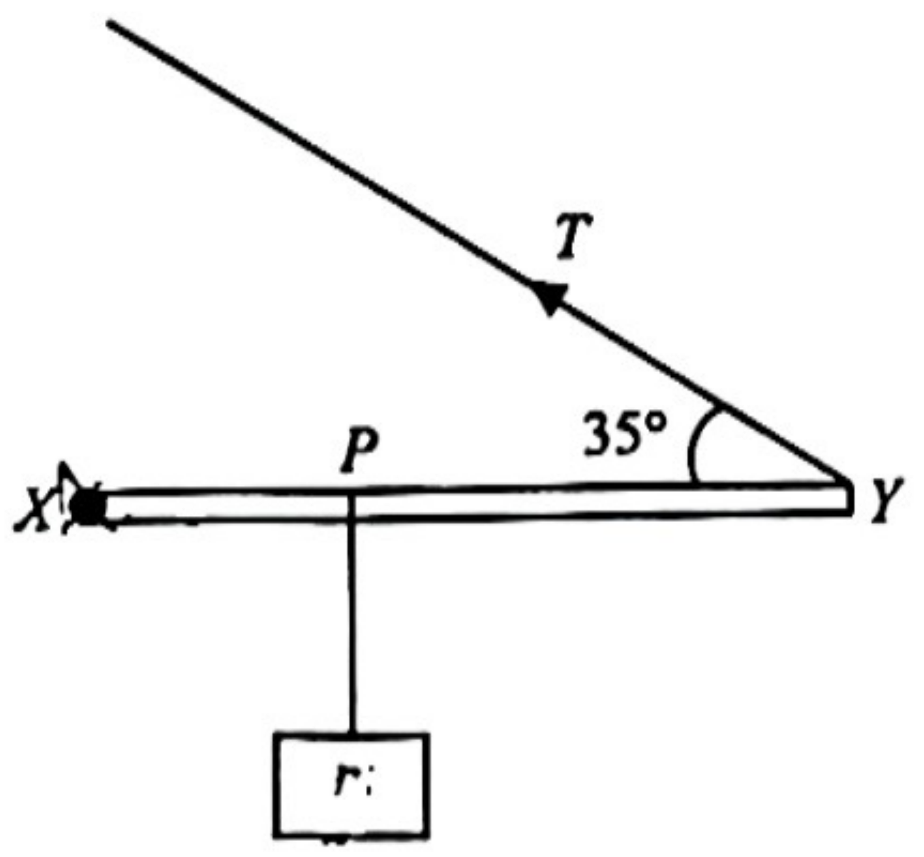
Two identical blocks P and Q are connected by an inextensible light string passes over a smooth pulley as shown in the above figure. The inclined plane is smooth and it makes an angle of 25° with the horizontal. When the system is released, what is the acceleration of the blocks ?

A. 1.42 m s^{-2}
B. 2.83 m s^{-2}
C. 4.26 m s^{-2}
D. 5.66 m s^{-2}

7. A block is projected with an initial velocity of 15 m s^{-1} along a rough horizontal plane. If the average friction acting on the block is equal to 0.65 times of its weight, calculate the distance travelled by the block before it stops.

A. 13.5 m
B. 17.6 m
C. 19.2 m
D. Cannot be determined as the mass of the block is not given.

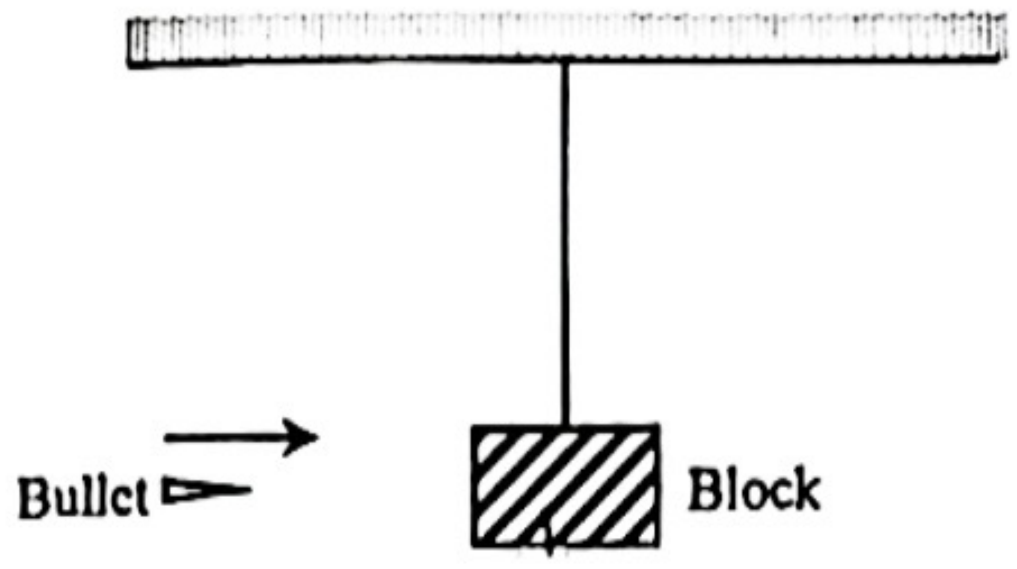
8.



In the figure shown, a light rod XY of length 60 cm is pivoted at X. A light string attached to Y keeps the rod at rest in the horizontal position. The string makes an angle 35° with the rod. A block of mass m is attached to point P as shown. If the tension of the string is equal to $0.75\ mg$, determine the distance between X and P.

A. 8.6 cm
B. 12.6 cm
C. 23.5 cm
D. 25.8 cm

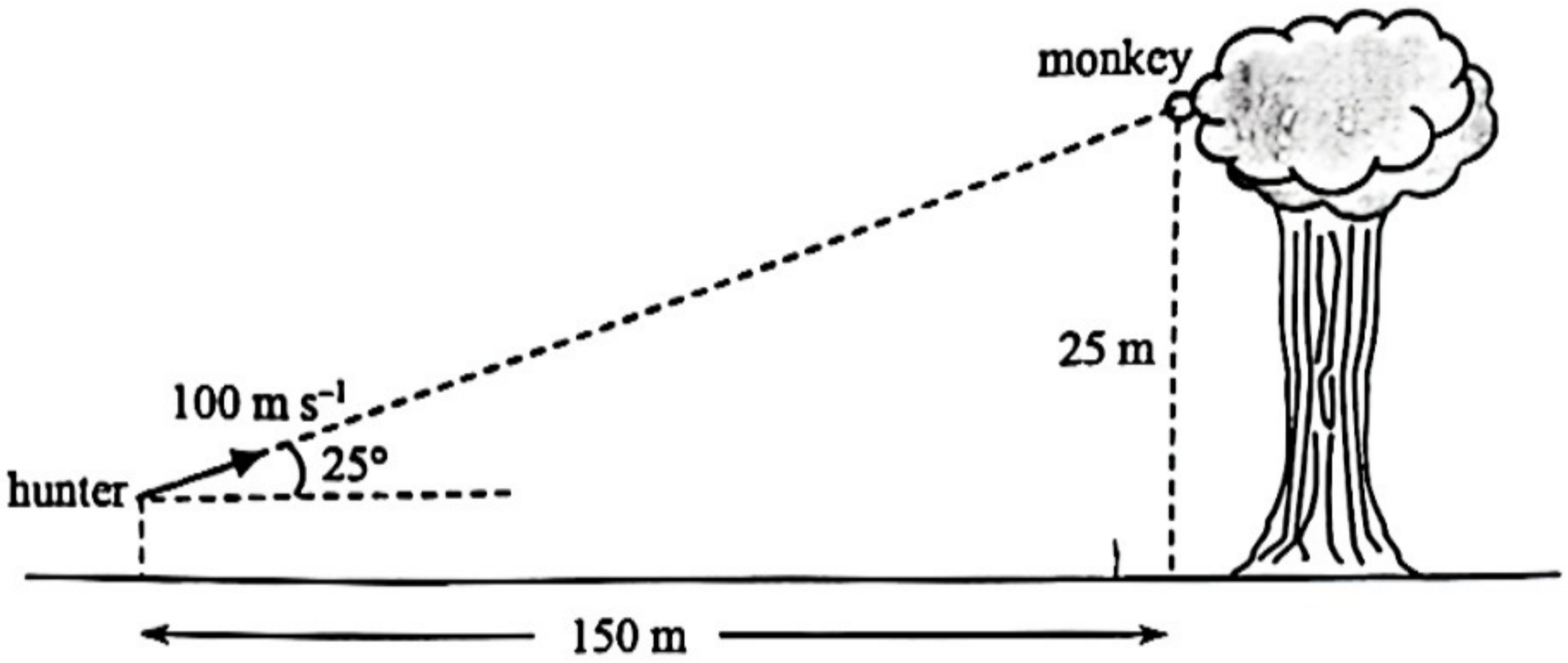
9.



A bullet of mass 20 g is moving with a horizontal velocity u towards a suspended block of mass 2.48 kg. After hitting, the bullet embeds in the block and the block swings upwards with a vertical height of 6.4 cm. What is the initial velocity u of the bullet ?

A. 120 m s^{-1}
B. 140 m s^{-1}
C. 160 m s^{-1}
D. 180 m s^{-1}

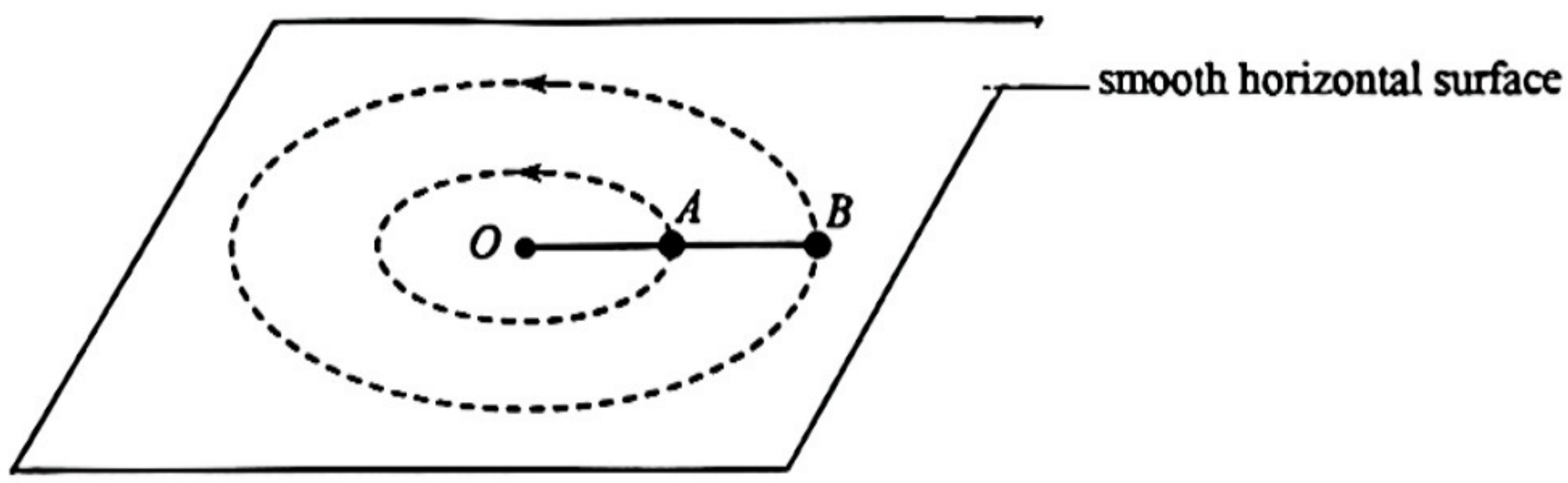
10.



A hunter aims directly at a monkey which is at a horizontal distance of 150 m from his position as shown in the above figure. The monkey is at a height of 25 m above the ground. At the moment the bullet is fired, the monkey drops itself such that it falls vertically from rest. If the velocity of the bullet is 100 m s^{-1}, making an angle of 25° with the horizontal, what is the height of the monkey above the ground at the moment the monkey is hit by the bullet.

A. 11 6 m
B. 13.4 m
C. 15.8 m
D. 17.6 m

11.



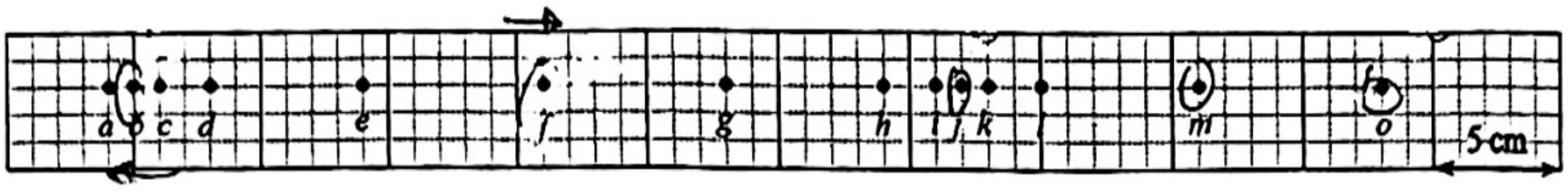
Two small particles A and B, of mass ratio 1 : 2, are connected by inextensible threads to a fixed point O as shown. The threads OA and AB are of the same length. Both A and B perform uniform horizontal circular motion about O with the same period. Suppose T_1 and T_2 denote the tensions in the threads OA and AB respectively. Find the ratio $T_1 : T_2$.

A. 3 : 1
B. 3 : 2
C. 5 : 2
D. 5 : 4

12. An artificial satellite revolves in a circular orbit above the Earth's surface at a height equal to the radius of the Earth. What is the period of the satellite ? Given : mass of the Earth = 6.0×10^{24} kg ; radius of the Earth = 6400 km

A. 2.8 hours
B. 4.0 hours
C. 5.6 hours
D. Answer cannot be found as the mass of the satellite is not known.

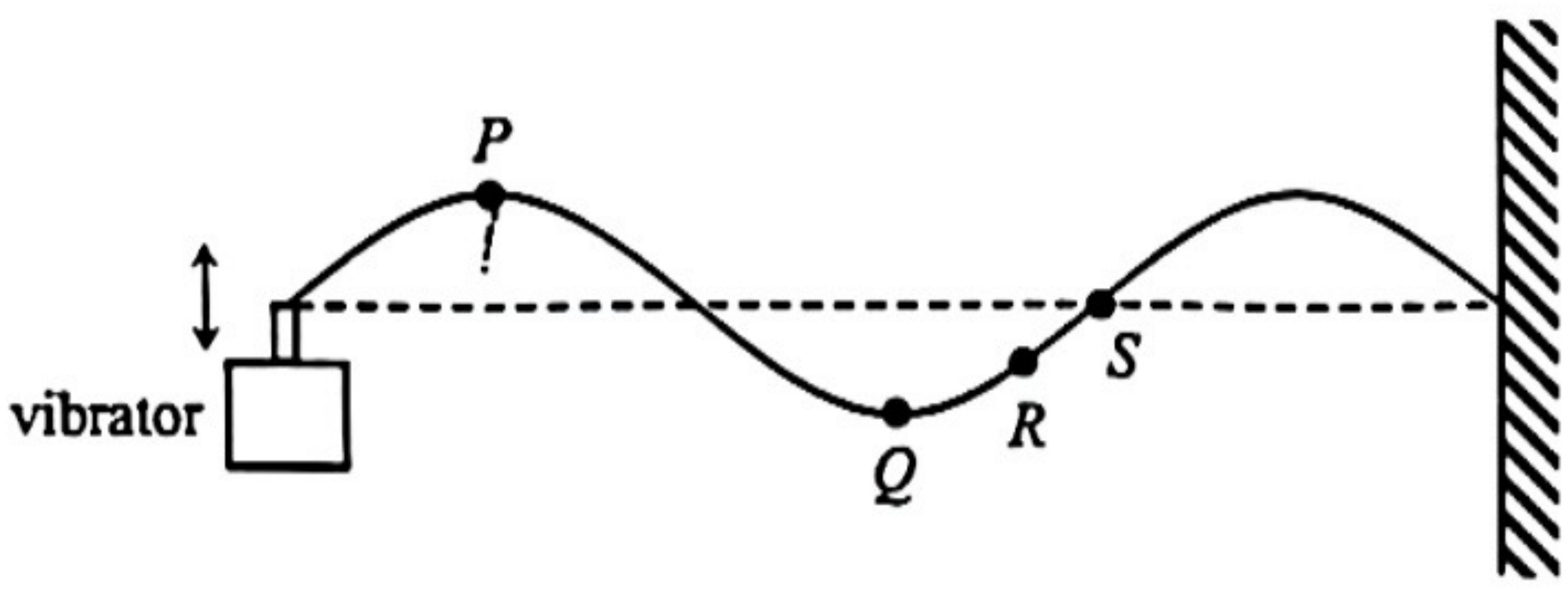
13.



A longitudinal wave travels to the left through a medium containing a series of particles. The above figure shows the positions of the particles at a certain instant. Which of the following statements concerning the longitudinal wave at this instant are correct ?

(1) The particle f is moving towards the right.
(2) The particles a and c are moving in opposite directions.
(3) The particle h is momentarily at rest.

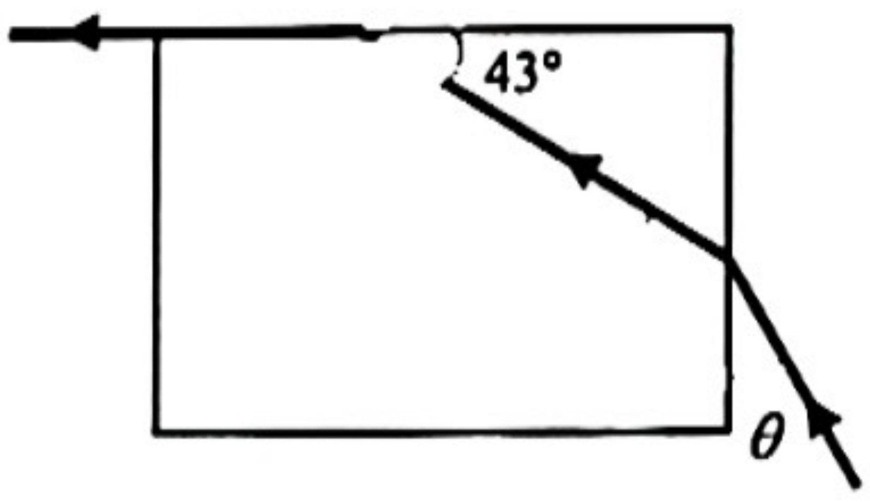
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)



A vibrator generates a stationary wave on a string which is attached to a fixed wall at its right end. At the instant shown in the above figure, particle P is moving downwards. Which of the following statements concerning the above stationary wave is NOT correct ?

Particle R is moving upwards at this instant.
B. The speed of particle Q is greater than that of R at this instant.
All the four particles P, Q, R and S are moving at this instant.
D. Particles P and R reach their equilibrium positions at the same time.

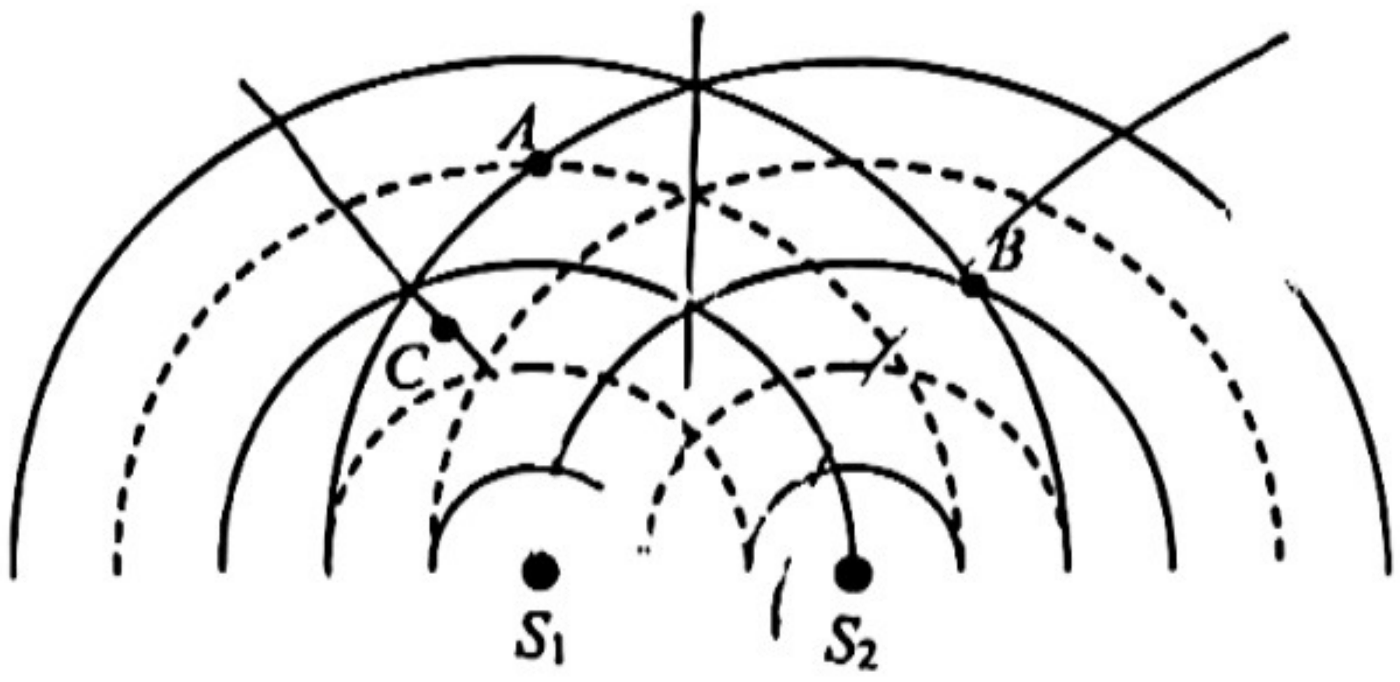
15.



A ray of light enters a rectangular plastic block from air and travels along the path shown in the above figure. It finally emerges from the block along the upper surface. Find the angle θ indicated in the figure.

A. 21°
B. 23°
C. 32°
D. 69°

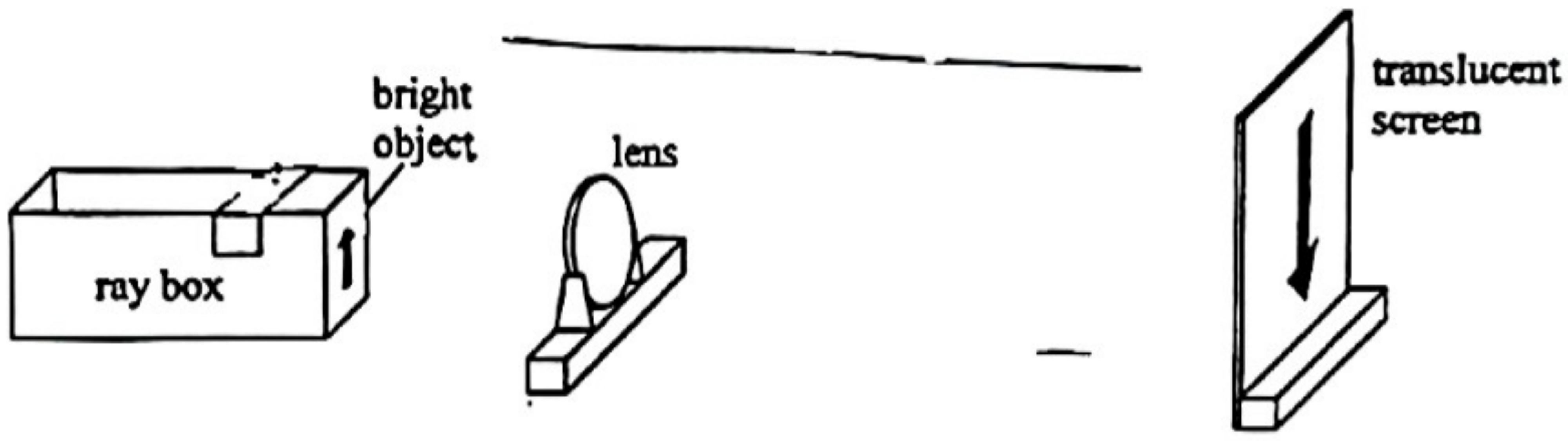
16.



Two point sources S_1 and S_2 are producing circular water waves in a ripple tank. The figure shows the wave pattern at a certain instant. Solid lines represent crests and dotted lines represent troughs. The separation between S_1 and S_2 is equal to 1.5λ, where λ the wavelength of the water waves. Which of the following statements is **NOT** correct ?

A. There are 3 antinodal lines in this wave pattern.
B. The water particle at A is always at rest.
C. The water particle at B is always at the crest.
D. The water particle at C is undergoing constructive interference.

17. In the below set-up, the separation between the bright object and the translucent screen is fixed at a separation of 40 cm. A convex lens is placed at a distance of 10 cm from bright object. A sharp inverted image of length 18 cm is formed on the screen, as shown.

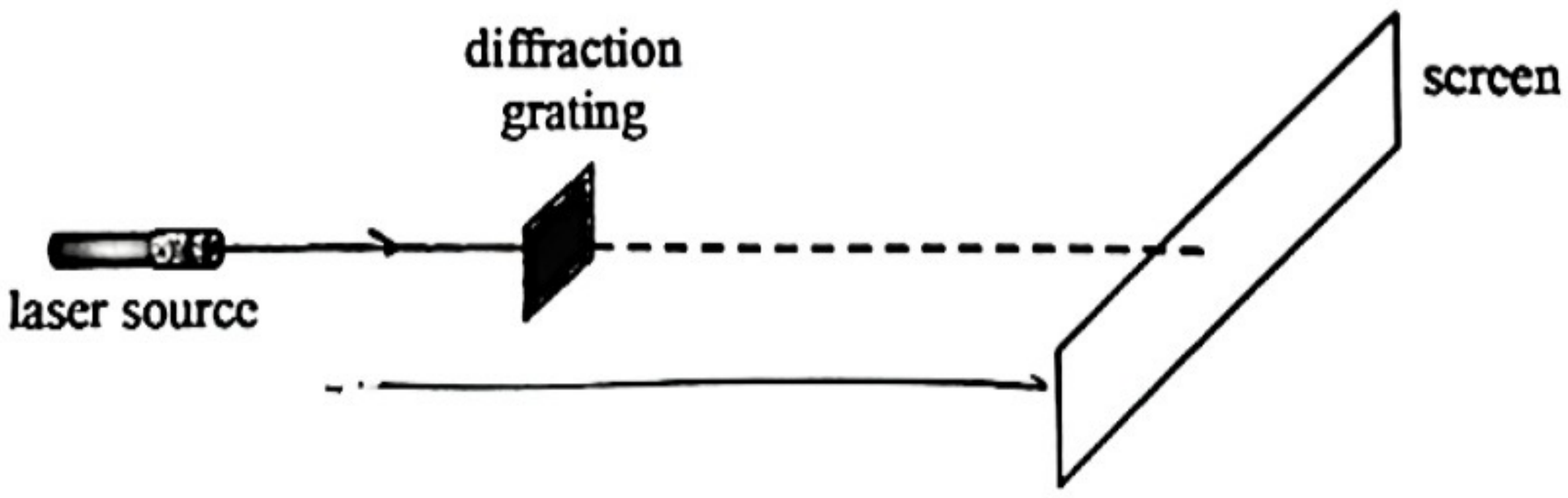


If now the lens is moved a distance d towards the screen, another sharp image is formed. Which of the following statements are correct ?

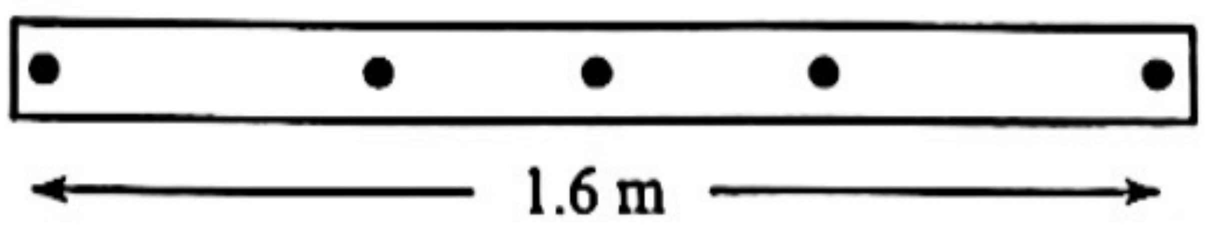
(1) The distance d moved by the lens to give the second sharp image on the screen is 20 cm.
(2) The length of the second sharp image on the screen is 2 cm.
(3) The focal length of the lens is 7.5 cm.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

18.



A diffraction grating of 4000 lines per cm is used in the above set-up. A laser light is directed onto the grating. A pattern of 5 bright spots is obtained on a screen placed at 1.5 m from the grating. The separation between the first and the fifth spots is 1.6 m as shown below.



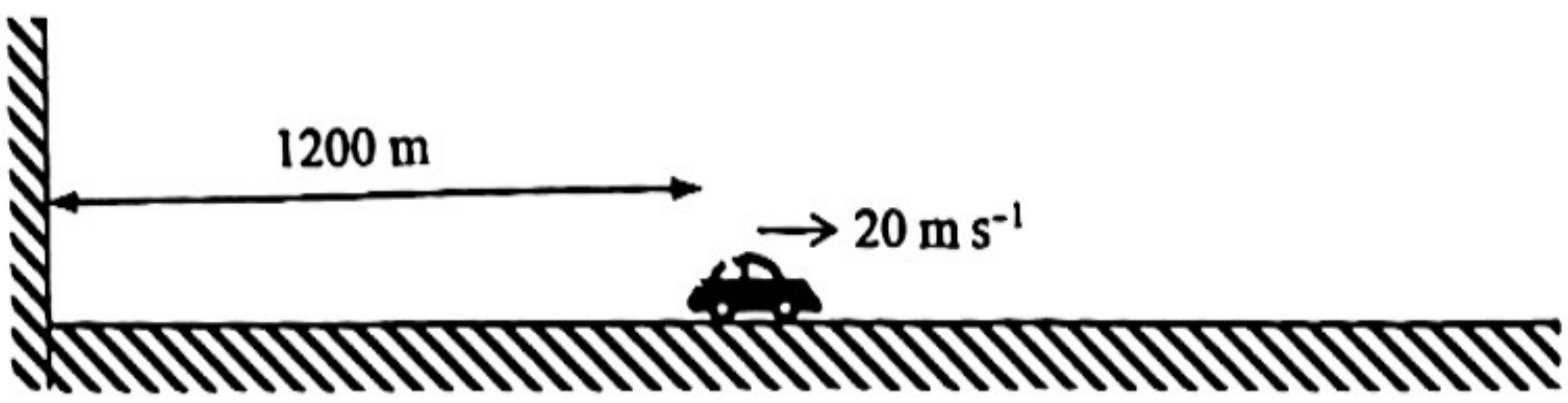
What is wavelength of the laser light emitted from the laser source ?

A. 565 nm
B. 588 nm
C. 612 nm
D. 645 nm

19. In a Young's double-slit experiment, a double-slit of slit separation 0.5 mm is used. When a beam of monochromatic light is directed onto the double-slit, alternate bright and dark fringes are observed on a screen placed at 1.6 m from the double-slit. If the separation between the first and the fifth bright fringes is 7.5 mm, what is the wavelength of the monochromatic light ?

A. 4.52×10^{-7} m
B. 5.24×10^{-7} m
C. 5.86×10^{-7} m
D. 6.48×10^{-7} m

20.



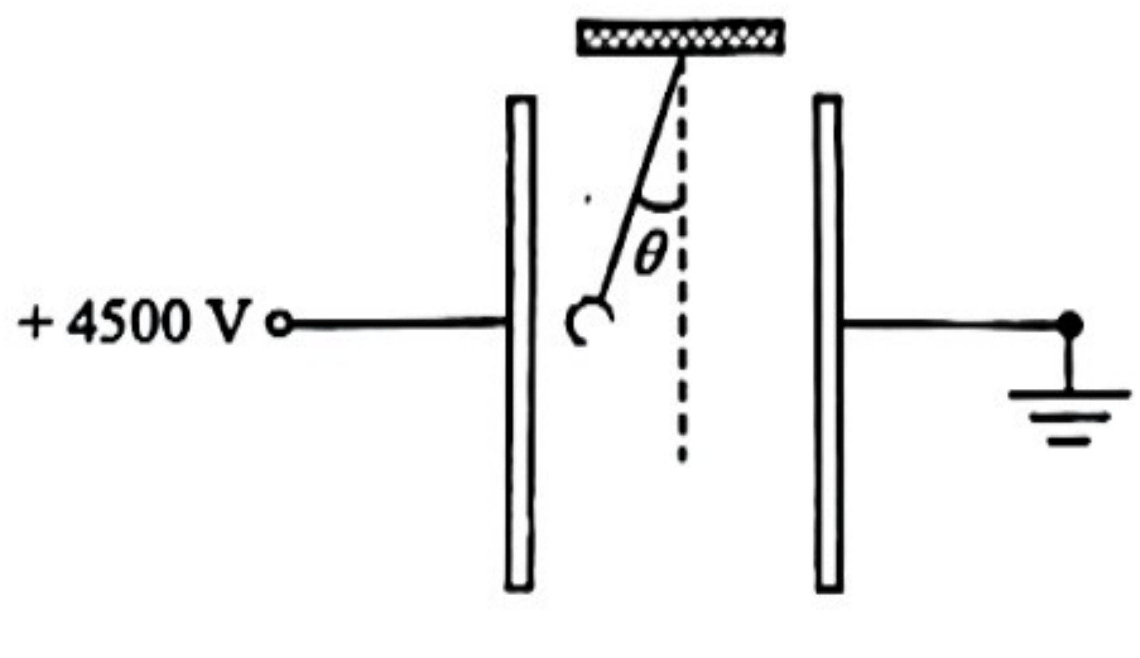
A car is travelling with a uniform velocity of 20 m s^{-1} along a straight horizontal road away from a vertical wall. When the car is at 1200 m from the wall, it emits a sound signal towards the wall. What is the time taken for the driver of the car to hear the echo of the sound ? Given : speed of sound in air = 340 m s^{-1}.

A. 3.75 s
B. 5.75 s
C. 7.06 s
D. 7.50 s

21. Which of the following statements about ultrasound is **CORRECT** ?

A. Ultrasound travels with a greater speed in air than that in water.
B Ultrasound can be used to detect cracks in railway tracks.
C. Ultrasound is a type of electromagnetic wave.
D. Ultrasound does not have diffraction.

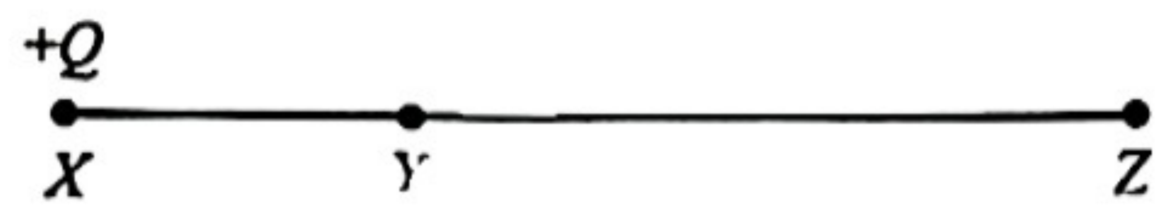
22.



A positive potential of 4500 V is connected to the left metal plate and the right metal plate is earthed as shown in the figure. The separation between the two metal plates is 10 cm. A small charged ball of mass 50 mg is suspended by a light inextensible string. When the charged ball is placed inside the region of the two metal plates, the string makes an angle of 12° with the vertical. What is the charge carried by the small ball ?

A. 2.3×10^{-6} C
B. 4.6×10^{-6} C
C. 2.3×10^{-9} C
D. 4.6×10^{-9} C

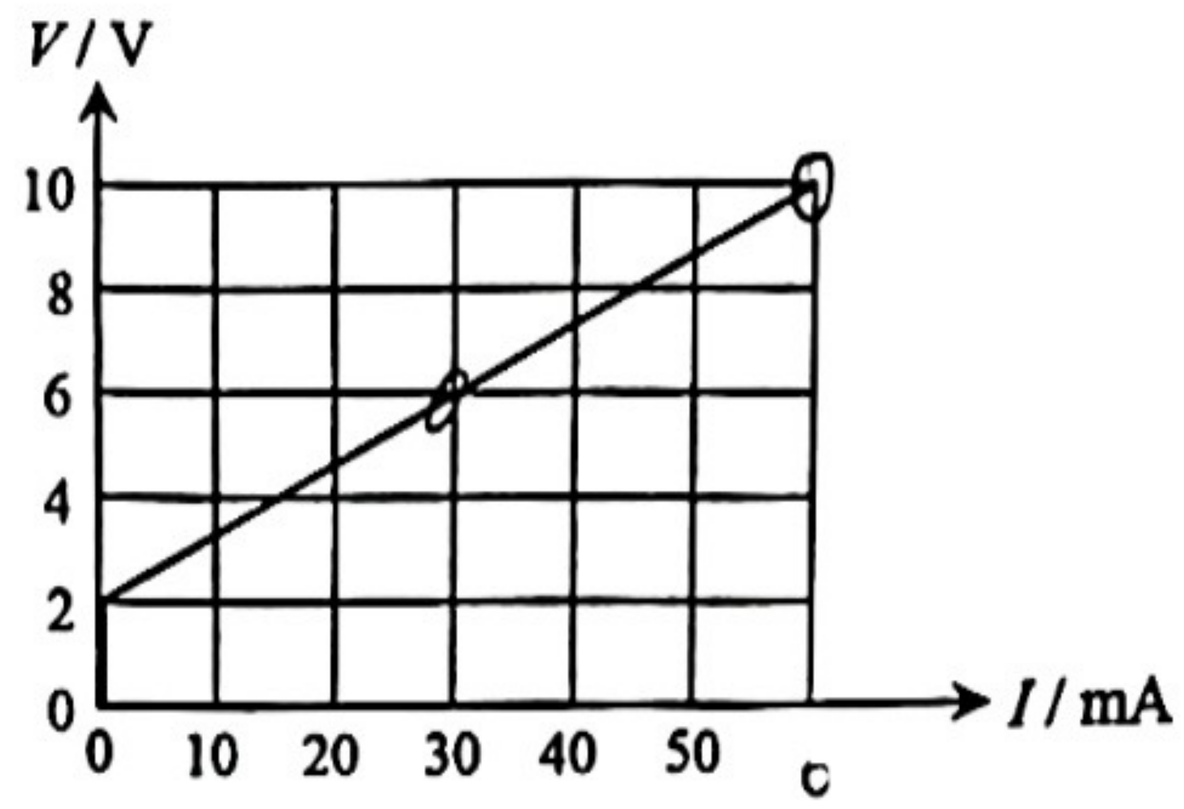
23.



A point charge $+Q$ is placed at X as shown in the above figure. The electric field at Y is E. If now a point charge $-2Q$ is placed at Z, where $XY : YZ = 1 : 2$, determine the resultant electric field at Y, both in magnitude and direction.

	Magnitude of resultant electric field	Direction of resultant electric field
A.	$0.5\ E$	rightwards
B.	$0.5\ E$	leftwards
C.	$1.5\ E$	rightwards
D.	$1.5\ E$	leftwards

24.

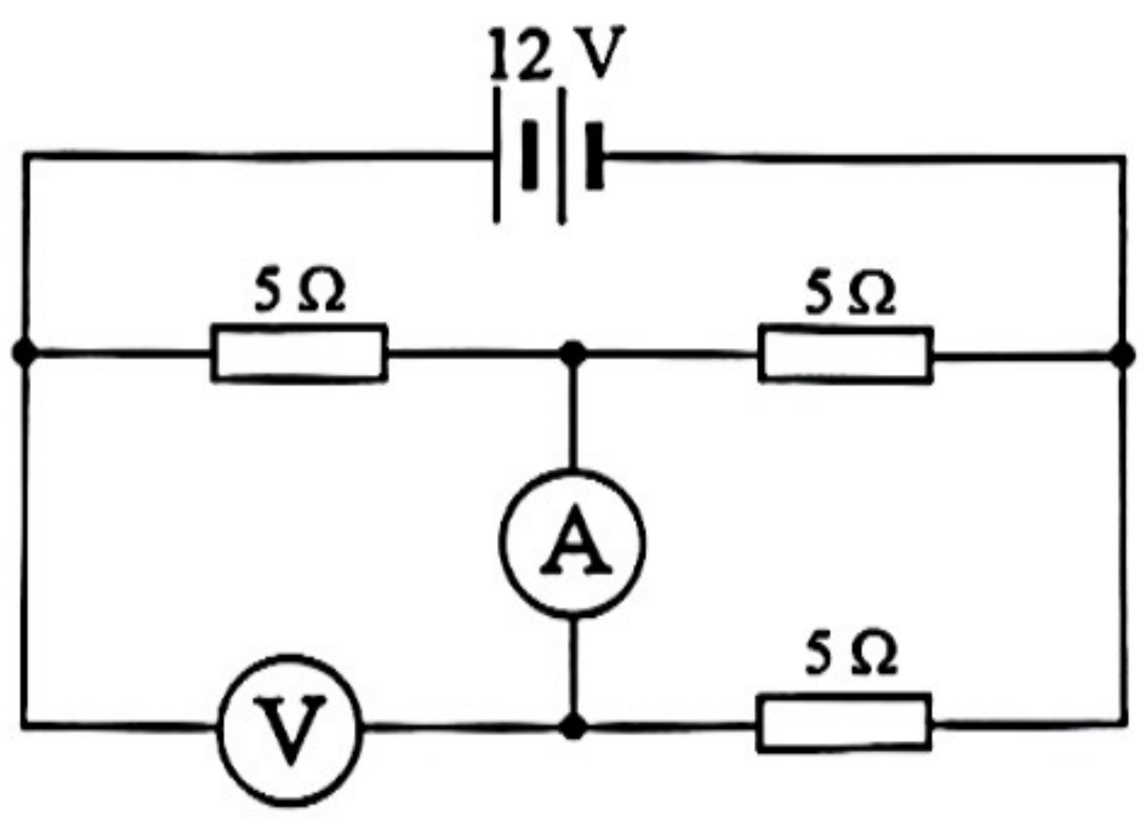


The relationship of the applied voltage V against the corresponding current I of an electrical device is shown in the above graph. Which of the following deductions are correct ?

(1) When the applied voltage increases from 2 V to 10 V, the resistance of the device gradually increases.
(2) When the applied voltage is 6 V, the resistance of the device is 200 Ω.
(3) When the applied voltage is 10 V, the power dissipated by the device is 600 mW.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

25.



In the above circuit, three identical resistors, each of 5 Ω, are connected to a battery of 12 V with negligible internal resistance. If the voltmeter and ammeter are ideal, what are their readings ?

	voltmeter reading	ammeter reading
A.	4 V	0.8 A
B.	4 V	1.6 A
C.	8 V	0.8 A
D.	8 V	1.6 A

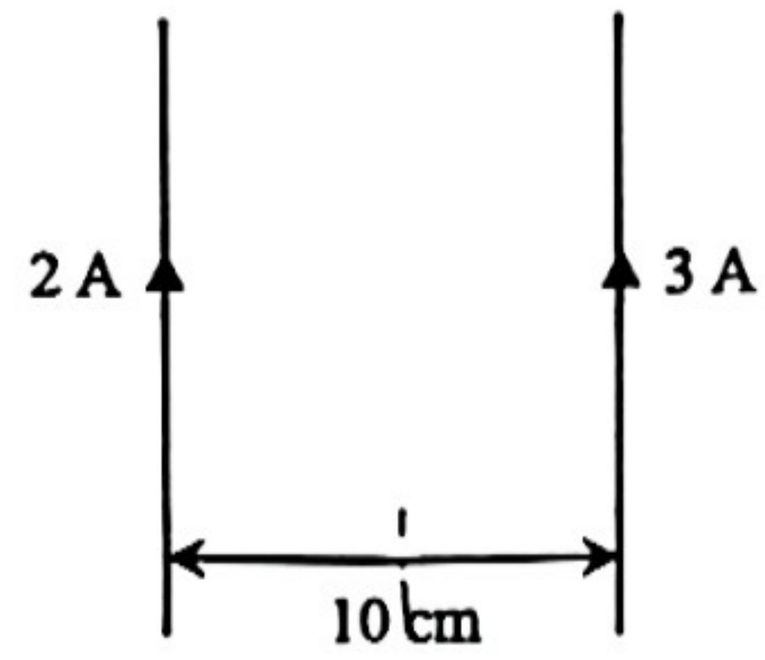
26. A uniform cylindrical metal wire of resistivity 7.5×10^{-8} Ω m is connected to a battery of 4.5 V with negligible internal resistance. A current of 2.4 A flows through the wire. If the volume of the metal wire is equal to 1.5×10^{-7} m^3, calculate the length of the metal wire.

A. 1.17 m
B. 1.36 m
C. 1.94 m
D. 3.75 m

27. Light bulb A is rated "8 V, 12 W" and light bulb B is rated "12 V, 18 W". If now these two light bulbs are connected in parallel to a power supply, what is the maximum current drawn from the power supply so that both light bulbs are working within the rated power ?

A. 2.0 A
B. 2.5 A
C. 3.0 A
D. 3.5 A

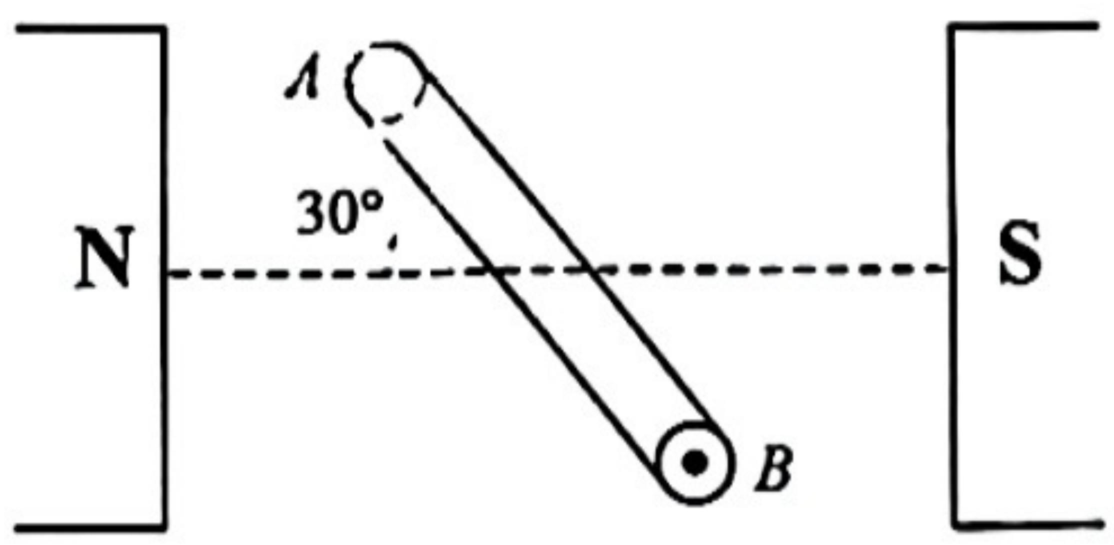
28.



The above figure shows two long straight parallel wires carrying currents 2 A and 3 A respectively in the same upward direction as shown. The separation between the two wires is 10 cm. If now another long straight wire carrying current 1 A in downward direction (not shown in the figure) is placed midway between the two above wires, what would be the resultant magnetic force per unit length acting on this wire, in both magnitude and direction ?

	magnitude	direction
A.	2×10^{-5} N m^{-1}	leftwards
B.	2×10^{-5} N m^{-1}	rightwards
C.	4×10^{-6} N m^{-1}	leftwards
D.	4×10^{-6} N m^{-1}	rightwards

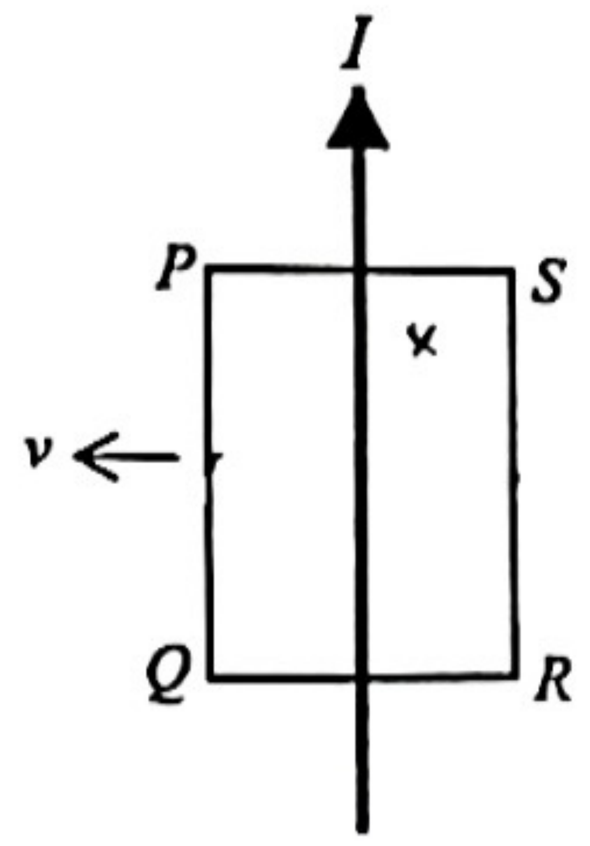
29



A coil AB of 20 turns carrying current of 4.5 A is placed inside a uniform magnetic field as shown in the above figure. The flux density of the magnetic field is 40 mT. The current at A is into the paper while that at B is out of paper. The coil makes an angle of 30° with the horizontal. What is the magnetic force per unit length acting on the side A ?

A. 1.2 N m^{-1}
B. 1.8 N m^{-1}
C. 3.1 N m^{-1}
D. 3.6 N m^{-1}

30.



A rectangular coil $PQRS$ is moving from right to left with a uniform speed v across an insulated metal wire carrying a steady current I in upward direction. At the instant shown when the coil is at the position that the current is exactly at the middle of the coil, which of the following statements are correct ? Neglect the effect of the Earth's magnetic field.

(1) The induced current in the coil is in clockwise direction.
(2) The electric potential at P higher than that at Q.
(3) The resultant magnetic force acting on the coil is zero.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

31. A radioactive sample contains 0.02 moles of active nuclei. If the half-life of the sample is 5 years, what is the activity of the sample ?

A. 6.5×10^{12} Bq
B. 5.3×10^{13} Bq
C. 8.4×10^{14} Bq
D. 3.2×10^{15} Bq

32. A GM counter is placed near a radioactive source which has a half-life of 2 hours. Initially, the counter registers a count rate of 720 c.p.m. After 4 hours, the count rate drops to 240 c.p.m. What would be the count rate after one more hour ?

A. 80 c.p.m.
B. 113 c.p.m.
C. 120 c.p.m.
D. 193 c.p.m.

33. A star radiates energy at a constant rate of 4.5×10^{26} W by nuclear fusion. The mass of the star is 4.0×10^{30} kg. Estimate the lifetime of the star if 0.07% of its mass is converted into radiation energy during its lifetime.

A. 1.8×10^{8} years
B. 1.8×10^{10} years
C. 1.8×10^{12} years
D. 1.8×10^{17} years

END OF SECTION A

List of data, formulae and relationships

Data

molar gas constant	$R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
acceleration due to gravity	$g = 9.81\ \text{m s}^{-2}$ (close to the Earth)
universal gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
speed of light in vacuum	$c = 3.00 \times 10^8\ \text{m s}^{-1}$
charge of electron	$e = 1.60 \times 10^{-19}\ \text{C}$
electron rest mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\ \text{N}^{-1}\ \text{m}^{-2}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
atomic mass unit	$\text{u} = 1.661 \times 10^{-27}\ \text{kg}$ (1 u is equivalent to 931 MeV)
astronomical unit	$\text{AU} = 1.50 \times 10^{11}\ \text{m}$
light year	$\text{ly} = 9.46 \times 10^{15}\ \text{m}$
parsec	$\text{pc} = 3.09 \times 10^{16}\ \text{m} = 3.26\ \text{ly} = 206265\ \text{AU}$
Stefan constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$

Rectilinear motion

For uniformly accelerated motion :

$$v = u + at$$

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

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

Mathematics

Equation of a straight line	$y = mx + c$
Arc length	$= r\theta$
Surface area of cylinder	$= 2\pi r h + 2\pi r^2$
Volume of cylinder	$= \pi r^2 h$
Surface area of sphere	$= 4\pi r^2$
Volume of sphere	$= \frac{4}{3}\pi r^3$

For small angles, $\sin\theta \approx \tan\theta \approx \theta$ (in radian)

Astronomy and Space Science

$U = -\dfrac{GMm}{r}$	gravitational potential energy
$P = \sigma A T^4$	Stefan's law
$\left\lvert\dfrac{\Delta f}{f_0}\right\rvert \approx \dfrac{v}{c} \approx \left\lvert\dfrac{\Delta\lambda}{\lambda_0}\right\rvert$	Doppler effect

Energy and Use of Energy

$E = \dfrac{\Phi}{A}$	illuminance
$\dfrac{Q}{t} = k\dfrac{A(T_H - T_C)}{d}$	rate of energy transfer by conduction
$U = \dfrac{k}{d}$	thermal transmittance U-value
$P = \dfrac{1}{2}\rho A v^3$	maximum power by wind turbine

Atomic World

$\dfrac{1}{2}m_e v_{max}^2 = hf - \phi$	Einstein's photoelectric equation
$E_n = -\dfrac{13.6}{n^2}\ \text{eV}$	energy level equation for hydrogen atom
$\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$	de Broglie formula
$\theta \approx \dfrac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)

Medical Physics

$\theta \approx \dfrac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)
$\text{power} = \dfrac{1}{f}$	power of a lens
$L = 10\log\dfrac{I}{I_0}$	intensity level (dB)
$Z = \rho c$	acoustic impedance
$\alpha = \dfrac{I_r}{I_0} = \dfrac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$	intensity reflection coefficient
$I = I_0 e^{-\mu x}$	transmitted intensity through a medium

A1.	$E = mc\,\Delta T$	energy transfer during heating and cooling
A2.	$E = l\,\Delta m$	energy transfer during change of state
A3.	$pV = nRT$	equation of state for an ideal gas
A4.	$pV = \frac{1}{3} Nm\overline{c^2}$	kinetic theory equation
A5.	$E_k = \frac{3RT}{2N_A}$	molecular kinetic energy

B1.	$F = m\frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$	force
B2.	$\text{moment} = F \times d$	moment of a force
B3.	$E_p = m\,g\,h$	gravitational potential energy
B4.	$E_k = \frac{1}{2}mv^2$	kinetic energy
B5.	$P = Fv = \frac{W}{t}$	mechanical power
B6.	$a = \frac{v^2}{r} = \omega^2 r$	centripetal acceleration
B7.	$F = \frac{Gm_1m_2}{r^2}$	Newton's law of gravitation

C1.	$\Delta y = \frac{\lambda D}{a}$	fringe width in double-slit interference
C2.	$d \sin\theta = n\,\lambda$	diffraction grating equation
C3.	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	equation for a single lens

D1.	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$	Coulomb's law
D2.	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	electric field strength due to a point charge
D3.	$E = \frac{V}{d}$	electric field between parallel plates (numerically)
D4.	$R = \frac{\rho l}{A}$	resistance and resistivity
D5.	$R = R_1 + R_2$	resistors in series
D6.	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	resistors in parallel
D7.	$P = IV = I^2R$	power in a circuit
D8.	$F = BQv\sin\theta$	force on a moving charge in a magnetic field
D9.	$F = BIl\sin\theta$	force on a current-carrying conductor in a magnetic field
D10.	$B = \frac{\mu_0 I}{2\pi r}$	magnetic field due to a long straight wire
D11.	$B = \frac{\mu_0 NI}{l}$	magnetic field inside a long solenoid
D12.	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$	induced e.m.f.
D13.	$\frac{V_s}{V_p} \approx \frac{N_s}{N_p}$	ratio of secondary voltage to primary voltage in a transformer

E1.	$N = N_0 e^{-kt}$	law of radioactive decay
E2.	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$	half-life and decay constant
E3.	$A = k\,N$	activity and the number of undecayed nuclei
E4.	$E = mc^2$	mass-energy relationship

Hong Kong Diploma of Secondary Education Examination

2023

Mock Examination

Please stick the barcode label here.

Candidate Number									

PHYSICS PAPER 1

SECTION B : Question-Answer Book B

This paper must be answered in English

Question No.	Marks
1	6
2	6
3	10
4	9
5	7
6	8
7	7
8	7
9	8
10	9
11	7

INSTRUCTIONS FOR SECTION B

(1) After the announcement of the start of the examination, you should first write you Candidate Number in the space provided on Page 1 and stick barcode labels in the spaces provided.

(2) Refer to the general instructions on the cover of the Question Paper for Section A.

(3) Answer **ALL** questions.

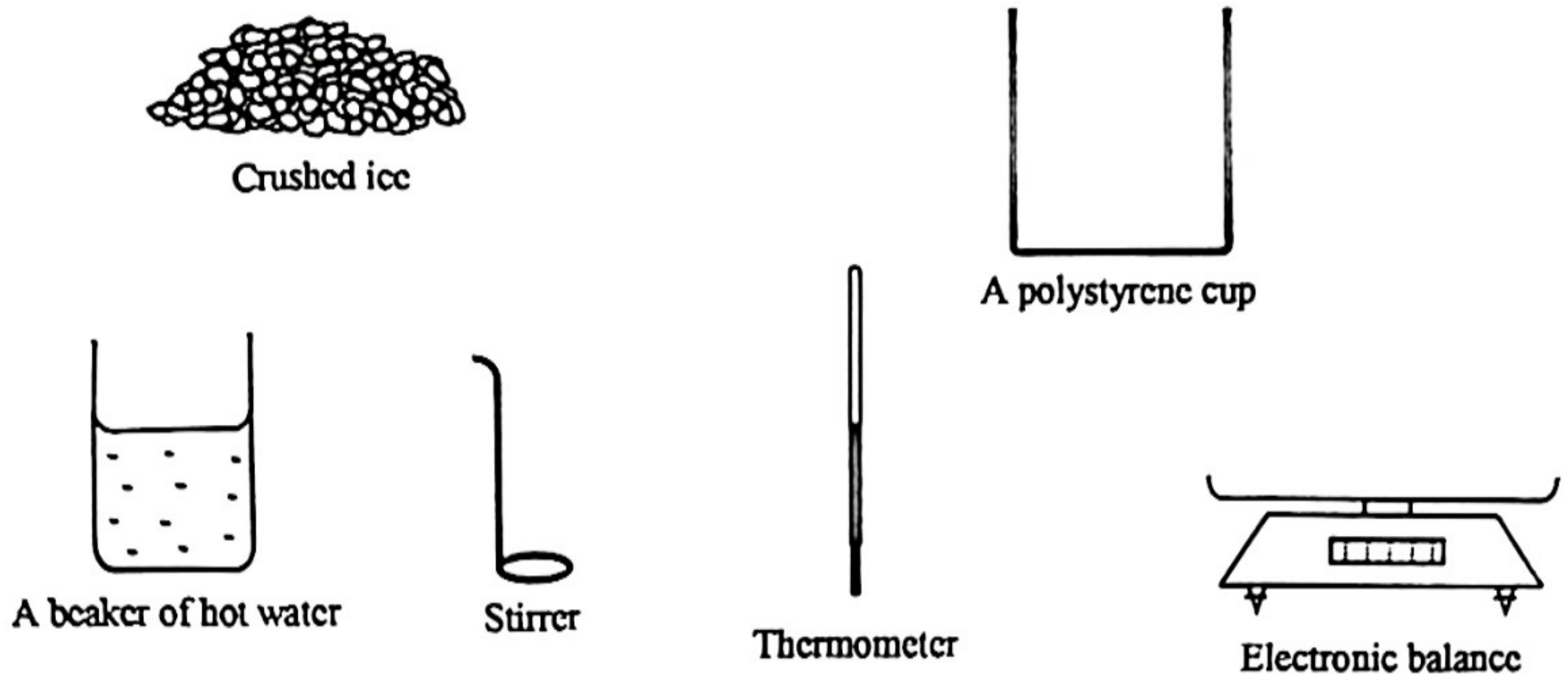
(4) Write your answers in the spaces provided in this Question-Answer Book. Do not write in the margins. Answers written in the margins will not be marked.

(5) Graph paper and supplementary answer sheets will be provided on request. Write your candidate number, mark the questions box and stick a barcode label on each sheet, and fasten them with string **INSIDE** this Question-Answer Book.

(6) No extra time will be given to candidates for sticking on the barcode labels or filling in the question number boxes after the 'Time is up' announcement.

Section B : Answer **ALL** questions. Write your answers in the spaces provided.

1



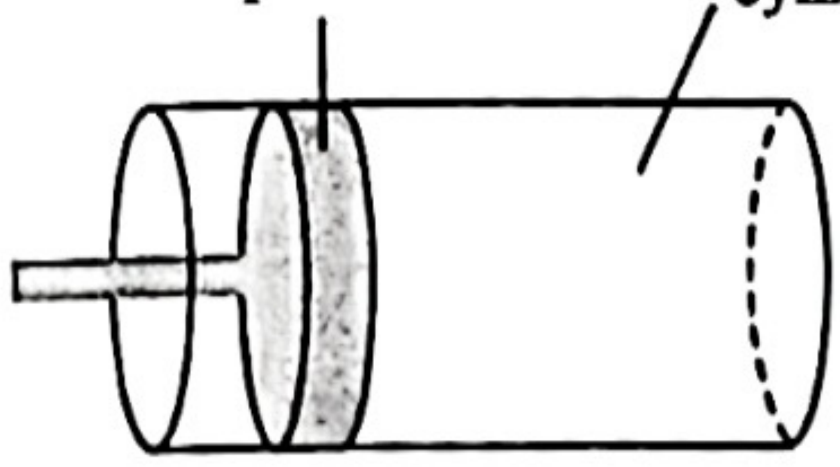
(a) You are given a beaker of hot water at 60 °C with known mass of 200 g. An electronic balance, a thermometer, a stirrer, a polystyrene cup and some crushed ice are also given. Using the apparatus provided, describe an experiment to measure the specific latent heat of fusion of ice l_f. Your description should include the physical quantities to be measured and the equation involved.

The specific heat capacity of water is known as 4200 J kg^{-1} $°C^{-1}$. (4 marks)

(b) State two sources of errors in the above experiment. (2 marks)

Answers written in the margins will not be marked.

2.



A cylinder containing an ideal gas is fitted with a piston which can move smoothly. The volume inside the cylinder is 450 cm^3. The mass of the gas inside the cylinder is 0.76 g and the temperature of the gas is 25 °C.

Given : molar mass of the ideal gas = 29 g mol^{-1}

(a) Calculate the pressure of the ideal gas inside the cylinder. (2 marks)

(b) If the atmospheric pressure outside the cylinder is 102 kPa, calculate the force that should be applied to the piston to hold it in equilibrium. Given that the cross-sectional area of the piston is 16 cm^2. (2 marks)

(c) If the applied force to the piston is removed, the piston would move until it finally stays at a new equilibrium position. Calculate the new volume of the ideal gas inside the cylinder. Assume the temperature of the ideal gas remains unchanged during the process. (2 marks)

Answers written in the margins will not be marked.

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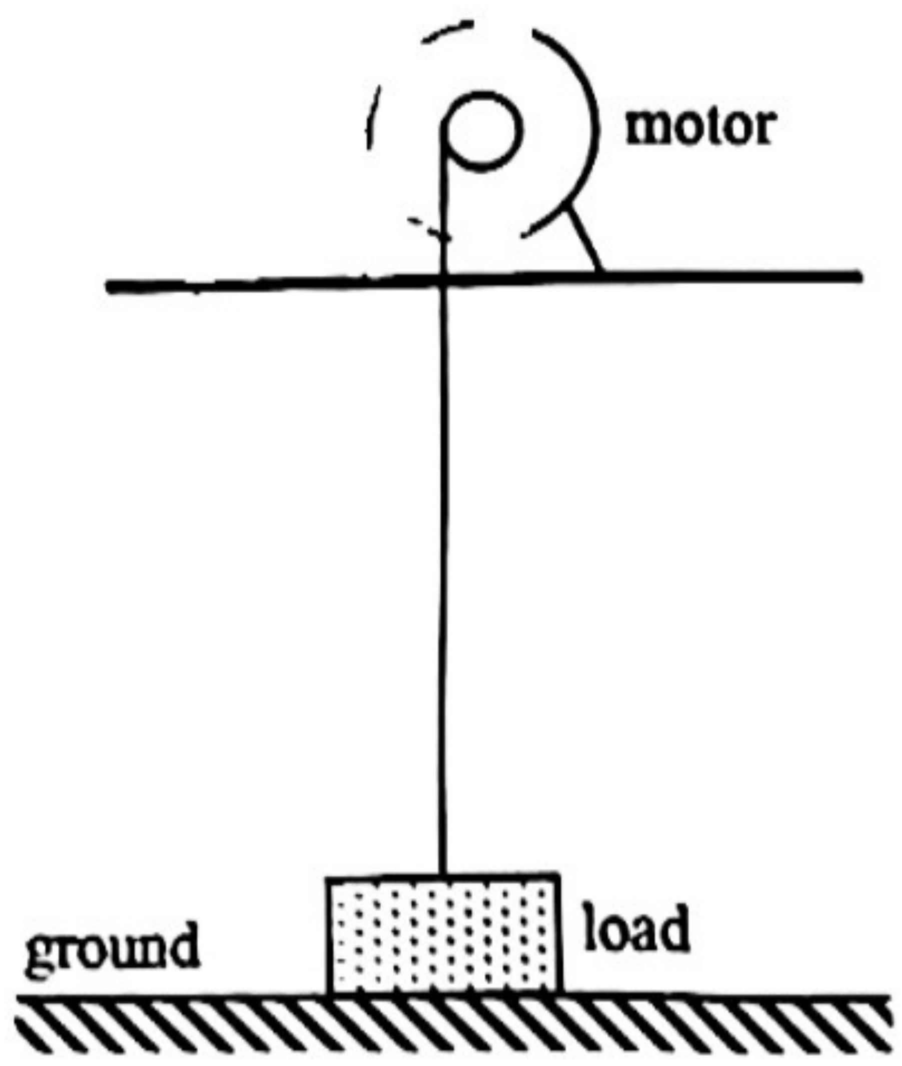

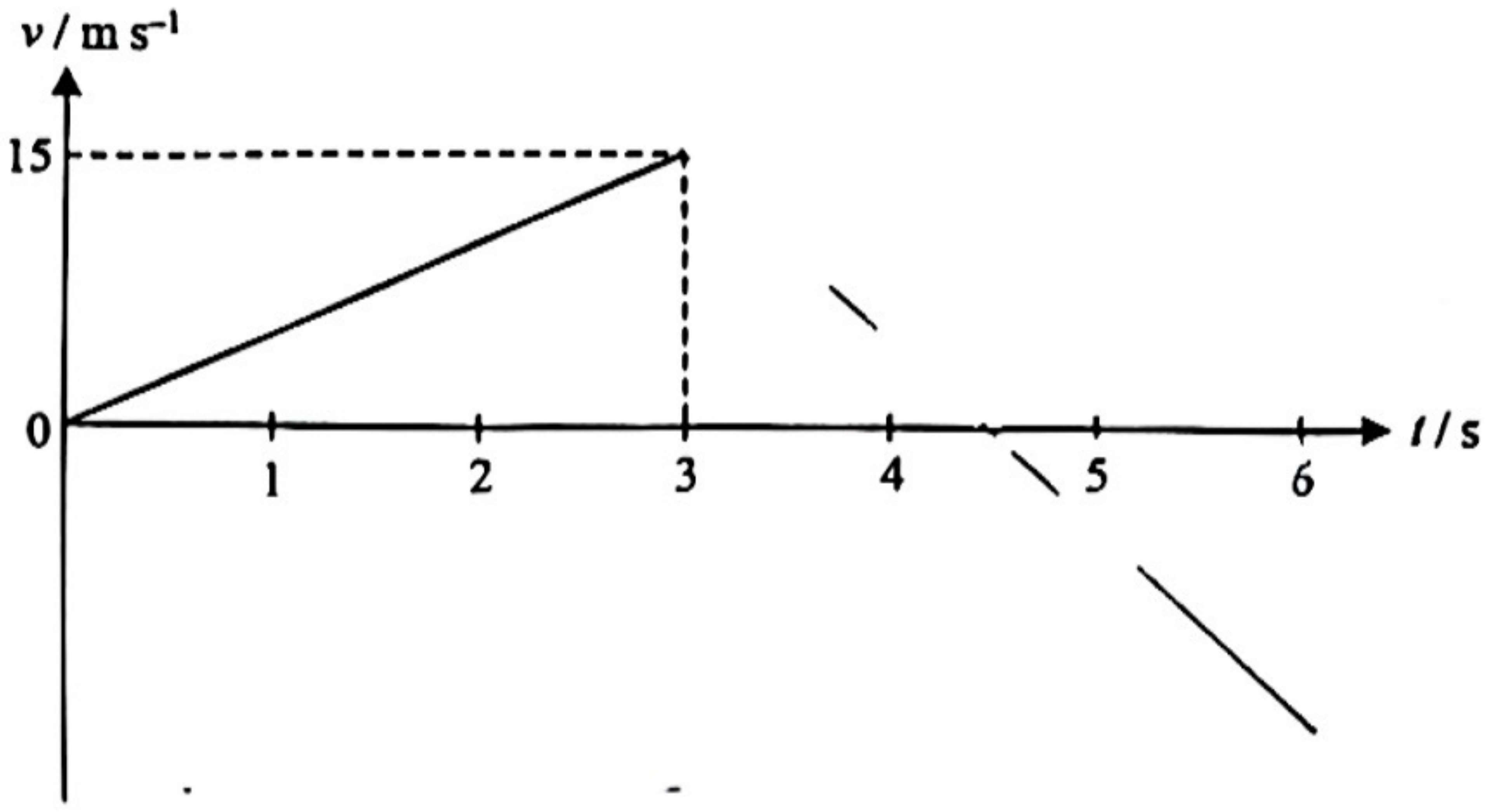

A load of mass 1.6 kg is raised from the ground by an inextensible string connected to a motor at the top of a building as shown in the figure. The velocity-time graph of the load for the first 3 s is shown. Upward direction is taken as positive. Air resistance is neglected. The acceleration due to gravity is taken as 10 m s^{-2}.

(a) Find the tension of the string during the first 3 s. (3 marks)

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(b) Calculate the average power output by the motor during the first 3 s. (3 marks)

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(c) At t = 3 s, the string suddenly breaks.

(i) Sketch the subsequent motion of the load in the above velocity-time graph until the time is 6 s. (1 mark)

(ii) Determine the maximum height above the ground that the load can reach. (1 mark)

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(iii) Comment on the following **TWO** statements . (2 marks)

1. The acceleration of the load is zero when it is at the maximum height.
2. The momentum of the load is conserved after the string breaks.

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Answers written in the margins will not be marked.

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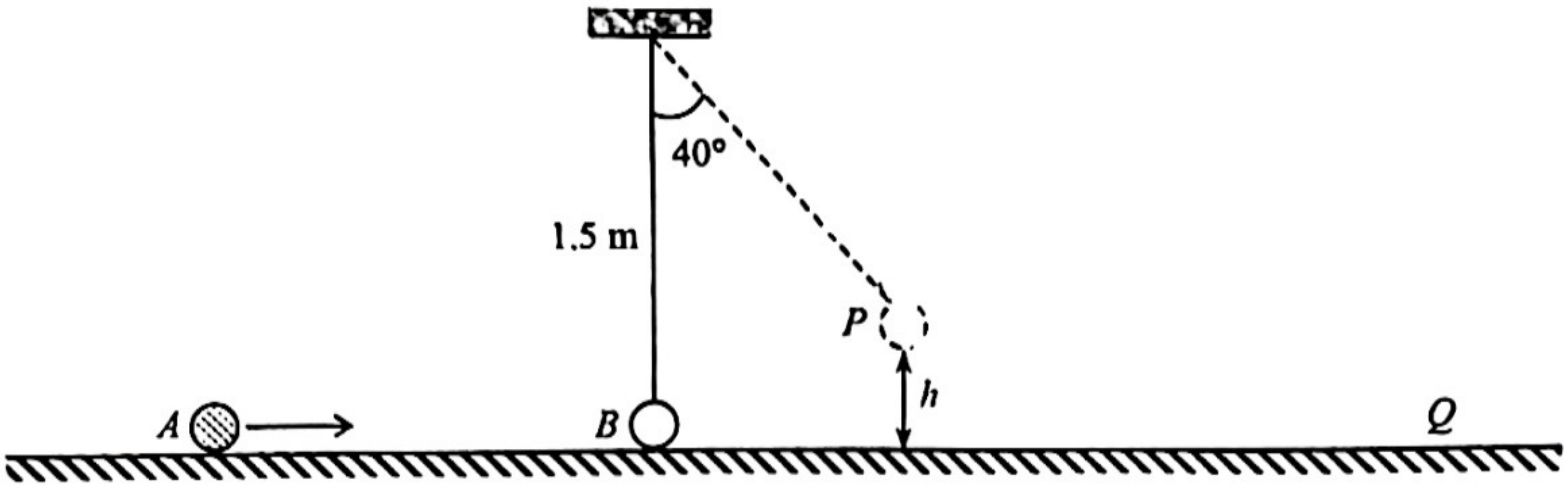

A small ball B of mass 0.8 kg is suspended by an inextensible string of length 1.5 m and is just touching the ground. Another small ball A of mass 1.2 kg is moving at a horizontal speed of 7.2 m s^{-1} towards B along the smooth ground. After collision, ball B moves off with a speed of 5.4 m s^{-1} towards the right.

(a) Calculate the speed of A immediately after the collision. (2 marks)

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(b) After collision, ball B swings up and reaches the position P at which the string makes an angle of 40° with the vertical as shown in the figure. Calculate the speed v of the ball B at this position. (2 marks)

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(c) When ball B is at the position P, the string suddenly breaks. Ball B then follows a projectile path with the initial speed v.

(i) In the above figure, draw an arrow to represent the velocity v of ball B at the position P, and mark the angle of this velocity made with the horizontal. (1 mark)

(ii) Calculate the maximum height above the ground reached by ball B. (2 marks)

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(iii) Ball B finally lands on the ground at point Q. Find the horizontal distance between P and Q. (2 marks)

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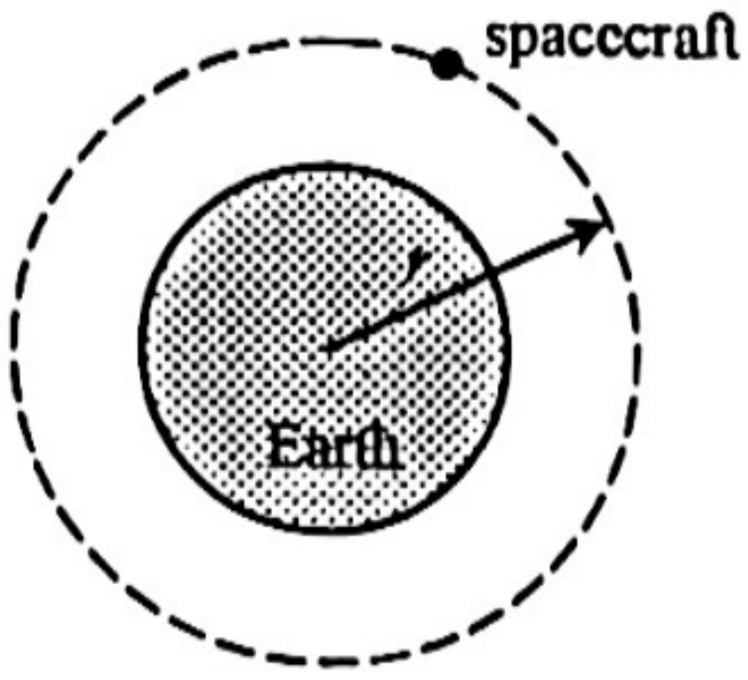
Answers written in the margins will not be marked

5.



A spacecraft of mass 5000 kg is sent to a circular orbit of radius 9600 km around the Earth. Given that radius of the Earth is 6400 km.

(a) Calculate the acceleration of the spacecraft at the circular orbit. (2 marks)

(b) Calculate the speed of the satellite in the circular orbit. (2 marks)

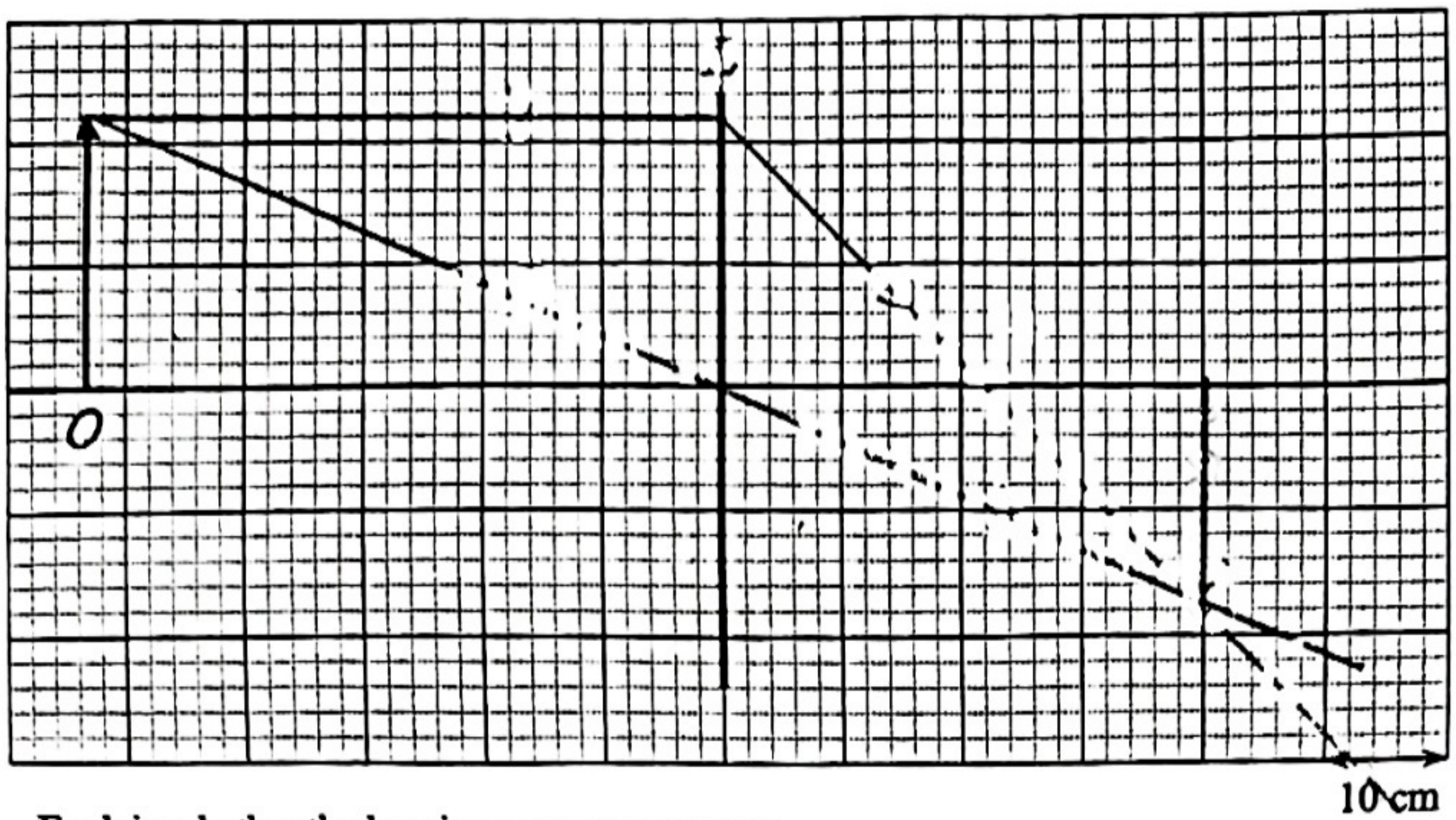
(c) Find the time taken by the satellite to perform 50 cycles of revolution around the Earth. (2 marks)

(d) Explain why the astronaut experiences weightless even though his weight is not zero. (1 mark)

Answers written in the margins will not be marked.

Answers written in the margins will not be marked.

6. (a) In the following figure, an object O is placed at a certain distance from a lens L. A screen placed at 40 cm from the lens can capture the sharp image of the object.



(i) Explain whether the lens is convex or concave. (1 mark)

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(ii) Draw the image in the above figure. (1 mark)

(iii) By drawing a suitable light ray, indicate the position of the principal focus F in the above figure. (1 mark)

(iv) If the object O is moved slightly towards the lens, how should the screen be moved in order to capture the sharp image again ? What is the change of the size of the image on the screen ? (2 marks)

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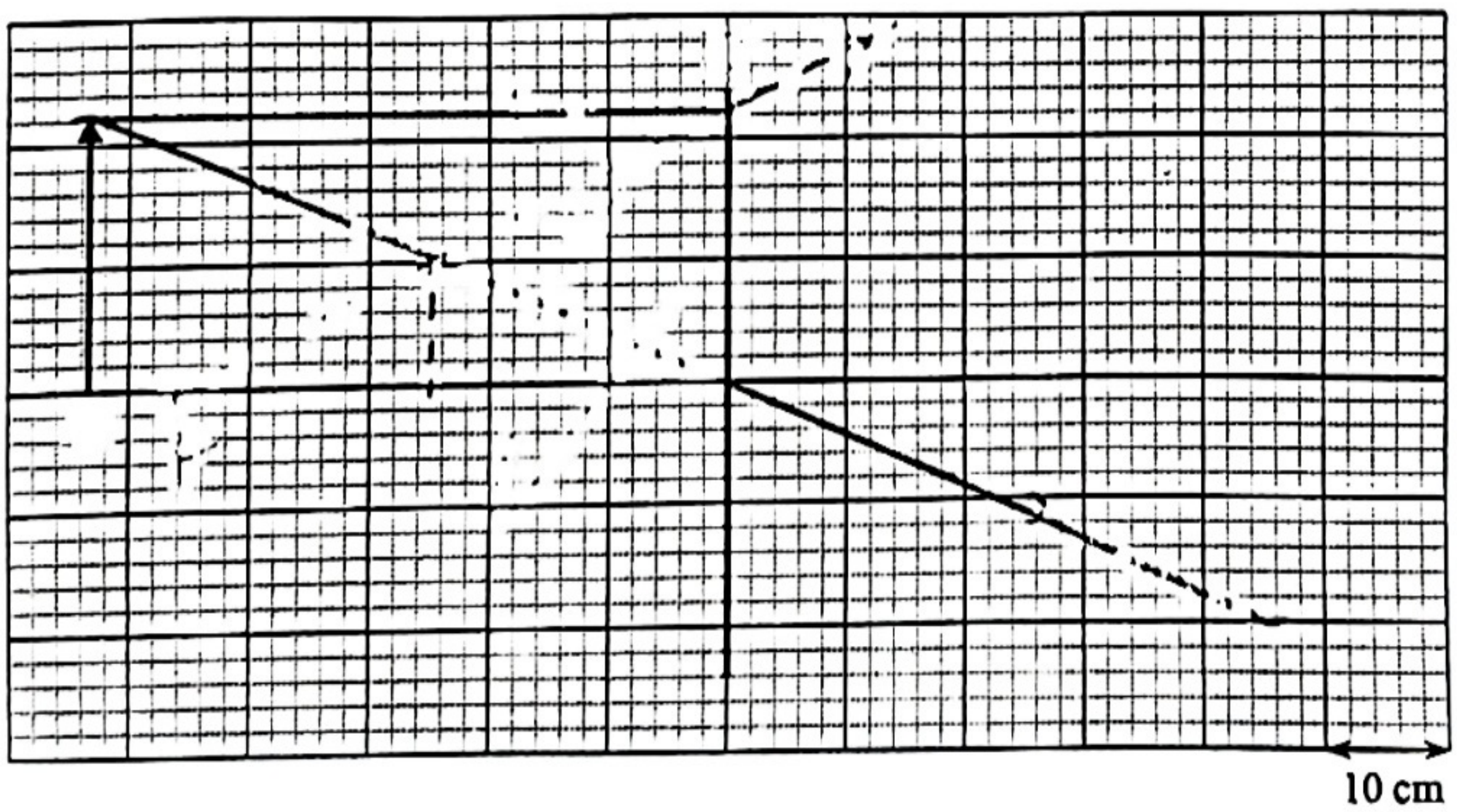
(b) If now the lens L is replaced by another lens L' and the same object O is placed in front, an erect image is formed at 25 cm from the lens.



(i) By drawing suitable light rays, indicate the principal focus F of the lens L' in the figure. (2 marks)

(ii) The lens L' is used as a peep-hole lens. State the reason of using it in this application. (1 mark)

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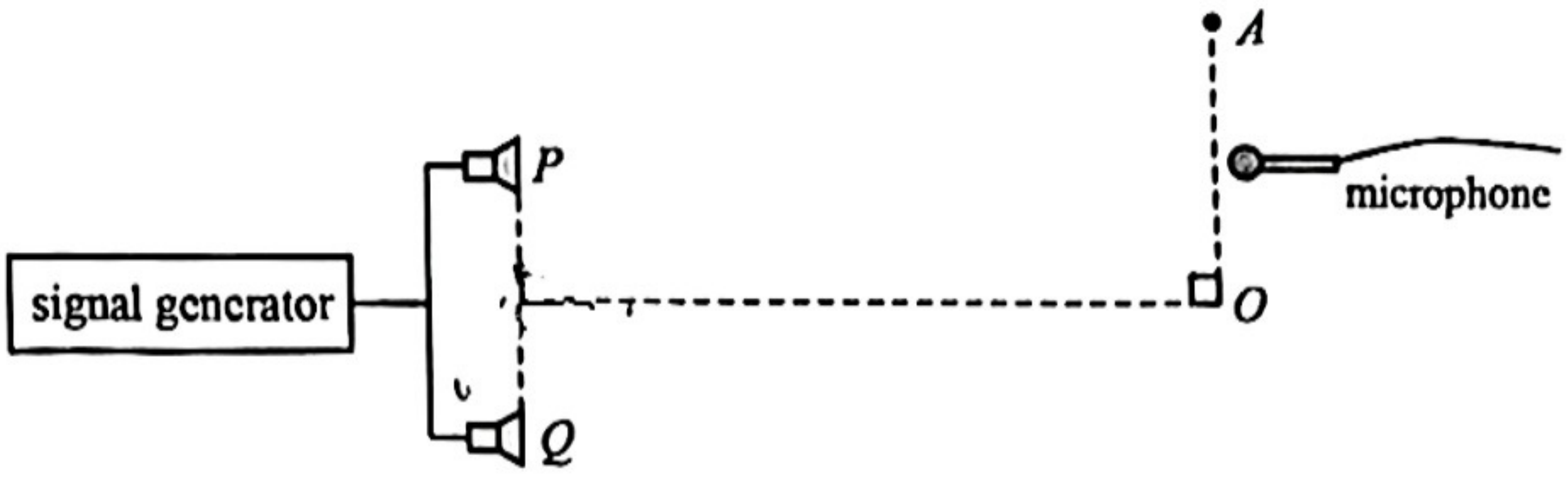
Answers written in the margins will not be marked.

7.



Two loudspeakers P and Q are connected to a signal generator as shown in the above figure. They emit sound waves of frequency 800 Hz and the sound waves produced by them are in phase. The separation between P and Q is 0.8 m. Point A is 2.23 m and 2.86 m away from P and Q respectively. Given that speed of sound in air is 336 m s^{-1}.

(a) Calculate the wavelength of the sound produced. (1 mark)

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(b) Determine the path difference at A. Hence explain the type of interference occurs at A. (2 marks)

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(c) A microphone is used to detect the loudness of the sound wave from O to A. In the figure below, sketch the variation of the loudness of the sound between O and A. (1 mark)

(d) Suppose the microphone is placed at point A to detect the sound. If now one loudspeaker is shut down, state the change of the pitch and loudness of the sound detected by the microphone. (1 mark)

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(e) If the microphone is now moved along the line OA upwards away from A, explain whether the microphone can detect a position of maximum loudness. (2 marks)

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Answers written in the margins will not be marked.

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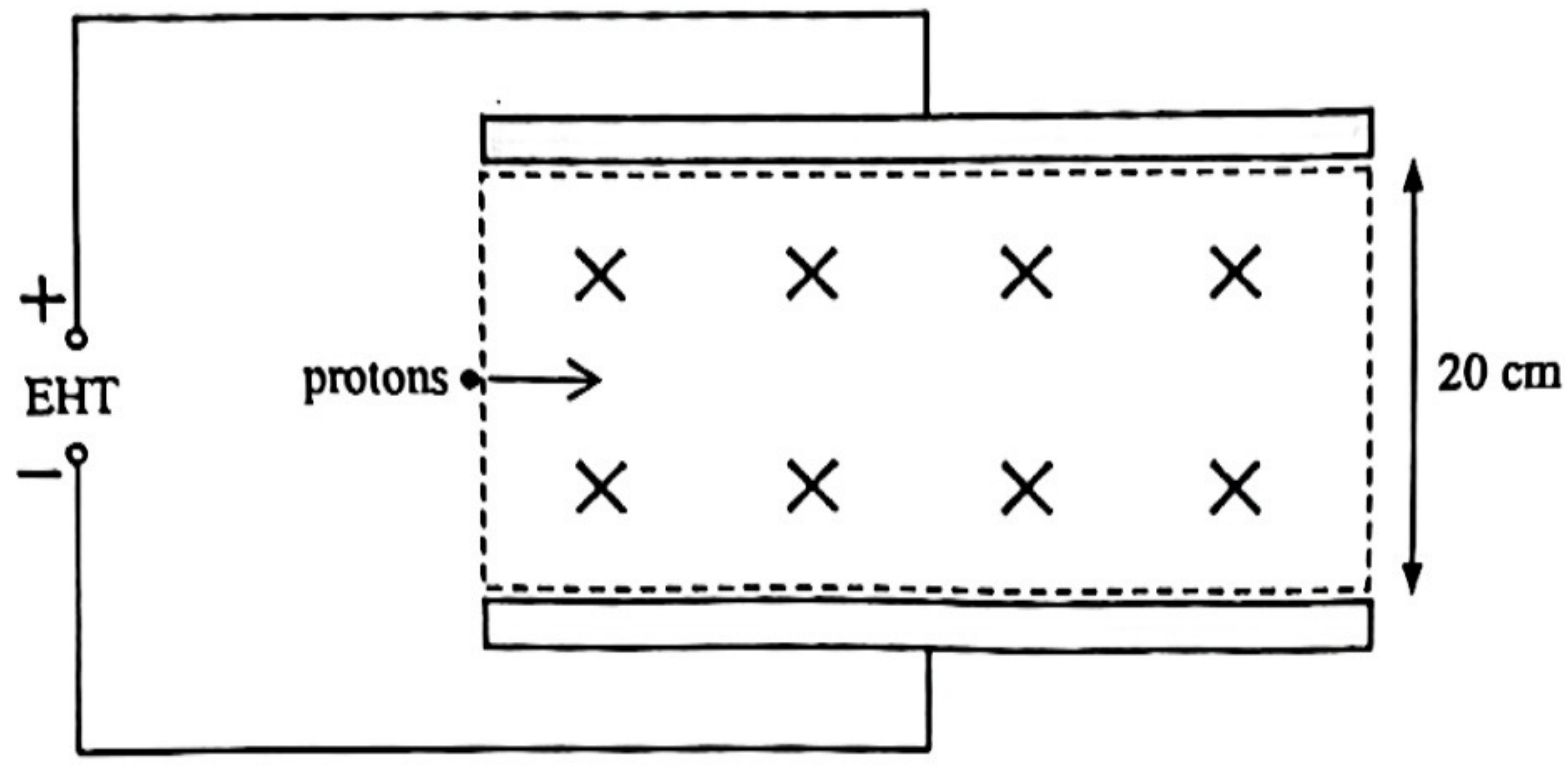
8.



In an evacuated chamber, a beam of protons with a horizontal velocity of 2.5×10^5 m s^{-1} enters midway into a region of cross electric and magnetic fields. The electric field is provided by an EHT supply of 1500 V applied across two parallel plates as shown. The separation between the two plates is 20 cm. The magnetic field is directed into paper as shown in the above figure. Effect of gravity is neglected.

(a) Find the electric field between the two plates. (2 marks)

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(b) The beam of protons moves across the parallel plates without deflection. Calculate the flux density of the magnetic field. (2 marks)

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(c) Suppose now the EHT supply in the above set-up is removed.

(i) Determine the radius of curvature of the path of the beam of proton. (2 marks)

Given : mass of a proton = 1.67×10^{-27} kg

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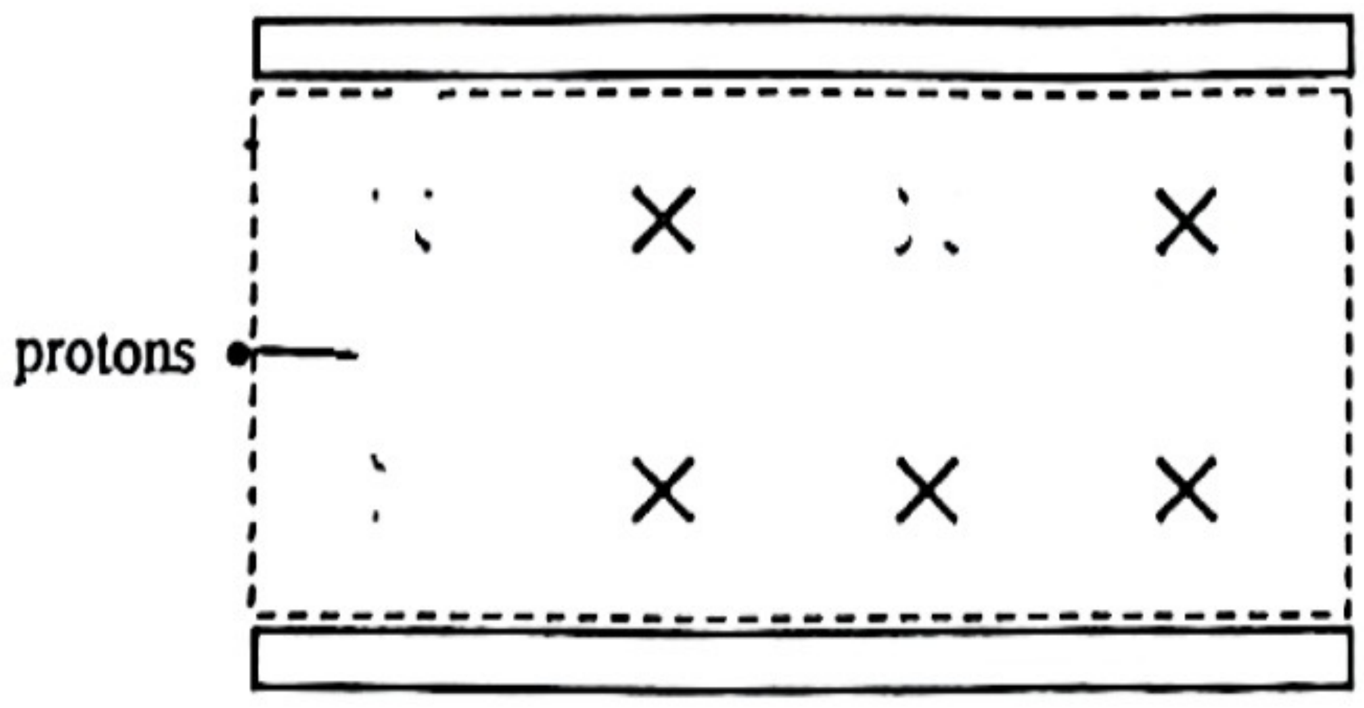
(ii) Sketch the possible path of the beam of protons in the below figure. (1 mark)



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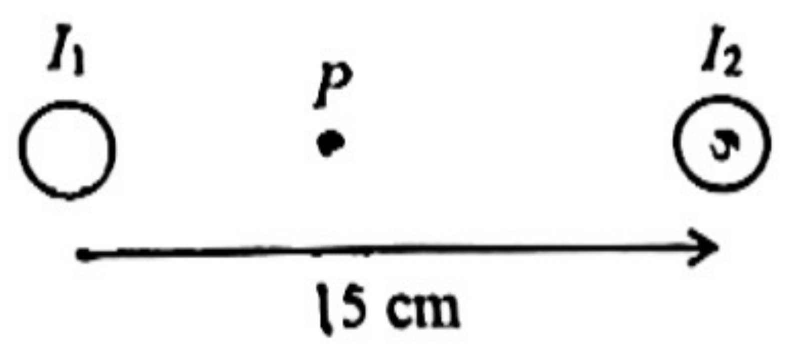

The above figure shows two parallel wires, each of length 2.5 m, carrying currents I_1 and I_2 in opposite directions. The current I_1 is perpendicularly into paper while the current I_2 is perpendicularly out of paper. The separation between the two parallel wires is 15 cm. Steady d.c. current flows in the two wires where I_1 is 0.6 A and I_2 is 0.4 A. P is a point between the two wires and is at 6 cm from I_1.

(a) Calculate the resultant magnetic field, magnitude and direction, at P due to the two currents. (3 marks)

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(b) Calculate the magnetic force acting on I_1, state the direction as well. (3 marks)

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(c) A third wire carries a current I_3 perpendicularly into paper. Find the position that it should be placed so that the resultant force acting on it is zero. (2 marks)

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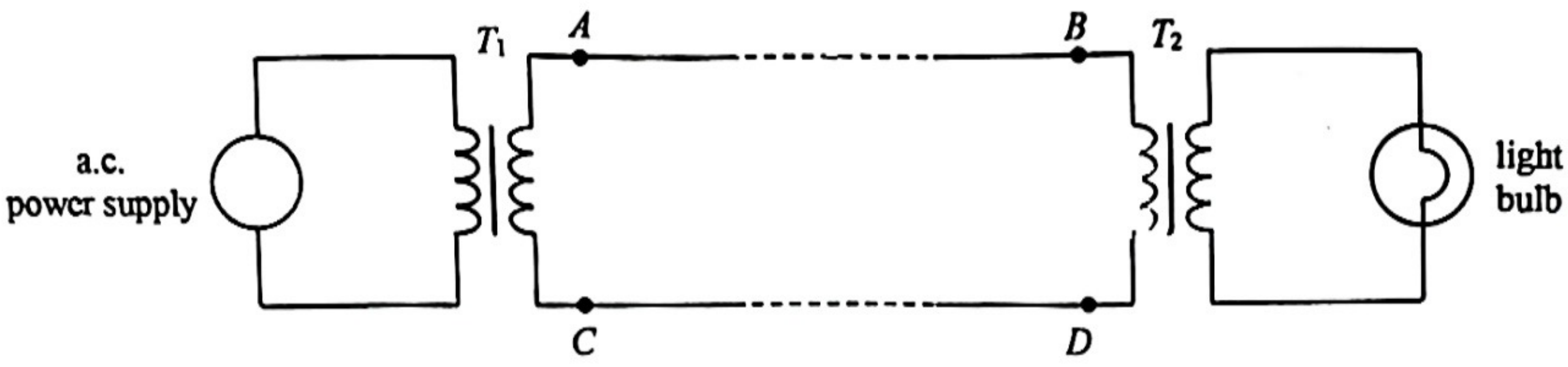
Answers written in the margins will not be marked.

10.



The figure above shows the power transmission through long cables to a light bulb. AB and CD are transmission cables, each of resistance 20 Ω. T_1 is an ideal step-up transformer with turns ratio of 100 : 400 and T_2 is an ideal step-down transformer with turns ratio of 400 : 100. The r.m.s. voltage of the a.c. power supply is 36 V. During the transmission of power, the r.m.s. current along the transmission cables is 0.6 A.

(a) Find the r.m.s. voltage across AC. (1 mark)

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(b) Find the r.m.s. voltage across BD. (1 mark)

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(c) Calculate the peak voltage across the light bulb. (2 marks)

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(d) Calculate the average power given to the light bulb. (1 mark)

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(e) Calculate the efficiency of the power transmission in the above system. (2 marks)

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(f) Suggest **TWO** methods to increase the efficiency of power transmission in the above system. (2 marks)

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Answers written in the margins will not be marked.

11. Radium-226 undergoes alpha decay into radon-222 as shown in the below nuclear equation :

$$^{226}_{88}\text{Ra} \longrightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{He}$$

Given : mass of a radium nucleus = 226.0254 u

mass of a radon nucleus = 222.0176 u

mass of an alpha particle = 4.0026 u

1 year = 3.15×10^7 s

(a) Calculate the energy released in the decay, express the answer in MeV. (2 marks)

(b) The half-life of radium-226 is 1600 years. Calculate the decay constant of radium-226 in s^{-1}. (1 mark)

(c) A sample contains a certain amount of radium-226 gives out nuclear power of 2.5 kW. Determine the activity of the radium-226 in the sample (2 marks)

(d) Calculate the mass of radium-226 in the sample. Given that mass of 1 mole of radium-226 is 226 g. (2 marks)

End of Paper I

Answers written in the margins will not be marked.

Answers written in the margins will not be marked.

Hong Kong Diploma of Secondary Education Examination

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2023

Candidate Number | | | | | | | | |

Mock Examination

PHYSICS PAPER 2

Question-Answer Book

(1 hour)

This paper must be answered in English

INSTRUCTIONS

(1) After the announcement of the start of the examination, you should first write you Candidate Number in the space provided on Page 1 and stick barcode labels in the spaces provided.

(2) This paper consists of **FOUR** sections, Section A, B, C and D. Each section contains eight multiple-choice questions and one structured question which carries 10 marks. Attempt **ALL** question in any **TWO** sections

(3) Write your answers to the structured questions in the **ANSWER Book** provided. For multiple-choice questions, blacken the appropriate circle with an HB pencil. You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARKS** for that question.

(4) Graph paper and supplementary answer sheets will be provided on request. Write your candidate number, mark the questions box and stick a barcode label on each sheet, and fasten them with string **INSIDE** this Question-Answer Book.

(5) The Question-Answer Book and Answer Book will be collected **SEPARATELY** at the end of the examination.

(6) The diagrams in this paper are **NOT** necessarily drawn to scale.

(7) The last two pages of this Question-Answer Book contain a list of data, formulae and relationship which you may find useful.

(8) No extra time will be given to candidates for sticking on the barcode labels or filling in the question number boxes after the 'Time is up' announcement.

Section A : Astronomy and Space Science

Q.1 : Multiple-choice questions

1.1 Which of the following statements concerning the orbital motion of planets around the Sun can be explained by Kepler's Laws ?

(1) The Sun is not at the centre of the orbit of each planet.
(2) The speed of a planet revolving around the Sun is not constant.
(3) The period of Mars is greater than that of Venus.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A B C D
○ ○ ○ ○

1.2 Which of the following statements concerning Ptolemy's geocentric model of the universe are correct ?

(1) It can explain why Mercury only appears in the morning or evening, but not in mid-night.
(2) It can explain the complete cycle of phases of Venus.
(3) It can explain the prograde and retrograde motion of Mars.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A B C D
○ ○ ○ ○

1.3 There are many satellites revolving around the planet Jupiter in elliptical orbits. One of the satellites orbits around the Jupiter with an orbital period of 8.5 days and major axis of 2.4×10^9 m. Another satellite orbiting around Uranus with semi-major axis of 850 000 km. Estimate the orbital period of this satellite.

A. 1.8 days
B. 3.6 days
C. 5.1 days
D. 7.2 days

A B C D
○ ○ ○ ○

1.4 A space capsule launching with an initial speed u from the surface of the Earth can just reach the maximum height above the ground equal to the radius of the Earth. For the same space capsule to just escape from the surface of the Earth, the required launching speed is v. Determine the ratio of the speed u to v.

A. $1 : \sqrt{2}$
B. $1 : 2$
C. $\sqrt{2} : 1$
D. $2 : 1$

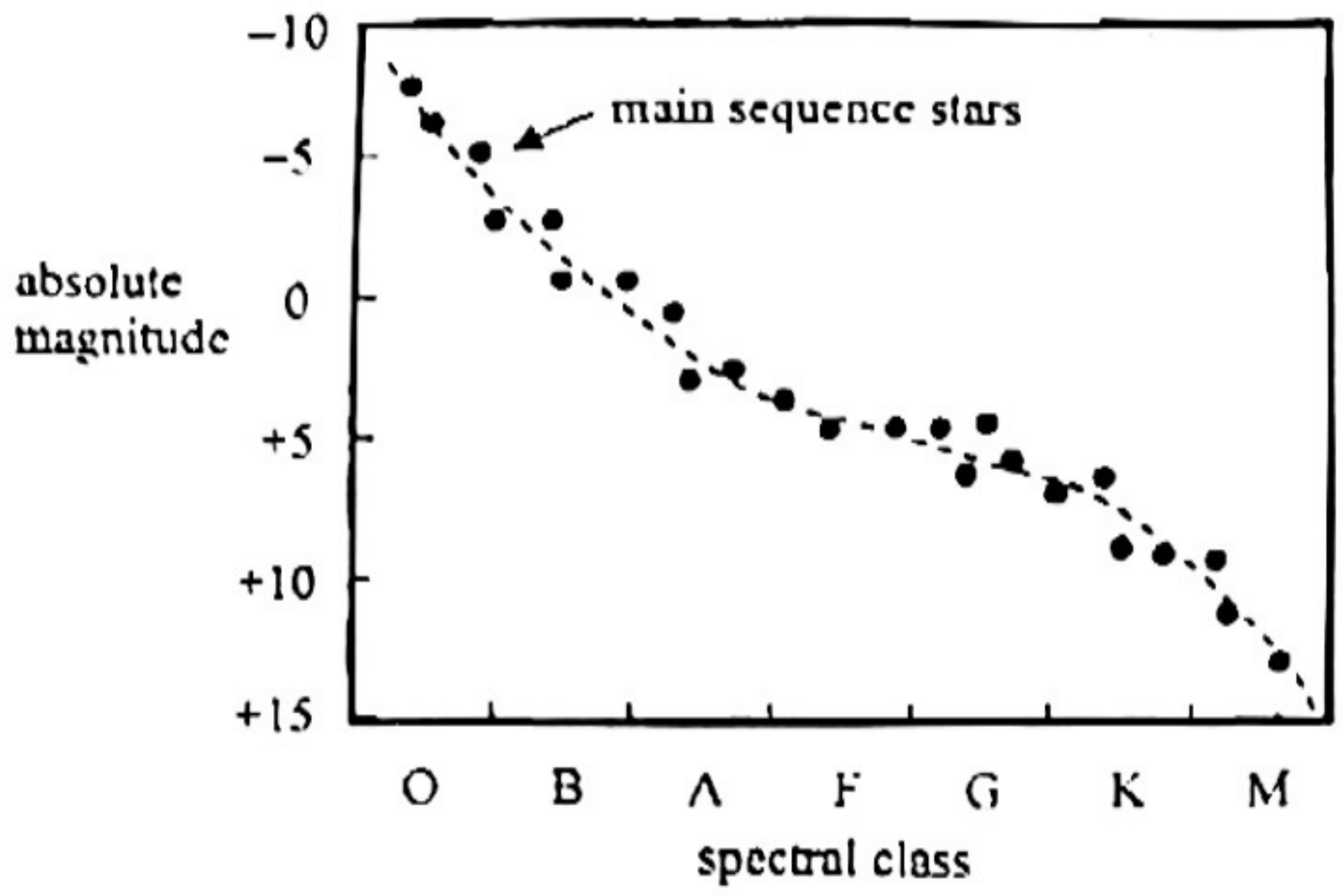
A B C D
○ ○ ○ ○

1.5 The apparent brightness of a star observed from the Earth is 3.6×10^{-15} W m^{-2}. If the stellar parallax of this star is measured as 0.025 arcsecond, what is the luminosity this star ?

A. 6.9×10^{22} W
B. 8.2×10^{22} W
C. 6.9×10^{24} W
D. 8.2×10^{24} W

A B C D
○ ○ ○ ○

1.6 The Hertzsprung-Russell (H-R) diagram below shows a series of main sequence stars.



The properties of three main sequence stars X, Y and Z are tabulated below.

star	apparent magnitude	spectral class
X	4	G
Y	3	O
Z	6	M

Arrange the distance of these 3 stars from the Earth in ascending order.

A. X, Y, Z
B. X, Z, Y
C. Z, X, Y
D. Z, Y, X

A B C D
O O O O

1.7 In the same star cluster, the ratio of the apparent brightness of star A to star B is 1 : 4. If the ratio of the surface temperatur of star A to star B is 1 : 2, what is the ratio of the radius of star A to that of star B ?

A. 1 : 2
B. 1 : 4
C. 2 : 1
D. 4 : 1

A B C D
O O O O

1.8 In a binary system, a star shows a periodic variation of wavelength of a certain spectral line, which is equal to 495.6 nı obtained in a laboratory. The maximum wavelength of this spectral line is observed to be 495.9 nm at a certain instan After a time interval of 75 hours, the same spectral line is observed to have the minimum wavelength of 495.3 nm. Estimat the radius of the orbit of this star around the central core.

A. 1.56×10^{10} m
B. 3.76×10^{10} m
C. 5.24×10^{10} m
D. 7.48×10^{10} m

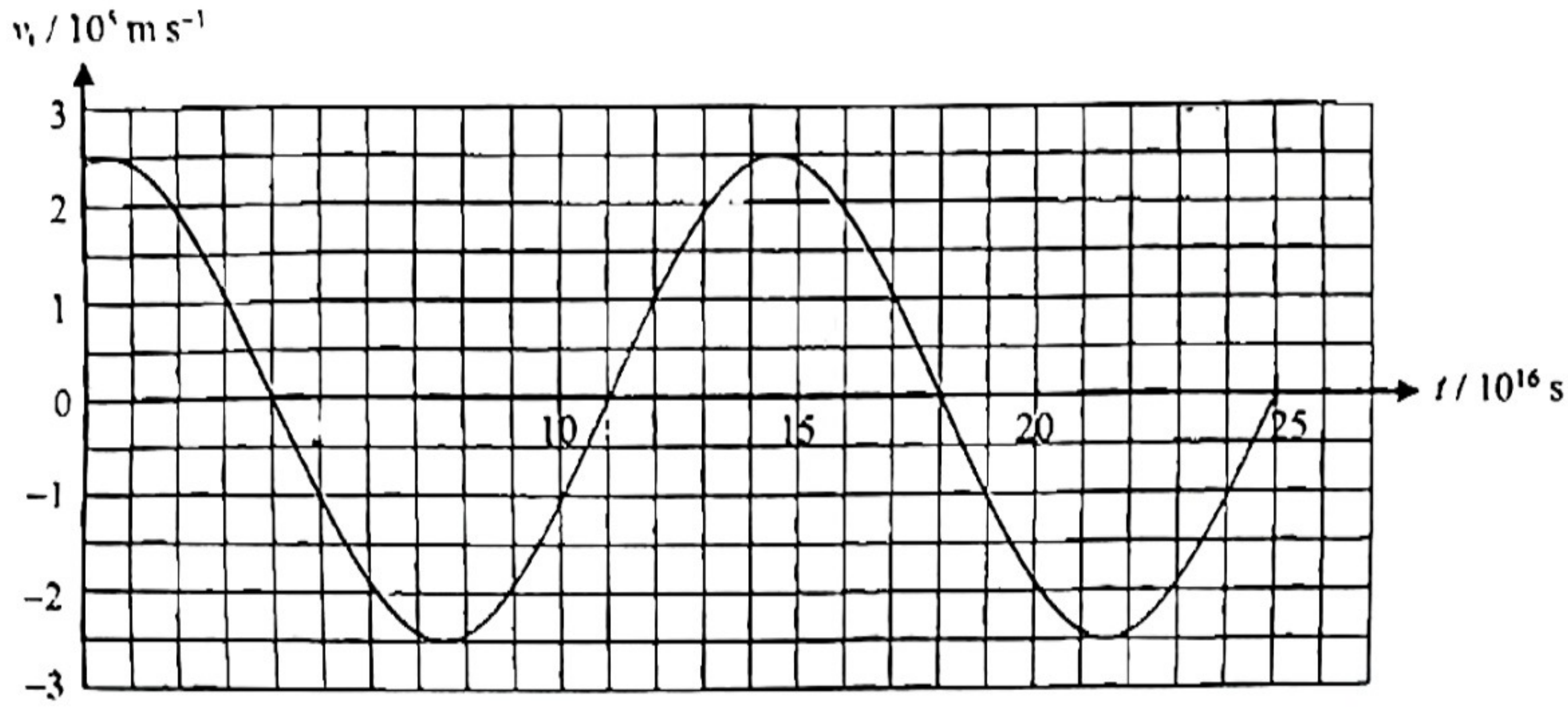
A B C D
O O O O

Q.1 : Structured question

The figure below shows the edge-on view of a spiral galaxy X. A is a star at the extreme end of the spiral arm of the galaxy. The velocity of the galaxy relative to the Earth is assumed negligible.

edge-on view of galaxy X

The radial velocity curve of the star A around the centre of the galaxy is shown in the figure below.



(a) Star A emits a set of hydrogen spectral lines. The wavelength of the H-α line measured in the laboratory is 656.28 nm. If star A is now moving directly along the line of sight of an observer away from the Earth, calculate the apparent wavelength of the H-α line observed on the Earth. Give your answer to 2 decimal places in nm. (2 marks)

(b) From the radial velocity curve, determine :

(i) the radius r of the star A from the centre of the galaxy (express the answer in pc) (2 marks)

(ii) the mass of the galaxy X, assume that the mass of X is concentrated at its centre (2 marks)

(c) The angular separation of the two extreme ends of the galaxy is 0.245°. Estimate the distance of the galaxy X from the Earth, express the answer in pc. (2 marks)

(d) Star B is closer to the centre of the galaxy X than the star A as shown.

(i) If the mass of the galaxy X is assumed to be concentrated at the centre, explain what would you expect the radial velocity of B compared with A ? (1 mark)

(ii) Actual measurement reveals that both of the two stars A and B have almost the same radial velocity around the centre of the galaxy X. Apart from the conclusion that the mass is not concentrated at the centre, what other conclusion can be made ? (1 mark)

Section B : Atomic World

Q.2 : Multiple-choice questions

2.1 Which of the conclusions could **NOT** be deduced from Rutherford's scattering experiment ?

(1) There are protons and neutrons inside the nucleus of an atom.
(2) Electrons are moving in orbits of certain specific energy.
(3) The nucleus of an atom has extremely high density.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

A B C D

2.2 A beam of monochromatic green light of wavelength 550 nm is incident on the cathode of a photocell. The maximum kinetic energy of the photoelectrons emitted from the cathode is found to be 0.65 eV. If now another beam of blue light of wavelength 450 nm is incident on the same cathode of the photocell, the maximum kinetic energy of the photoelectrons emitted from the cathode is

A. 0.85 eV
B. 1.15 eV
C. 1.30 eV
D. 1.56 eV

A B C D

2.3 In an experiment to investigate the photoelectric effect, a beam of monochromatic light is incident onto the cathode metal plate of the photocell to emit photoelectrons. The maximum speed of the photoelectrons reaching the anode is

A. independent of the intensity of the incident light.
B. independent of the type of metal.
C. independent of the voltage applied to the photocell.
D. directly proportional to the frequency of the incident light.

A B C D

2.4 A beam of monochromatic light is incident onto the cathode surface of a photocell. The light intensity is 0.075 W m^{-2} and each photon of the monochromatic light carries 2.8 eV of energy. If the area of the cathode surface is 4.5 cm^2, what is the saturation current in the photocell ? Assume that each photon can give out one photoelectron.

A. 17 μA
B. 18 μA
C. 24 μA
D. 36 μA

A B C D

2.5 An electron with energy 4.5 eV strikes an atom to make an inelastic collision. The electron then rebounds away with speed v and the atom subsequently emits a photon of frequency 6.5×10^{14} Hz. Determine the speed v of the rebound electron.

A. 5.5×10^5 m s^{-1}
B. 6.0×10^5 m s^{-1}
C. 7.5×10^5 m s^{-1}
D. 8.0×10^5 m s^{-1}

A B C D

2.6 A beam of particles with different mass m and different charge Q are accelerated from rest by voltage V in vacuum. Which of the following statements concerning the de Broglie wavelength of the accelerated particles are correct ?

(1) The de Broglie wavelength decreases with the mass m of the particles.
(2) The de Broglie wavelength decreases with the charge Q of the particles.
(3) The de Broglie wavelength increases with the p.d. V of the electric field.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A	B	C	D
●	○	○	○

2.7 Given that the radius of the orbit for the electron of a hydrogen atom in the ground state is 5.3×10^{-11} m. What is the de Broglie wavelength of the electron in the orbit of the first excited state ?

A. 3.3×10^{-10} m
B. 6.7×10^{-10} m
C. 1.3×10^{-9} m
D. 2.7×10^{-9} m

A	B	C	D
○	●	○	○

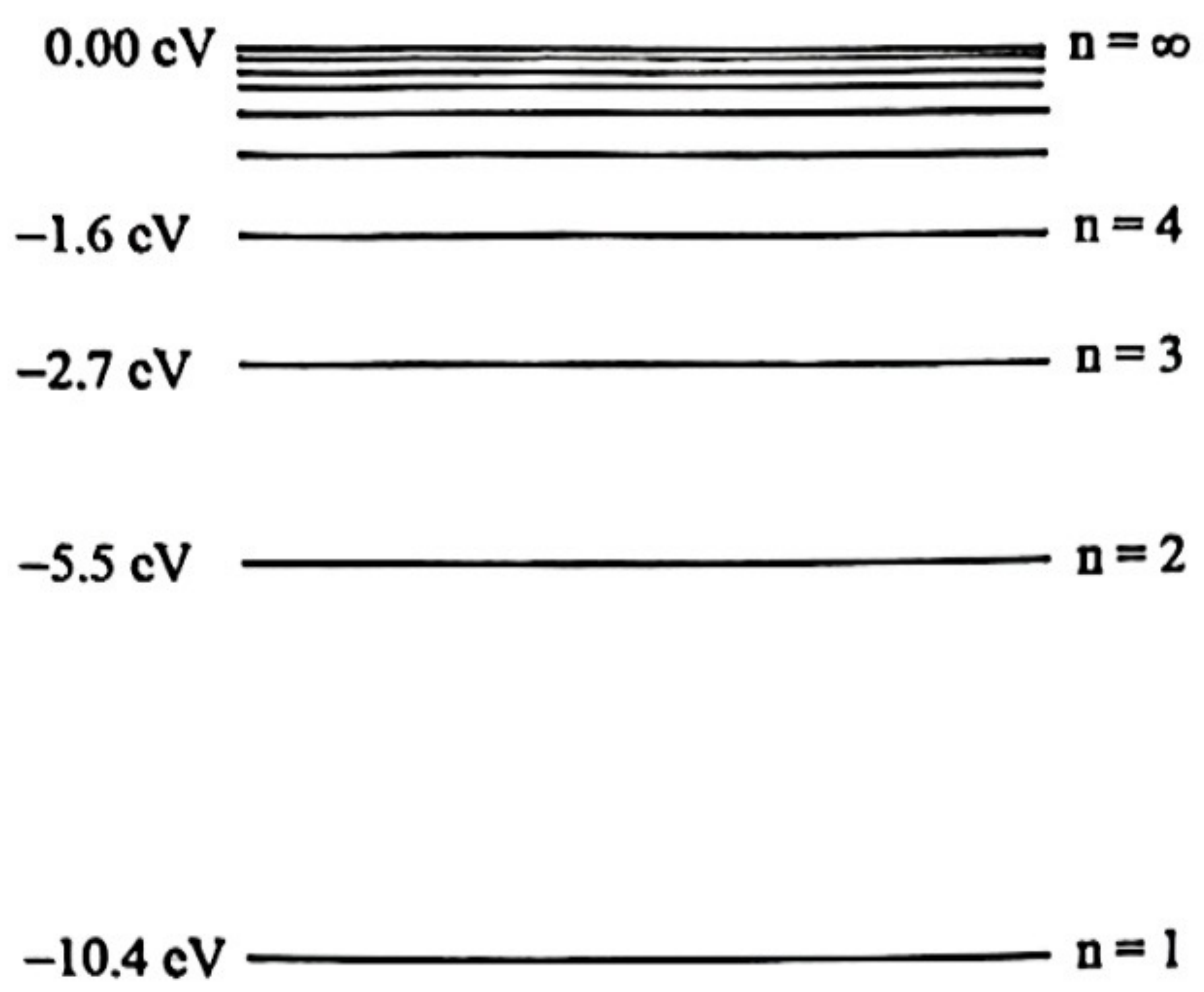
2.8 In a transmission electron microscope (TEM), electrons are accelerated through a voltage of 12 kV. If the diameter of the aperture of the microscope is 2.5 cm, calculate the resolving power of the TEM.

A. 2.2×10^{-10} rad
B. 2.2×10^{-10} rad
C. 3.3×10^{-10} rad
D. 5.5×10^{-10} rad

A	B	C	D
○	○	○	●

Q.2 : Structured question

The Figure below shows some of the energy levels for an atom of a certain element.



(a) Explain what is meant by ionization energy of an atom. State the ionization energy of the above atom. (2 marks)

(b) Suppose an electron with kinetic energy of 6.0 eV makes collision with the atom.

(i) What type of collision would occur ? (1 mark)

(ii) What happens to the atom ? (1 mark)

(iii) After collision, the atom emits a photon. Calculate the wavelength of this photon. State the type of electromagnetic wave it belongs to. (2 marks)

(iv) Calculate the final speed of the electron after collision. (2 marks)

(c) Explain what would happen in the following cases :

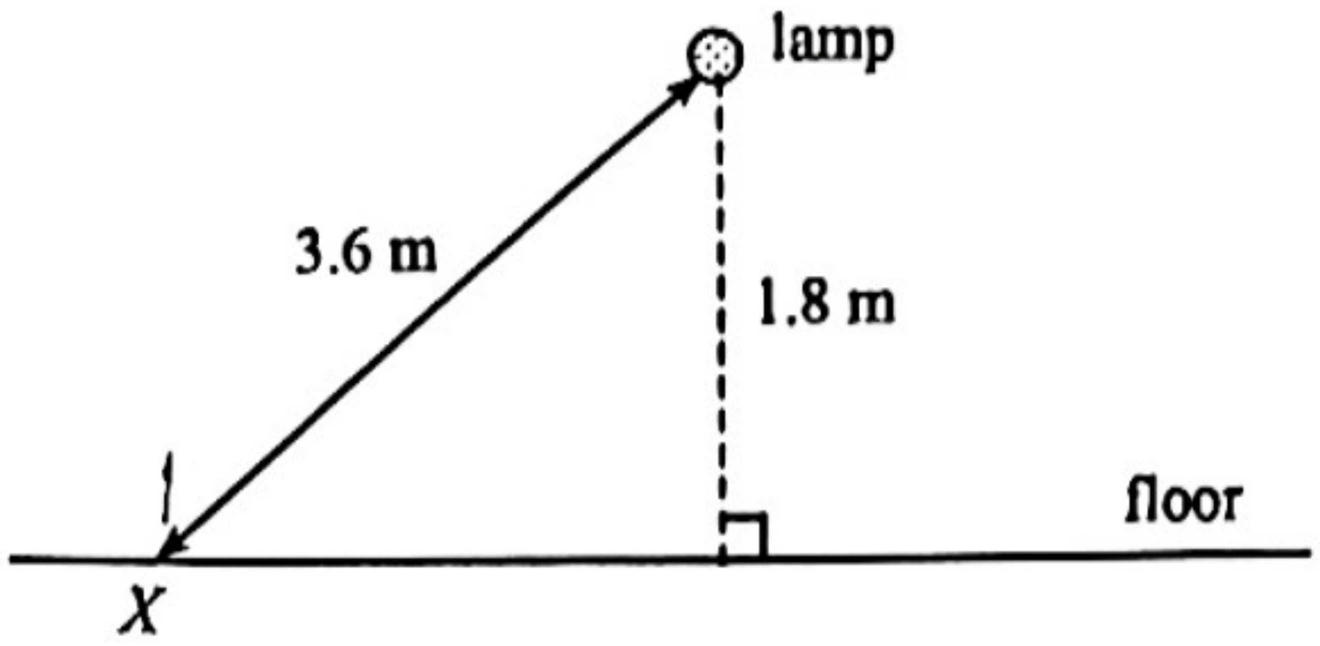
(i) a photon with energy 6 eV makes collision with the atom ; (1 mark)

(ii) a photon with energy 12 eV makes collision with the atom. (1 mark)

Section C : Energy and Use of Energy

Q.3 : Multiple-choice questions

3.1



A small lamp has a power rating of 35 W. It is fixed on the ceiling of a room as the only light source. The illuminance on the floor at a point X as shown in the figure is 10 lux. Neglect any reflections of light from the walls and the ceiling. What is the efficacy of the lamp ?

A. 68 lm W^{-1}
B. 73 lm W^{-1}
C. 85 lm W^{-1}
D. 93 lm W^{-1}

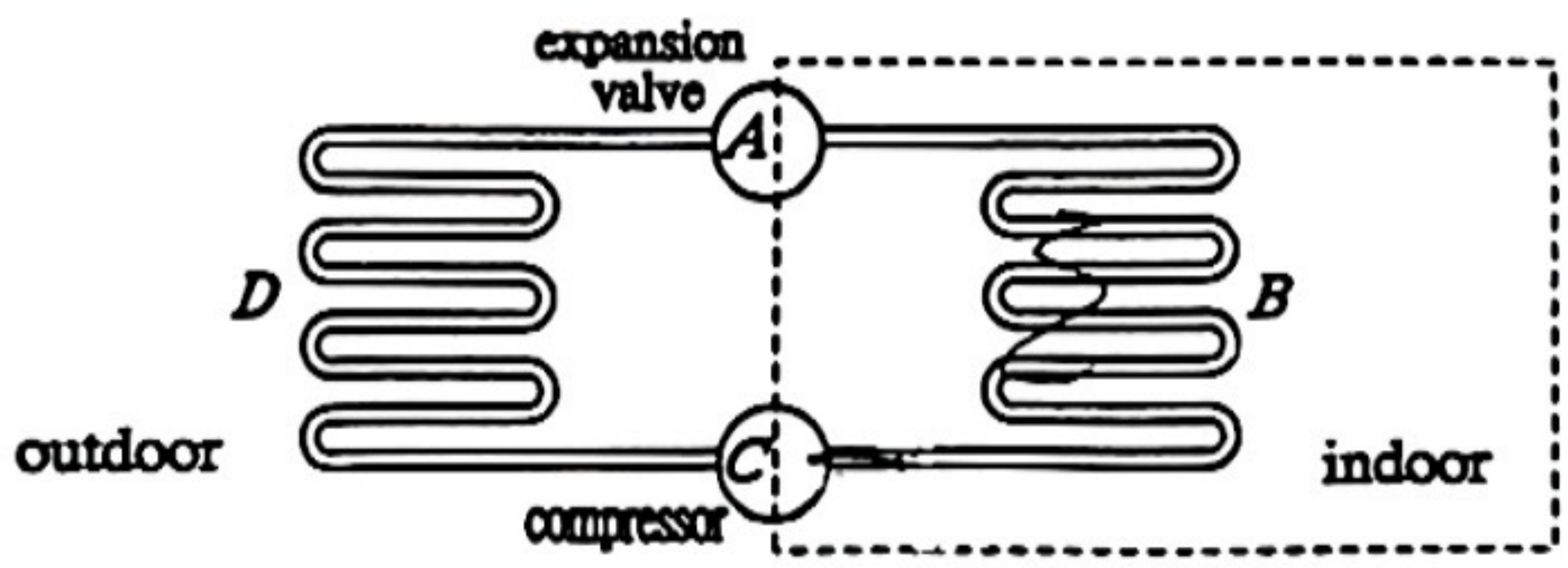
A B C D

3.2 The COP (coefficient of performance) of an air-conditioner is 3.5. If it is replaced by another one with the same COP but double input power, what is the ratio of the thermal energy released to the environment by the first one to that of the second one in a same period of time ?

A. 3 : 7
B. 4 : 9
C. 8 : 15
D. 9 : 16

A B C D

3.3



The above figure shows the simplified schematic diagram of a 'reverse-cycle air conditioners' (RCAC) that can work in either cooling mode or warming mode. If it is working in the mode of giving warm air to indoor, which of the following statements are correct ?

(1) The direction of flow of the refrigerant through the components is *CDAB*.
(2) Component *B* is the condenser.
(3) The refrigerant has the lowest temperature at the component *D*.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A B C D

3.4 A room is kept cool by an air-conditioner of cooling capacity P. The temperatures inside and outside the room are 25 °C and 30 °C respectively. The rate of heat flowing into the room by radiation through windows and that by conduction are in the ratio 1 : 2. If the temperature outside the room changes to 35 °C, what should be the cooling capacity of the air-conditioner so that the temperature inside the room is maintained at 25 °C ? Assume the rate of heat flowing into the room by radiation remains the same.

A. 1.5 P
B. 1.6 P
C. 1.7 P
D. 1.8 P

A B C D

3.5 A racing car of mass 2000 kg has a peak power of 450 kW. When it is operating at its peak power, it takes a time of 3.8 s to accelerate from rest to 100 km h^{-1}. What is the efficiency of the car engine ?

A. 40%
B. 45%
C. 50%
D. 55%

A B C D

3.6 Given : mass of a $^{235}_{92}$U nucleus = 235.0439 u

mass of a $^{144}_{56}$Ba nucleus = 143.9139 u

mass of a $^{90}_{36}$Kr nucleus = 89.8973 u

mass of a neutron = 1.0087 u

A typical fission reaction is as follow : $^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{144}_{56}\text{Ba} + ^{90}_{36}\text{Kr} + 2^{1}_{0}\text{n}$

Calculate the total nuclear energy release by 1 mole of U-235 nuclei.

A. 2.0×10^{13} J
B. 3.2×10^{13} J
C. 5.4×10^{13} J
D. 7.6×10^{13} J

A B C D

3.7 A wind turbine generator consists of 3 blades, each of length 15 m. In a certain day, wind blows towards the turbine normally with variable speed. In the first two hours, wind blows at speed of 20 m s^{-1}. In the next three hours, wind blows at speed of 10 m s^{-1}. What is the total electrical energy output by the generator in these five hours ? The overall efficiency of the generator is 30%, and the average density of air is 1.2 kg m^{-3}.

A. 5.6 GJ
B. 6.4 GJ
C. 7.5 GJ
D. 8 - GJ

A B C D

3.8 The upper and lower reservoirs of a hydroelectric power plant have a height difference of 75 m in water levels. The turbine of the power plant gives an output power of 230 MW when the water flows from high to low reservoir with an average flow rate of 2.5×10^{6} m^{3} in an hour. What is the overall efficiency of the power plant ? Given : density of water is 1000 kg m^{-3}.

A. 35%
B. 40%
C. 45%
D. 50%

A B C D

Q.3 : Structured question

This question concerns with the below nuclear fission reaction :

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3^{1}_{0}n$$

Given : mass of a proton = 1.00728 u

mass of a neutron = 1.00867 u

mass of a uranium $^{235}_{92}U$ nucleus = 235.04396 u

(a) From the above given information, calculate the binding energy per nucleon of the $^{235}_{92}U$ nucleus. Express your answer in MeV per nucleon. (2 marks)

(b) The above nuclear reaction is applied in a fission reactor. For a nuclear fission reactor in normal operation, nuclear fissions must be carefully controlled so that on average only one neutron from each fission produces another fission. Explain the consequence :

(i) if more than one neutron per fission is produced ; (1 mark)

(ii) if less than one neutron per fission is produced. (1 mark)

(c) Moderator and control rod are two key components in a nuclear fission reactor for controlling the number of neutrons producing further fission reaction. Explain the consequence

(i) if all the control rods are inserted into the fission reactor ; (1 mark)

(ii) if the moderator fails to operate. (1 mark)

(d) Given that the average binding energy per nucleon of Ba-142 is 8.35 MeV and that of Kr-91 is 8.57 Mev.

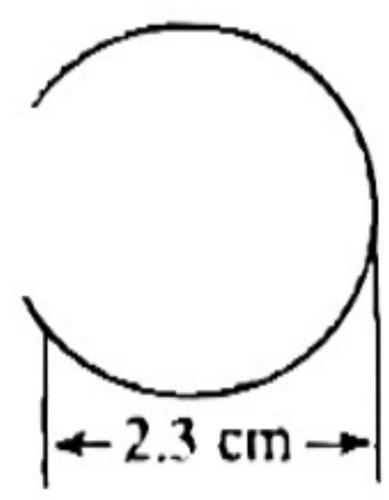
(i) Calculate the energy release in each fission of a U-235 nucleus, give your answer in MeV. Hence, determine the mass defect in the fission reaction of a U-235 nucleus. (2 marks)

(ii) In a nuclear power plant, the mass of U-235 in the fuel rod is decreased at a rate of 45 μg per second. Calculate the electrical power generated by the power plant, given that the overall efficiency of energy conversion is 35%. (Molar mass of U-235 is 235 g.) (2 marks)

Section D : Medical Physics

Q.4 : Multiple-choice questions

4.1



The diagram shows an eyeball of a person suffering from an eye defect. The distance between the retina and optical centre of the refracting parts is 2.3 cm while the maximum power of the refracting parts is + 45 D. What is the power of the spectacles required to correct the defect ? (Given that the range of normal eye is from 25 cm to infinity.)

A. − 2.5 D
B. − 5.5 D
C. + 2.5 D
D. + 5.5 D

A B C D
○ ○ ○ ○

4.2 Two small objects are separated at 4 mm emitting blue light of wavelength 450 nm. Paul finds that he can just resolve the two objects when he is at a distance of 25 m from them. Determine the diameter of the pupils of his eyes.

A. 3.0 mm
B. 3.2 mm
C. 3.4 mm
D. 3.8 mm

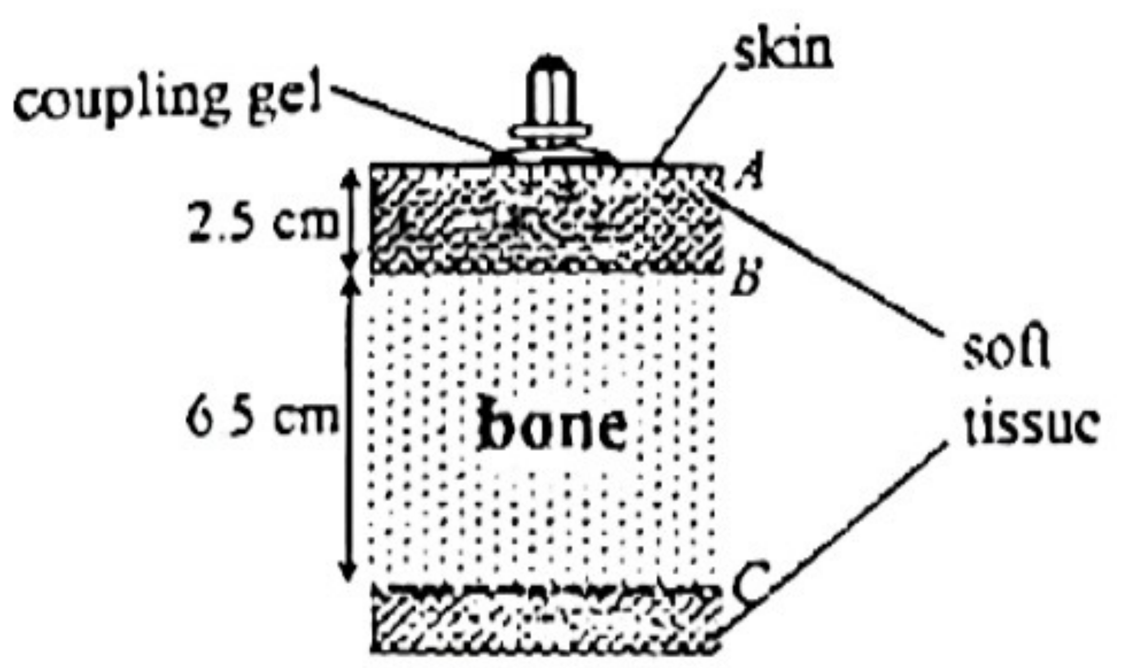
A B C D
○ ○ ○ ○

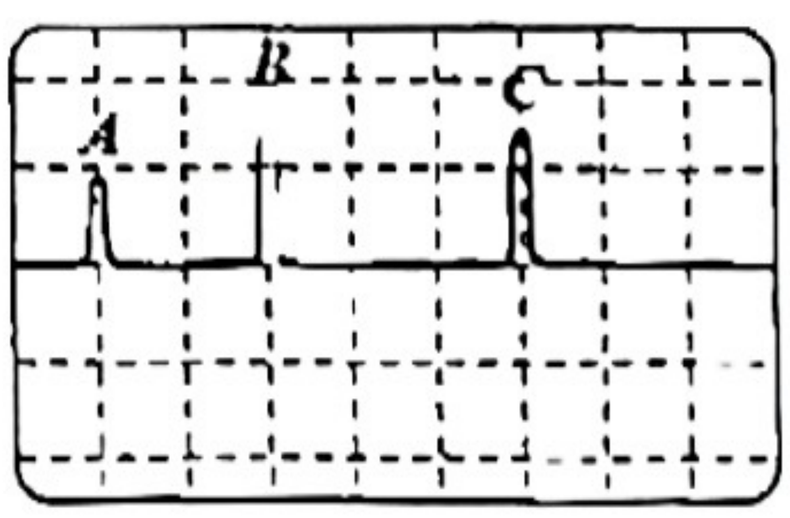
4.3 A small loudspeaker emits a sound. The sound intensity level measured at 10 m away from it is 50 dB. The power output of the loudspeaker is then doubled. What is the approximate sound intensity level measured at 8 m away from the loudspeaker ? Ignore the background sound.

A. 52 dB
B. 55 dB
C. 58 dB
D. 61 dB

A B C D
○ ○ ○ ○

4.4





The Figure shows a cross-section of a piece of bone with 6.5 cm thickness situated below a layer of soft tissue that is 2.0 cm thick. An ultrasound transducer with coupling gel is applied to the skin. The ultrasound pulses reflected from various boundaries *A*, *B* and *C* are displayed on a CRO. If the speed of ultrasound in the soft tissue is 1510 m s^{-1}, what is the speed of ultrasound in the bone ?

A. 3140 m s^{-1}
B. 3270 m s^{-1}
C. 3360 m s^{-1}
D. 3450 m s^{-1}

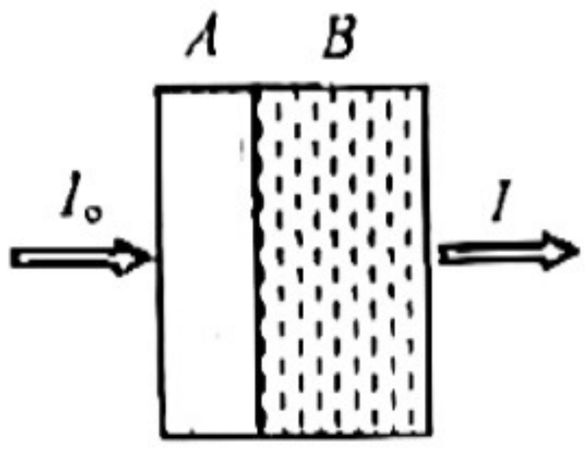
A B C D
○ ○ ○ ○

4.5 Two tissues X and Y have density 932 kg m^{-3} and 1085 kg m^{-3} respectively. The speed of sound in these two tissues X and Y are 1470 m s^{-1} and 1580 m s^{-1} respectively. If an ultrasound of intensity 25 mW cm^{-2} is incident onto an interface between tissues X and Y, what is the intensity of the ultrasound transmitted through this interface ?

A. 0.305 mW cm^{-2}
B. 0.416 mW cm^{-2}
C. 24.7 mW cm^{-2}
D. 24.9 mW cm^{-2}

A B C D
○ ○ ○ ○

4.6



An object is made up of two different materials A and B, with thickness 1.5 cm and 2.5 cm respectively. The half-value thickness of A and B for X-rays are 2.8 cm and 3.6 cm respectively. An X-ray beam of intensity I_o is incident onto the object. What is the intensity I of the X-ray after emerging from the object ?

A. 0.43 I_o
B. 0.54 I_o
C. 0.62 I_o
D. 0.73 I_o

A B C D
○ ○ ○ ○

4.7 The physical half-life of radioactive tracer is 8 hours. It is used as a tracer to inject into the bloodstream of a patient. If the biological half-life is 2 days, what is the percentage of the activity of the tracer left inside the body after 12 hours ?

A. 25%
B. 30%
C. 35%
D. 40%

A B C D
○ ○ ○ ○

4.8 Which of the following statements concerning radiographic imaging and computed tomography scan are correct ?

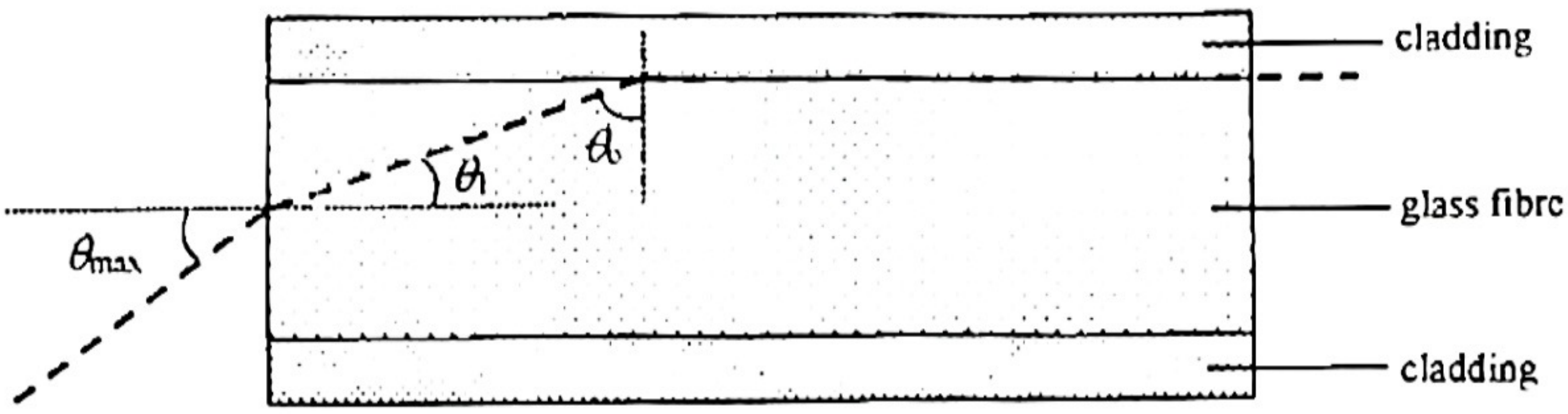
(1) Both of them make use of the different degree of attenuation of the radiation beam through various body tissues.
(2) Both of them involve the use of ionizing radiation.
(3) Both of them can give high resolution images of various body tissues.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A B C D
○ ○ ○ ○

Q.4 : Structured question

The figure below shows the cross-section of an optical fibre in endoscope. The refractive index of the glass fibre is 1.58 and that of cladding is 1.35. The angle θ_{max} shows the range of guided mode for light rays to undergo a series of total internal through the glass fibre. The angle θ_1 is the refracted angle corresponding to θ_{max} and the angle θ_c is the critical angle between the glass fibre and the cladding.



(a) Determine whether a light ray with incident angle of 60° at the axis of the glass fibre can be transmitted to the other end along the glass fibre. (3 marks)

(b) In order to increase the angle θ_{max} of the range of guided mode, state whether the refractive index of the cladding should increase or decrease. (1 mark)

(c) In an endoscope, the optical fibres are grouped into coherent bundle and non-coherent bundle. Compare the difference in function between these two bundles. (2 marks)

(d) Colonic polyp is an abnormal growth of tissue projecting from the colonic wall inside the large intestine. Colonic polyp may develop into cancer growth after some time.

(i) Briefly describe how an endoscope could be used to examine and cut the polyp of a patient. (2 marks)

(ii) State **TWO** advantages of using endoscope in this procedure. (2 marks)

END OF PAPER

Section A

Answers

1. B	6. B	11. D	16. C	21. B	26. C	31. B
2. C	7. B	12. B	17. D	22. C	27. B	32. D
3. A	8. D	13. B	18. B	23. C	28. C	33. B
4. D	9. B	14. C	19. C	24. C	29. D	
5. A	10. A	15. A	20. D	25. C	30. A	

Solution

1. B

① $P\,t = m\,l_f$ $\qquad P(2.5) = (m) \times (334\,000)$

② $P\,t = m\,c\,\Delta T$ $\qquad P(t) = (m + m) \times (4200) \times (100 - 0)$

Combine the two expressions : $\dfrac{P(2.5)}{P(t)} = \dfrac{(m)(334000)}{(2m)(4200)(100)}$ $\quad \therefore\ t = 6.3$ minutes

2. C

By $P\,V = n\,R\,T$

$\therefore\ (1.35 \times 10^5)(2) = n\,(8.31)(25 + 273)$ $\qquad \therefore\ n = 109$ mol

Number of gas molecules $= 109 \times (6.02 \times 10^{23}) = 6.56 \times 10^{25}$

3. A

By $P\,V = \dfrac{1}{3} N\,m\,c^2$ $\qquad \therefore\ P\,V = \dfrac{1}{3} M\,c^2$

$\therefore\ \rho = \dfrac{M}{V} = \dfrac{3P}{c^2} = \dfrac{3(150 \times 10^3)}{(575)^2} = 1.36$ kg m^{-3}

4. D

(1) Total distance travelled : $d = \frac{1}{2} \times 15 \times 10 + \frac{1}{2} \times 10 \times 20 = 175$ m

Average speed $= \dfrac{d}{t} = \dfrac{(175)}{(25)} = 7$ m s^{-1}

(2) Resultant displacement : $s = -\frac{1}{2} \times 15 \times 10 + \frac{1}{2} \times 10 \times 20 = 25$ m

Average velocity $= \dfrac{s}{t} = \dfrac{(25)}{(25)} = 1$ m s^{-1}

(3) The greatest separation between the car and the road sign occurs at the time instant of 15 s, where the car is at the extreme left of the road sign.

Greatest separation $= \frac{1}{2} \times 15 \times 10 = 75$ m

5 A

(1) There are two forces acting on the man : the weight W downwards and the normal reaction R upwards.
As the direction of velocity is downwards and under deceleration, direction of a is upwards.
$\therefore\ R > W$
As normal reaction gives the feeling of weight, $R > W$ indicates that the man feels heavier.

× (2) $R - mg = ma = m(0.1g) \quad \therefore\ R = 1.1\,mg$
The normal reaction increases by 10% of the weight, but the weight remains unchanged.

× (3) The force acting on the man by the floor is the normal reaction R.
They are not action-reaction since both R and W act on the same body
The force acting on the man by floor and the force acting on the floor by man are action-reaction pair.

6. B

Let the mass of each block be m and tension of the string be T.

For P : $T - mg\sin\theta = ma$

For Q : $mg - T = ma$

$\therefore\ mg - mg\sin\theta = 2ma \qquad \therefore\ g(1 - \sin\theta) = 2a$

$\therefore\ (9.81)(1 - \sin 25°) = 2a \qquad \therefore\ a = 2.83\ \text{m s}^{-2}$

7. B

Friction : $f = 0.65\,mg$

Loss of kinetic energy = work done against friction

$\therefore\ \frac{1}{2}mu^2 - fs = (0.65\,mg) \times s$

$\therefore\ \frac{1}{2}(15)^2 = (0.65 \times 9.81) \times s$

$\therefore\ s = 17.6\ \text{m}$

8. D

Take moment about X. Let the distance XP be d.

$\therefore\ mg\,d = T\sin 35° \times (60)$

$\therefore\ mg\,d = (0.75\,mg) \times \sin 35° \times (60)$

$\therefore\ d = 25.8\ \text{cm}$

9 B

Consider the swing up of the block after the block is hit by the bullet. By Conservation of mechanical energy :

$\therefore\ \frac{1}{2}Mv^2 = Mgh$

$\therefore\ \frac{1}{2} \times v^2 = (9.81)(0.064) \qquad \therefore\ v = 1.12\ \text{m s}^{-1}$

Consider the collision of the block by the bullet. By Conservation of momentum :

$\therefore\ m_1 u = (m_1 + m_2)v$

$\therefore\ (0.020) \times u = (0.020 + 2.48)(1.12) \qquad \therefore\ u = 140\ \text{m s}^{-1}$

10. A

The monkey must be hit vertically below its initial position.

Consider the horizontal component of the bullet :

By $s_x = u_x t$ $\therefore$ $(150) = (100 \cos 25°)\, t$ $\therefore$ $t = 1.655$ s

Displacement of the monkey : $s = \frac{1}{2} g t^2 = \frac{1}{2} \times (9.81) \times (1.655)^2 = 13.4$ m

Height of hitting $= 25 - 13.4 = 11.6$ m

11. D

Since the two particles have the same period, they must have the same angular speed ω

Let the mass of particle A, B be m, $2m$ respectively and let OA be r and OB be $2r$.

Consider A : $T_1 - T_2 = (m)(r)\,\omega^2$

Consider B : $T_2 = (2m)(2r)\,\omega^2$

Combine the two equations : $4\,(T_1 - T_2) = T_2$ $\therefore$ $T_1 : T_2 = 5 : 4$

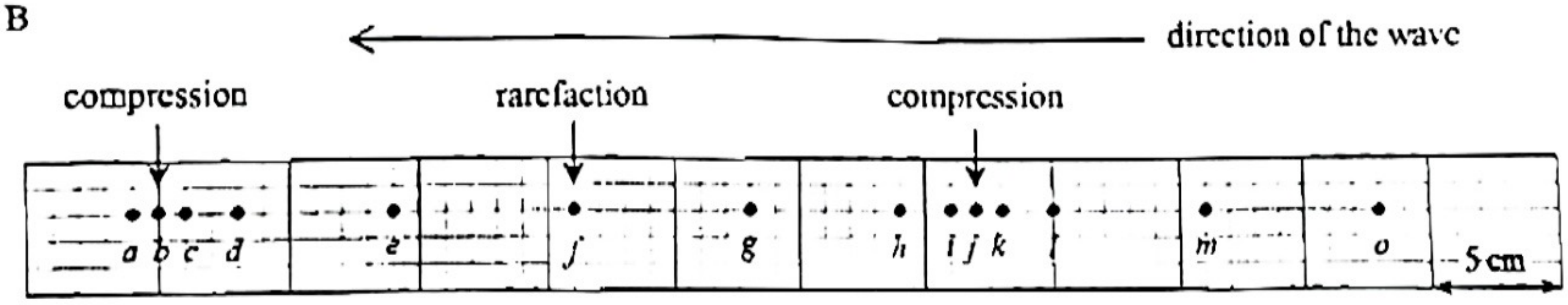
12. B

Radius of the orbit of the satellite $= R + h = R + R = 2R$

As $\dfrac{G M m}{(2R)^2} = m\,(2R)\,\omega^2$

$\therefore$ $\dfrac{G M}{(2R)^3} = \omega^2 = (\dfrac{2\pi}{T})^2$ $\therefore$ $\dfrac{(6.67\times10^{-11})(6.0\times10^{24})}{(2\times6.4\times10^{6})^3} = (\dfrac{2\pi}{T})^2$ $\therefore$ $T = 14383$ s $= 4.0$ hours

13. B



Particle b and j are at the centres of compression and particle f is at the centre of rarefaction.

(1) Particles around the compression move in the same direction of the wave while those particles around the rarefaction move in the opposite direction of the wave. Thus, particle f is moving towards the right

(2) Particles a and c should be moving in the same direction as b, both move towards the left.

(3) Between f and j, there are 3 particles. Particle h is at the middle and must have the maximum displacement (extreme point) at this instant. Thus, particle h is momentarily at rest at this instant.

14. C

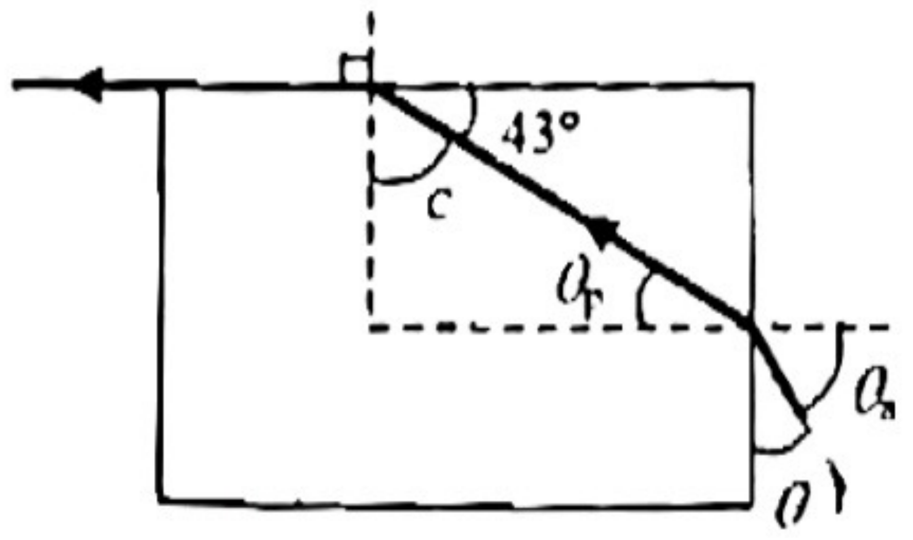
A. Since particle R and particle P are in anti-phase, they must move in opposite direction at the same time.

B. Particle Q is an antinode with greater energy, thus its speed is always greater than that of other particles.

C. Particle S is a node, it is always at rest, without moving.

D. When P reaches the equilibrium position, all particles must also reach their equilibrium positions.

15. A



From the figure, critical angle : $c = 90° - 43° = 47°$ and $\theta_p = 43°$ (alternate angle)

Refractive index of the plastic : $n = \dfrac{1}{\sin c} = \dfrac{1}{\sin 47°} = 1.367$

By $n_p = \dfrac{\sin\theta_a}{\sin\theta_p}$ $\quad\therefore (1.367) = \dfrac{\sin\theta_a}{\sin 43°}$ $\quad\therefore \sin\theta_a = 68.8°$

$\therefore \theta = 90° - 68.8° = 21.17° \approx 21°$

16. C

✓ A. There are 3 antinodal lines which have path difference of 0λ, $\pm 1\lambda$.
Since the sources separation $a = 1.5\lambda$, there are no antinodal line with path difference > 1.5λ.

B. At A, crest meets trough to give destructive interference, thus the particle there is always at rest.

C. At B, crest meets crest to give constructive interference, B then vibrates with the greatest amplitude. However, B would be sometimes at the crest and sometimes at the trough as it vibrates up and down.

D. From the graph, $S_1C = 1.25\lambda$ and $S_2C = 2.25\lambda$. Path difference at $C = 2.25\lambda - 1.25\lambda = 1\lambda$.
Thus C is undergoing constructive interference.

17. D

(1) The positions of the object and the real image can be interchanged.
For the first image, $u = 10$ cm and $v = 30$ cm.
For the second image, $u = 30$ cm and $v = 10$ cm
Thus, the distance moved by the lens $= 30 - 10 = 20$ cm

(2) For the first image, $m = \dfrac{v}{u} = \dfrac{h_i}{h_o}$ $\quad\therefore \dfrac{(30)}{(10)} = \dfrac{(18)}{h_o}$ $\quad\therefore h_o = 6$ cm

For the second image, $m = \dfrac{v}{u} = \dfrac{h_i}{h_o}$ $\quad\therefore \dfrac{(10)}{(30)} = \dfrac{h_i}{(6)}$ $\quad\therefore h_i = 2$ cm

(3) By $\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$ $\quad\therefore \dfrac{1}{f} = \dfrac{1}{(10)} + \dfrac{1}{(30)}$ $\quad\therefore f = 7.5$ cm

18. B

In the pattern, the middle spot is the zeroth order. The first and the fifth spots are the second order maxima.

Second order bright spot : $\tan\theta_2 = \dfrac{(1.6/2)}{(1.5)}$ $\quad\therefore \theta_2 = 28.07°$

By $d\sin\theta = n\lambda$

$\dfrac{(10^{-2})}{(4000)}\sin 28.07° = (2)\lambda$

$\lambda = 5.88 \times 10^{-7}$ m $= 588$ nm

19. C

Fringe separation : $\Delta y = 7.5\text{ mm} \times \frac{1}{4} = 1.875\text{ mm}$

By $\Delta y = \dfrac{\lambda D}{a}$ $\quad \therefore \quad (1.875\times10^{-3}) = \dfrac{\lambda\cdot(1.6)}{(0.5\times10^{-3})}$ $\quad \therefore \quad \lambda = 5.86\times10^{-7}\text{ m}$

20. D

Let the time taken for the echo to be heard.

During this time, the car has travelled a distance of $20\,t$.

By $d = vt$ $\quad \therefore \quad (1200\times2 + 20\,t) = (340)\,t$ $\quad \therefore \quad t = 7.50\text{ s}$

21. B

× A. Ultrasound or common sound travels with greater speed in liquid than that in gas.

✓ B. One of the application of ultrasound is the detection of cracks in railway tracks by echo

× C. Ultrasound is a type of mechanical wave that travels in material medium. It is not electromagnetic wave.

× D. Ultrasound has diffraction, although the degree of diffraction is less than that of common sound.

22. C

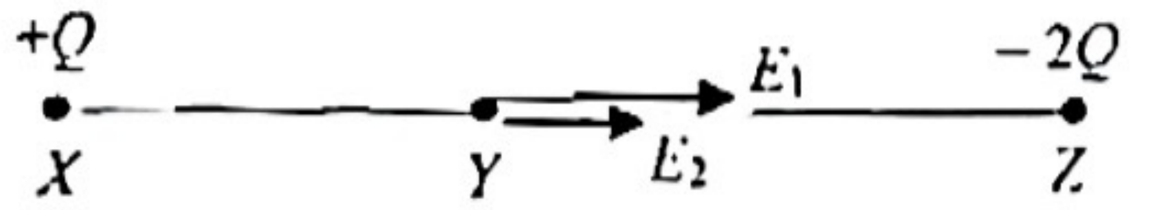
Electric field between the parallel plates : $E = \dfrac{V}{d} = \dfrac{(4500)}{(0.10)} = 45\,000\text{ V m}^{-1}$

Resolve the tension T of the string into vertical and horizontal components.

① $T\sin\theta = F$ ② $T\cos\theta = W$

$\therefore \quad \tan\theta = \dfrac{F}{W} = \dfrac{qE}{mg}$ $\quad \therefore \quad \tan 12^\circ = \dfrac{q\,(45000)}{(50\times10^{-6})\,(9.81)}$ $\quad \therefore \quad q = 2.3\times10^{-9}\text{ C}$

23. C



Electric field at Y due to $+Q$: $E_1 = \dfrac{Q}{4\pi\varepsilon_o(r)^2} = E$ (towards the right)

Electric field at Y due to $-2Q$: $E_2 = \dfrac{2Q}{4\pi\varepsilon_o(2r)^2} = \dfrac{1}{2}\times\dfrac{Q}{4\pi\varepsilon_o r^2} = \dfrac{1}{2}E$ (towards the right)

Resultant electric field at $Y = E + \dfrac{1}{2}E = 1.5\,E$ (towards the right)

24. C

(1) When the applied voltage increases from 2 V, the resistance of the device should gradually decrease.

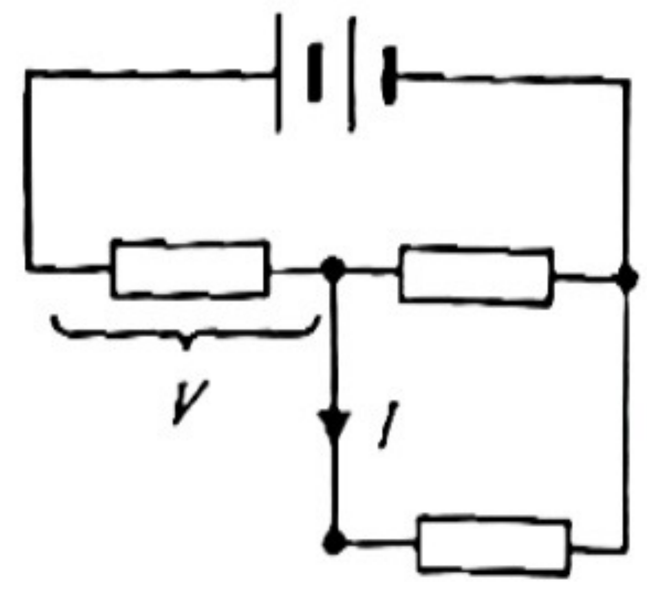
(2) When the applied voltage is 6 V, current is 30 mA. $\therefore \quad R = \dfrac{V}{I} = \dfrac{(6)}{(30\times10^{-3})} = 200\ \Omega$

(3) When the applied voltage is 10 V, current is 60 mA. $\therefore \quad P = VI = (10)\,(60) = 600\text{ mW}$

25. C

An ideal voltmeter has infinite resistance that acts like an open circuit.

An ideal ammeter has zero resistance that acts like a short circuit.



The equivalent resistance of the circuit $= 5 + \frac{5}{2} = 5 + 2.5 = 7.5\ \Omega$

Reading of the voltmeter : $V = 12 \times \frac{5}{5+2.5} = 8$ V

Reading of the ammeter : $I = \frac{12}{7.5} \times \frac{1}{2} = 0.8$ A

26. C

Resistance of the wire : $R = \frac{V}{I} = \frac{(4.5)}{(2.4)} = 1.875\ \Omega$

By $R = \frac{\rho \cdot \ell}{A} = \frac{\rho \cdot \ell}{A} \times \frac{\ell}{\ell} = \frac{\rho \cdot \ell^2}{V}$ where volume V of the wire is equal to $A \cdot \ell$

$\therefore (1.875) = \frac{(7.5\times10^{-8})\cdot \ell^2}{(1.5\times10^{-7})}$ $\quad \therefore \ell = 1.94$ m

27. B

In order to work within the rated power, the maximum voltage of the power supply should be 8 V.

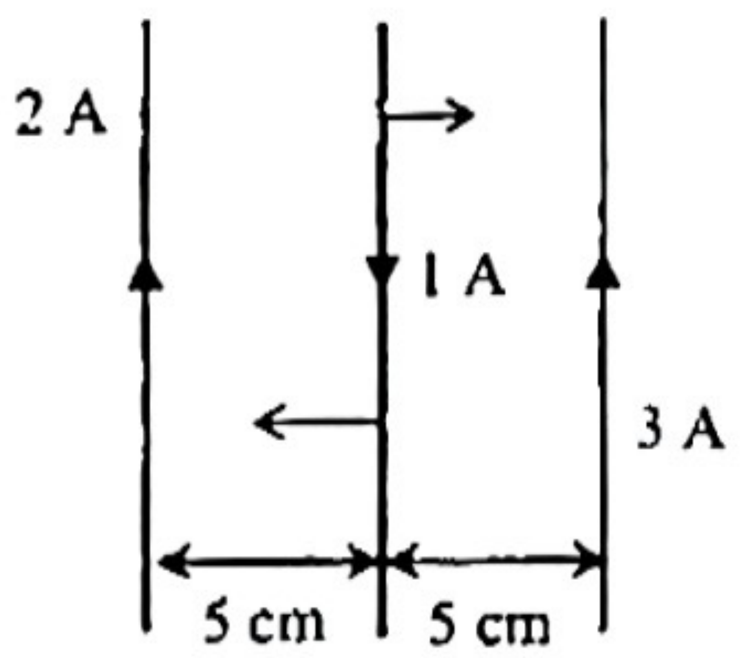
Light bulb A is then working in rated condition while light bulb B works with power lower than normal

Current flow through light bulb A : $I_r = \frac{P_r}{V_r} = \frac{(12)}{(8)} = 1.5$ A

Resistance of light bulb $B = \frac{V_r^2}{P_r} = \frac{(12)^2}{(18)} = 8\ \Omega$ $\quad \therefore$ Current flow through light bulb $B = \frac{(8)}{(8)} = 1$ A

Total current drawn $= 1.5 + 1 = 2.5$ A

28. C



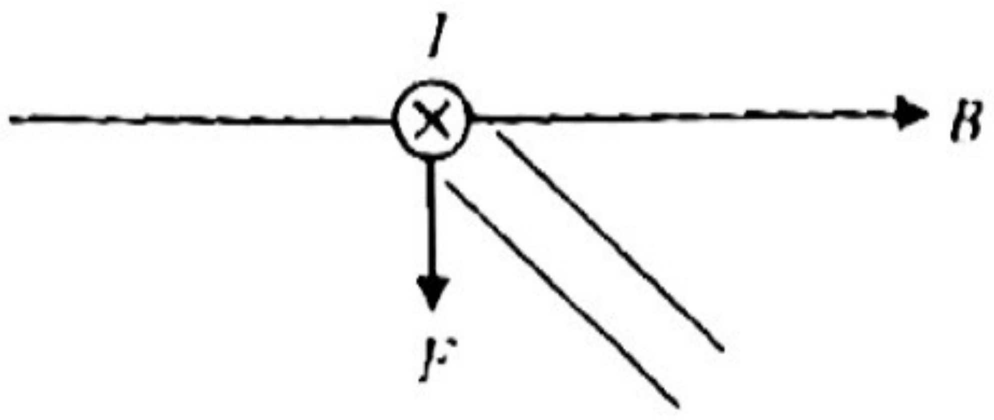
Magnetic force per length : $\frac{F}{\ell} = \frac{\mu_0 \cdot I_1 \cdot I_2}{2\pi \cdot r}$

Magnetic force per length between 2 A and 1 A $= \frac{(4\pi\times10^{-7})\cdot(2)\cdot(1)}{2\pi\cdot(0.05)} = 8 \times 10^{-6}$ N m^{-1} (rightwards)

Magnetic force per length between 1 A and 3 A $= \frac{(4\pi\times10^{-7})\cdot(1)\cdot(3)}{2\pi\cdot(0.05)} = 12 \times 10^{-6}$ N m^{-1} (leftwards)

Resultant magnetic force per length on 1 A $= 12 \times 10^{-6} - 8 \times 10^{-6} = 4 \times 10^{-6}$ N m^{-1} (leftwards)

29. D



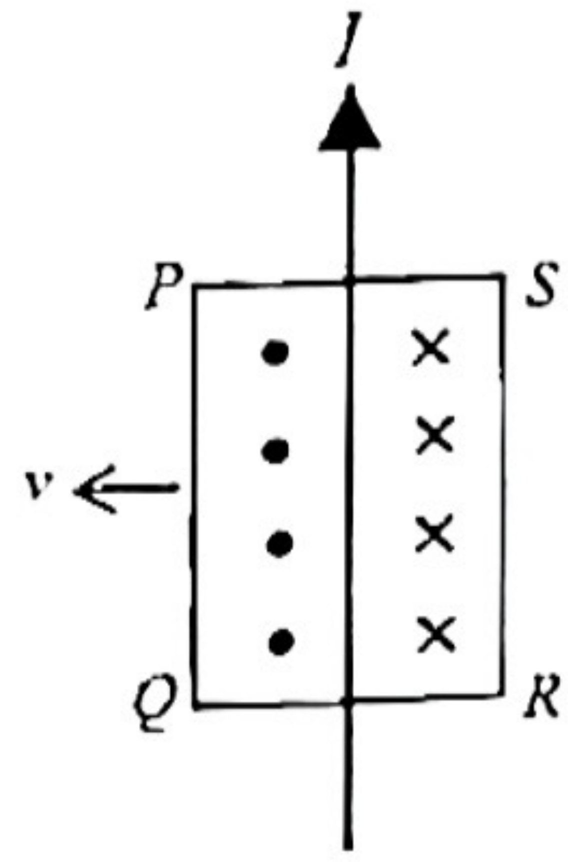
Use Left hand rule, the magnetic force on the current I at side A of the coil is downwards.

Magnetic force on current I inside a magnetic field B : $F = BIL$ (note that B and I are perpendicular)

Magnetic force per unit length on one turn : $\frac{F}{L} = BI = (40 \times 10^{-3})(4.5) = 0.18\ \text{N m}^{-1}$

Magnetic force per unit length on 20 turns : $\frac{F}{L} = 0.18 \times 20 = 3.6\ \text{N m}^{-1}$

30. A



(1) At the right side of the current, the magnetic field is into the paper.
By Right hand rule, the induced current is along SR.
At the left side of the current, the magnetic field is out of paper.
By Right hand rule, the induced current is along QP.
The overall induced current is in clockwise direction of $QPSR$.

(2) By Right hand rule, the induced e.m.f. is from Q to P.
Thus, P is at a higher potential than Q.

(3) Both the magnetic force on RS and PQ are rightwards by Left hand rule, thus the resultant magnetic force is in rightward direction.

OR

By Lenz's Law, there is magnetic force to oppose the motion, thus the resultant magnetic force is rightwards.

31. B

Decay constant : $k = \frac{\ln 2}{5 \times 365 \times 24 \times 3600} = 4.396 \times 10^{-9}\ \text{s}^{-1}$

Number of active nuclei : $N = 0.02 \times (6.02 \times 10^{23}) = 1.204 \times 10^{22}$

Activity : $A = kN = (4.396 \times 10^{-9})(1.204 \times 10^{22}) = 5.3 \times 10^{13}\ \text{Bq}$

32. D

Let the background count rate be b.

$(720 - b)(\frac{1}{2})^{4/2} = (240 - b)$ $\therefore b = 80$ c.p.m.

After one more hour : $C = (240 - 80)(\frac{1}{2})^{1/2} + 80 = 193$ c.p.m.

33. B

$E = mc^2 = (4.0 \times 10^{30} \times 0.07\%) \times (3 \times 10^{8})^2 = 2.52 \times 10^{44}\ \text{J}$

$E = Pt$ $\therefore (2.52 \times 10^{44}) = (4.5 \times 10^{26})\, t$ $\therefore t = 5.6 \times 10^{17}\ \text{s} = 1.8 \times 10^{10}$ years

Section B

1. (a) Use the electronic balance to measure the mass of the polystyrene cup.

Put some crushed ice into the polystyrene cup and measure the mass again to obtain the mass of ice m_i. [1]

Pour all the hot water into the polystyrene cup. Well stir the mixture with the stirrer until all the ice melts. [1]

Put the thermometer into the cup to measure the final temperature θ. [1]

The specific latent heat of ice l_f is found by the following equation :

$m_i l_f + m_i c \Delta T_i = m_w c \Delta T_w$

$m_i l_f + m_i (4200)\, \theta = (0.2)(4200)(60 - \theta)$ [1]

(b) **Sources of errors** : (any **TWO** of the followings) [2]

* The hot water may have heat lost to the surrounding air.
* The temperature of ice may not be at 0 °C.
* There is heat gain by the polystyrene cup (**OR** thermometer) after adding hot water.
* In reading the final temperature of water, the water may not have uniform temperature.
* Some ice may have melted into water before hot water is added.

2. (a) $PV = nRT$

$\therefore\ P \times (450 \times 10^{-6}) = (\frac{0.76}{29}) \times (8.31) \times (25 + 273)$ [1]

$\therefore\ P = 144\,000$ Pa   < **OR** 144 kPa > [1]

(b) $F = \Delta P \times A$

$\therefore\ F = (144 - 102) \times 10^3 \times (16 \times 10^{-4})$ [1]

$\therefore\ F = 67.2$ N   < accept 67 N - 68 N > [1]

(c) $P_1 V_1 = P_2 V_2$

$\therefore\ (144)(450) = (102)\, V_2$ < the piston would move until the pressure inside equals pressure outside > [1]

$\therefore\ V_2 = 635$ cm^3 < accept 636 cm^3 > [1]

3. (a) a = slope = $\frac{15}{3} = 5$ m s^{-2} [1]

$T - mg = ma$ [1]

$\therefore\ T - (1.6 \times 10) = (1.6) \times (5)$ $\therefore\ T = 24$ N [1]

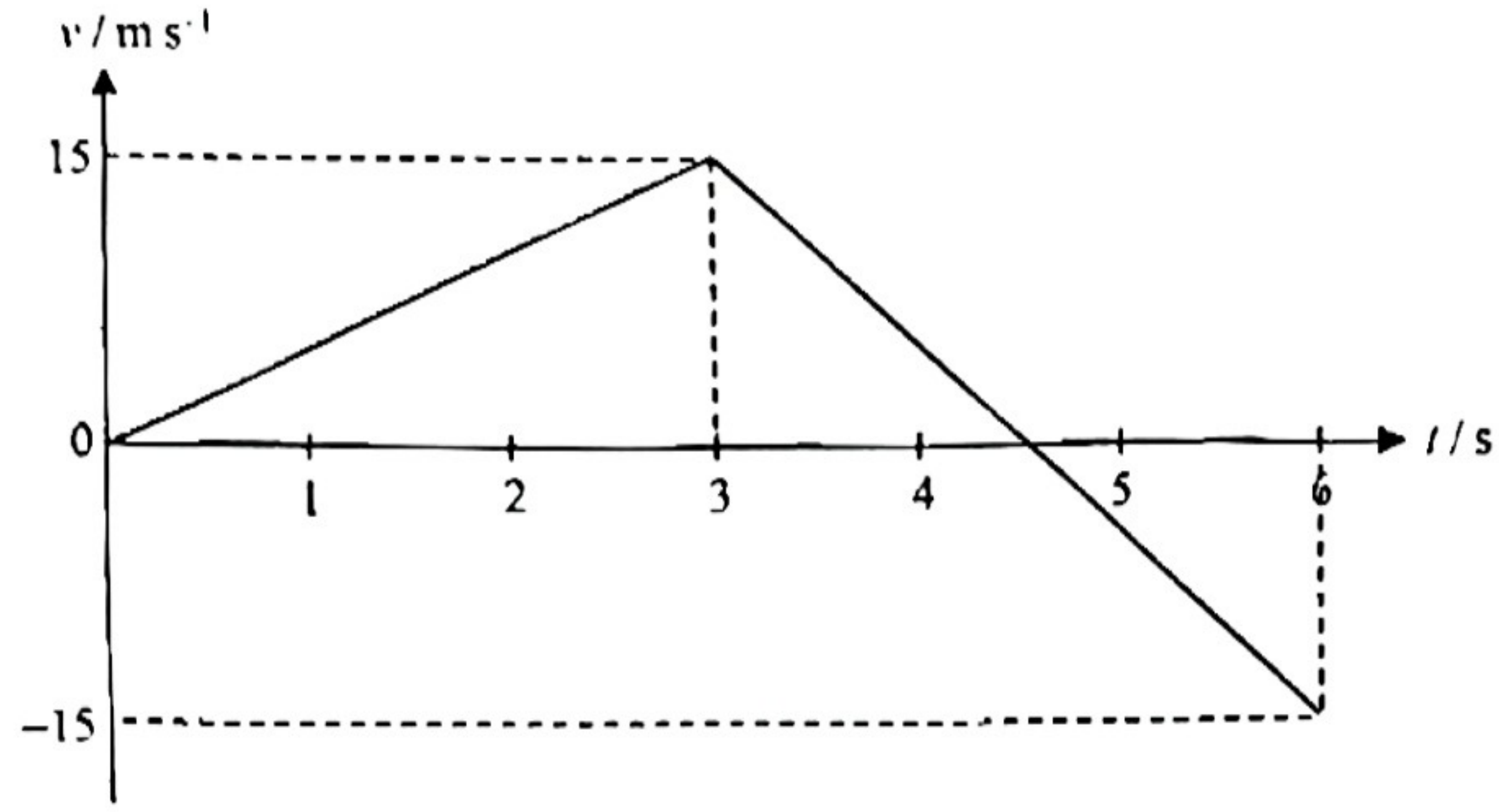
(b) s = area = $\frac{1}{2} \times (15) \times (3) = 22.5$ m [1]

$W = Fs = (24) \times (22.5) = 540$ J   **OR** $W = KE + PE = \frac{1}{2}(1.6) \times (15)^2 + (1.6)(10)(22.5) = 540$ J [1]

$P = \frac{W}{t} = \frac{540}{3} = 180$ W [1]

[Note that $P = Fv = (24) \times (15) = 360$ W is wrong since it is the instantaneous power at $t = 3$ s]

3. (c) (i)



< A straight line with slope equal to g = −10 m s^{-2} until t = 6 s > [1]

< The velocity is zero at 4.5 s at maximum height >

(ii) Maximum height = area from 0 s to 4.5 s = $\frac{1}{2} \times (4.5) \times (15)$ = 33.75 m < accept 33.8 m > [1]

OR

$v^2 = u^2 + 2as$ ∴ $(0) = (15)^2 + 2(-10)s$ ∴ s = 11.25 m

Maximum height = 22.5 + 11.25 = 33.75 m < accept 33.8 m > [1]

(iii) 1. It is false since the acceleration of the load is equal to $-g$ (**OR** g) (**OR** −10) at the maximum height. [1]

2. It is false since there is external force (the weight) acting on the load. [1]

OR

It is false since the momentum of the load changes throughout the motion. [1]

4. (a) $m_A u_A + m_B u_B = m_A v_A + m_B v_B$ [1]

$(1.2) \times (7.2) = (1.2) \times v_A + (0.8) \times (5.4)$

∴ v_A = 3.6 m s^{-1} [1]

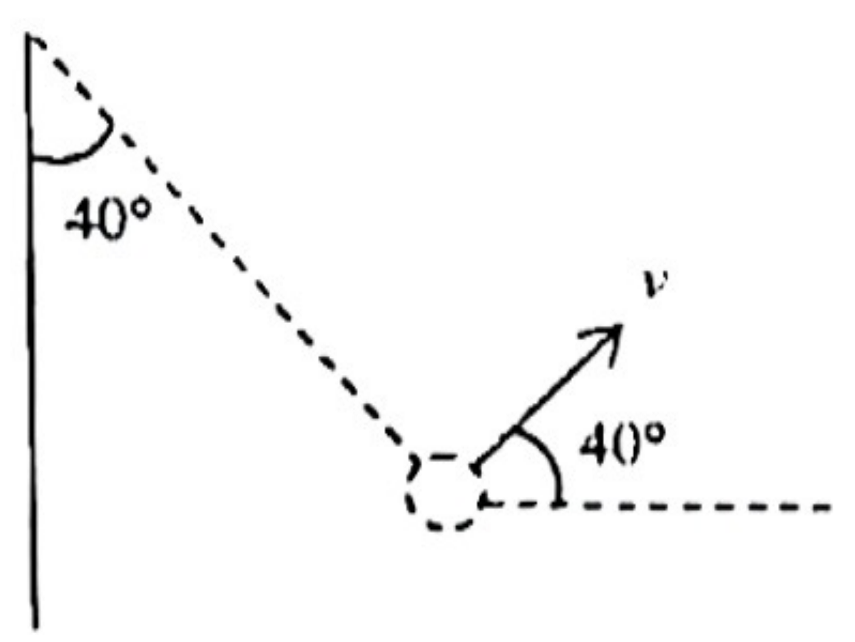
(b) Height of P above the ground : $h = 1.5 \times (1 - \cos 40°)$ = 0.351 m

By $\frac{1}{2} m_B u^2 = \frac{1}{2} m_B v^2 + m_B g h$

∴ $\frac{1}{2}(5.4)^2 = \frac{1}{2}v^2 + (9.81) \times (0.351)$ [1]

∴ v = 4.72 m s^{-1} [1]

(c) (i)



< direction of v should be perpendicular to the radius and the angle of 40° is correctly marked > [1]

4 (c) (ii) By $v_y^2 = u_y^2 + 2a_y s_y$

$\therefore\ (0) = (4.72 \sin 40^\circ)^2 + 2(-9.81)s_y$ [1]

$\therefore\ s_y = 0.469$ m

Maximum height = 0.351 + 0.469 = 0.820 m < accept 0.810 to 0.830 m > [1]

(iii) By $s_y = u_y t + \frac{1}{2} a_y t^2$

$\therefore\ (-0.351) = (4.72 \sin 40^\circ)t + \frac{1}{2}(-9.81)t^2$ [1]

$\therefore\ t = 0.7182$ s

Horizontal distance :

$s_x = (4.72 \cos 40^\circ) \times 0.7182 = 2.60$ m < accept 2.58 m to 2.62 m > [1]

5. (a) Acceleration of the satellite is equal to the gravitational field at the orbit.

$g \propto \frac{1}{r^2}$

$\therefore\ g = (9.81) \times \left(\frac{6400}{9600}\right)^2$ [1]

$\therefore\ a = g = 4.36$ m s^{-2} (**OR** 4.36 N kg^{-1}) [1]

(b) By $mg = \frac{mv^2}{r}$

$\therefore\ v = \sqrt{gr} = \sqrt{(4.36)(9600 \times 10^3)} = 6470$ m s^{-1} [1]

$\therefore\ v = 6470$ m s^{-1} [1]

(c) By $t = 50 \times \frac{2\pi r}{v} = 50 \times \frac{2\pi(9600 \times 10^3)}{(6470)}$ [1]

$\therefore\ t = 466140$ s = 129 hours < accept 128 to 130 hours > [1]

OR

By $mg = mr\omega^2$ $\therefore\ g = r \times \left(\frac{2\pi}{T}\right)^2$

$\therefore\ (4.36) = (9600 \times 10^3) \times \left(\frac{2\pi}{T}\right)^2$ [1]

$\therefore\ T = 9323$ s

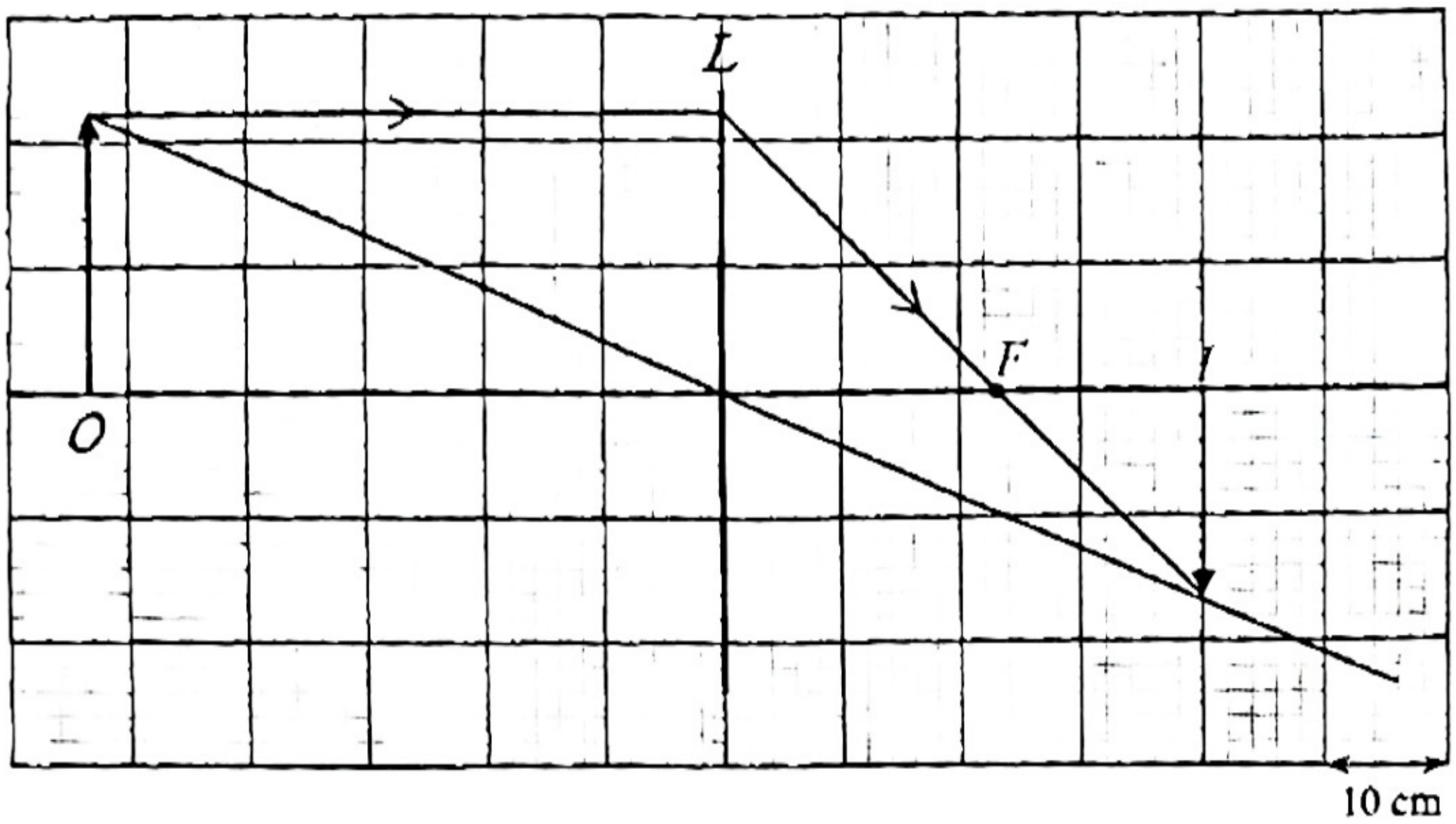
$\therefore\ t = 50T = 130$ hours < accept 128 to 130 hours > [1]

(d) Any ONE of the following reason : [1]

* All the weight of the astronaut is used to provide the centripetal force for circular motion.
* All the gravitational force acting on the astronaut is used to provide the centripetal force for circular motion.
* Both astronaut and spacecraft are moving with the same acceleration due to gravity towards the Earth.

6. (a) (i) The lens is convex since it can form a real image on a screen [1]

(ii)



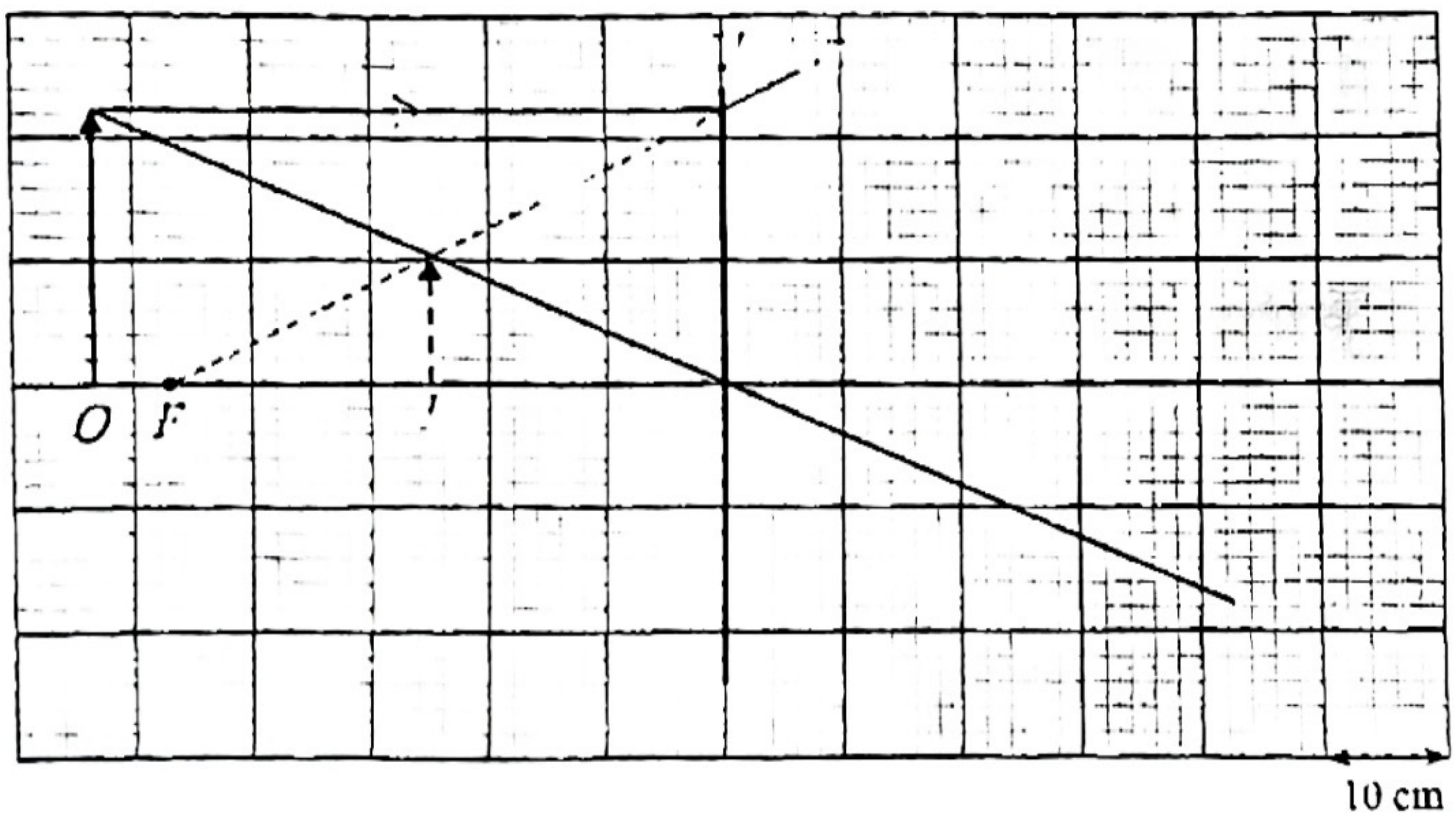
< correct position, size of image is determined by the ray through optical centre > [1]

(iii) < parallel light ray from O and F correctly marked, F should be between 22 to 24 cm > [1]

(iv) The screen should be moved away from the lens to capture the sharp image. [1]

The size of image would increase. [1]

(b)



(i) < Image correctly drawn, size is determined by the ray through optical centre > [1]

< Parallel light ray from O, focus F correctly marked, between 46 to 48 cm > [1]

(ii) Lens L' is a concave lens that can give a wider field of view. [1]

7. (a) By $v = f\lambda$

$\therefore (336) = (800)\lambda$

$\therefore \lambda = 0.42$ m [1]

7. (b) Path difference at A = 2.86 − 2.23 = 0.63 m = 1.5 λ [1]

Since the two waves reaching A are in opposite phase, destructive interference occurs at A. [1]

(c)

< correct shape, not touching the bottom > [1]

(d) The pitch remains unchanged and the loudness increases. [1]

(e) For the next maximum, the path difference should be 2λ, that is, 0.84 m.

Since the path difference must always be less than the separation between the two sources (0.8 m), [1]

there is no maximum loudness beyond A along OA. [1]

8. (a) $E = \dfrac{V}{d} = \dfrac{(1500)}{(0.20)}$ [1]

$= 7500 \text{ V m}^{-1}$ (**OR** 7500 N C^{-1}) [1]

(b) $BQv = QE$ [1]

$\therefore B(2.5\times10^5) = (7500)$

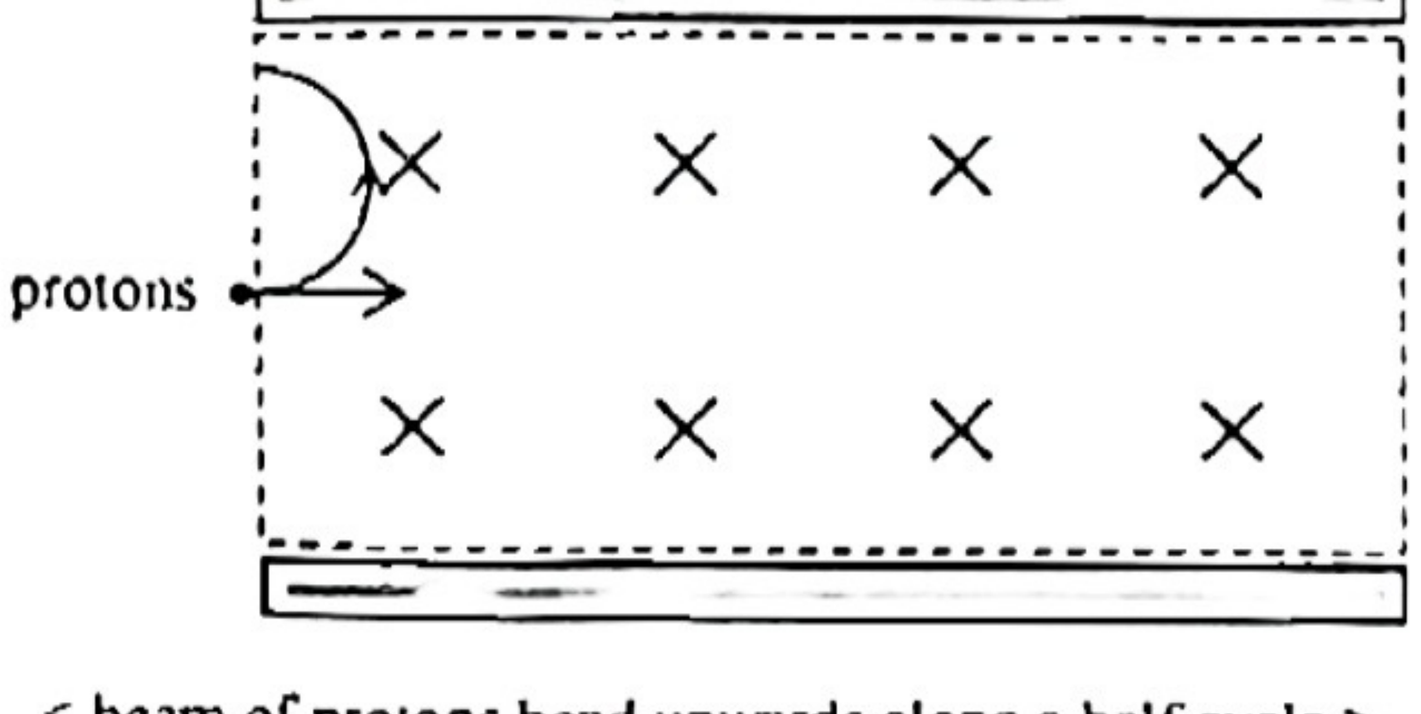
$\therefore B = 0.03$ T [1]

(c) (i) $BQv = \dfrac{mv^2}{r}$ [1]

$\therefore (0.03)(1.6\times10^{-19}) = \dfrac{(1.67\times10^{-27})(2.5\times10^5)}{r}$

$\therefore r = 0.0870$ m < accept 0.087 m > [1]

(ii)



< beam of protons bend upwards along a half cycle > [1]

9. (a) The resultant magnetic field at P is in downward direction. [1]

$$B = B_1 + B_2 = \frac{\mu_o I_1}{2\pi r_1} + \frac{\mu_o I_2}{2\pi r_2}$$

$$\therefore\ B = \frac{(4\pi\times10^{-7})}{2\pi}\left(\frac{0.6}{0.06}+\frac{0.4}{0.09}\right)$$ [1]

$$= 2.89\times10^{-6}\ \text{T}$$ [1]

(b) By $\frac{F}{\ell} = \frac{\mu_o I_1 I_2}{2\pi r}$ [1]

$$\therefore\ F_1 = \frac{(4\pi\times10^{-7})\times(0.6)\times(0.4)}{2\pi\times(0.15)}\times(2.5) = 8\times10^{-7}\ \text{N}$$ [1]

The direction of magnetic force on I_1 is towards the left. [1]

(c) For the resultant force to be zero, the position is a neutral point that should be at the right hand side of I_2.

$$B_1 = B_2$$

$$\therefore\ \frac{\mu_o I_1}{2\pi r_1} = \frac{\mu_o I_2}{2\pi r_2}$$

$$\therefore\ \frac{(0.6)}{(0.15+d)} = \frac{(0.4)}{(d)}$$ [1]

$$\therefore\ d = 0.3\ \text{m}$$

The position of zero resultant force is at 30 cm to the right of I_2. [1]

10. (a) $V_{AC} = 36\times\frac{400}{100} = 144\ \text{V}$ [1]

(b) $V_{BD} = 144 - 0.6\times20\times2 = 120\ \text{V}$ [1]

(c) $V_{rms} = 120\times\frac{100}{400} = 30\ \text{V}$ [1]

$V_o = \sqrt{2}\times30 = 42.4\ \text{V}$ [1]

(d) $P = VI = (120)\times(0.6) = 72\ \text{W}$ [1]

OR

$P = (144)\times(0.6) - (0.6)^2(20+20) = 72\ \text{W}$ [1]

(e) $P_{loss} = (0.6)^2\times(20+20) = 14.4\ \text{W}$ [1]

$\eta = \frac{P_{out}}{P_{in}} = \frac{72}{72+14.4}\times100\% = 83.3\%$ [1]

(f) ① Use cables with smaller resistance. [1]

② Increase the secondary turns of T_1 to step-up AC to a higher voltage. [1]

11. (a) Mass defect = 226.0254 − 222.0176 − 4.0026 = 0.0052 u [1]

Energy released = 0.0052 × 931 = 4.84 MeV [1]

(b) $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{1600 \times 3.15 \times 10^{7}} = 1.38 \times 10^{-11}\ s^{-1}$ <accept $1.37 \times 10^{-11}\ s^{-1}$> [1]

(c) By $P = EA$

∴ $(2.5 \times 10^{3}) = (4.84 \times 10^{6} \times 1.6 \times 10^{-19})A$ [1]

∴ $A = 3.23 \times 10^{15}$ Bq <accept 3.2 to 2.3 × 10^{15} Bq> [1]

(d) By $A = kN$

∴ $(3.23 \times 10^{15}) = (1.38 \times 10^{-11})N$

∴ $N = 2.34 \times 10^{26}$ [1]

Mass of radium-226 :

$M = \frac{2.34 \times 10^{26}}{6.02 \times 10^{23}} \times 0.226$

$= 87.9$ kg <accept 87.5 to 88.2 kg> [1]

Section A : Astronomy and Space Science

1.1 D

(1) By Kepler's first law, the Sun is at one of the focus of the elliptical orbit, not at the centre.

(2) By Kepler's second law, each planet sweeps equal areas in equal times.
Thus, the closer the planet to the Sun, the greater is the speed of the planet.
Therefore, each planet moves around the Sun with varying speed.

(3) By Kepler's third law, $T^2 \propto a^3$, where a is the semi-major axis or average radius from the Sun.
Since the average radius of Mars from the Sun is greater than that of Venus, its period is greater.

1.2 B

(1) By using epicycles, Ptolemy's model can explain the morning and evening star of Mercury or Venus.

× (2) Ptolemy's model can only give incomplete phases of Venus.

(3) Ptolemy's model can explain the retrograde motion of Mars, by using epicycles.

1.3 C

Semi-major axis of the first satellite $= (2.4 \times 10^9) \times \frac{1}{2} = 1.2 \times 10^9$ m

Semi-major axis of the second satellite $= 850\,000 \times 10^3 = 0.85 \times 10^9$ m

By Kepler's third law,

$\therefore\ T^2 \propto a^3 \qquad \therefore\ \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{a_1}{a_2}\right)^3 \qquad \therefore\ \left(\frac{8.5}{T_2}\right)^2 = \left(\frac{1.2}{0.85}\right)^3$

$\therefore\ T_2 \approx 5.1$ days

1.4 A

To reach the height equal to the radius R of the Earth, by conservation of mechanical energy :

$\frac{1}{2}mu^2 + \left(\frac{-GMm}{R}\right) = \left(\frac{-GMm}{2R}\right) \qquad \therefore\ u = \sqrt{\frac{GM}{R}}$

To just escape from the surface of the Earth, the speed of escape : $v = \sqrt{\frac{2GM}{R}}$

$\therefore\ \frac{u}{v} = \frac{1}{\sqrt{2}}$

1.5 A

By $p = \frac{1}{d}$

$\therefore\ (0.025'') = \frac{1}{d} \qquad \therefore\ d = 40\text{ pc} = 40 \times 3.09 \times 10^{16} = 1.236 \times 10^{18}$ m

By $b = \frac{L}{4\pi d^2}$

$\therefore\ (3.6 \times 10^{-15}) = \frac{L}{4\pi(1.236 \times 10^{18})^2} \qquad \therefore\ L = 6.9 \times 10^{22}$ W

1.6 C

Star X : $m = 4$ and $M = +5$ (spectral G) $\quad \therefore\ m - M = (4) - (5) = -1$

Star Y : $m = 3$ and $M = -5$ (spectral O) $\quad \therefore\ m - M = (3) - (-5) = +8$

Star Z : $m = 6$ and $M = +12$ (spectral M) $\quad \therefore\ m - M = (6) - (12) = -6$

The value of $(m - M)$ represents the distance from the Earth.

The greater the value of $(m - M)$, the further away is the star from the Earth.

$\therefore\ d_Z < d_X < d_Y \quad (-6 < -1 < +8)$

Therefore, the distance of these 3 stars in ascending order from the Earth is Z, X, Y

1.7 C

As the two stars are inside the same star cluster, they have the same distance d from the Earth.

By $b = \dfrac{L}{4\pi d^2}$, apparent brightness b is proportional to the luminosity L : $b \propto L$

$$\therefore\ \frac{L_A}{L_B} = \frac{b_A}{b_B} = \frac{1}{4}$$

Luminosity : $L = 4\pi R^2 \sigma T^4 \quad \therefore\ L \propto R^2 T^4$

$$\therefore\ \frac{L_A}{L_B} = \left(\frac{R_A}{R_B}\right)^2 \left(\frac{T_A}{T_B}\right)^4$$

$$\therefore\ \left(\frac{1}{4}\right) = \left(\frac{R_A}{R_B}\right)^2 \left(\frac{1}{2}\right)^4$$

$$\frac{R_A}{R_B} = \frac{2}{1}$$

1.8 A

The Doppler shift of wavelength : $\Delta\lambda = 495.9 - 496.6 = 0.3$ nm

By $\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$

$$\therefore\ \frac{(0.3)}{(495.6)} = \frac{v}{(3 \times 10^8)}$$

$\therefore\ v = 181\,600$ m s^{-1}

From the instant of maximum wavelength to the instant of minimum wavelength, it takes a time of half period.

$\therefore$ period of the orbital motion of the star $= 75 \times 2 = 150$ hours

By $v = \dfrac{2\pi r}{T}$

$$\therefore\ (181600) = \frac{2\pi r}{(150 \times 3600)}$$

$\therefore\ r = 1.56 \times 10^{10}$ m

Q1. (a) The radial velocity is 2.5×10^5 m s^{-1} as shown by the graph.

By $\frac{v_r}{c} = \frac{\Delta\lambda}{\lambda_0}$ $\quad \therefore \frac{(2.5\times10^5)}{(3\times10^8)} = \frac{\Delta\lambda}{656.28}$ $\quad \therefore \Delta\lambda = 0.547$ nm [1]

As the star is moving away from the observer, red shift occurs and the apparent wavelength is longer.

$\therefore \lambda = 656.28 + 0.547 = 656.83$ nm [1]

(b) (i) From the graph, period $T = 14 \times 10^{16}$ s

By $2\pi r = vT$

$\therefore 2\pi r = (2.5\times10^5)\times(14\times10^{16})$ [1]

$\therefore r = 5.57\times10^{21}$ m $= 5.57\times10^{21}\times\frac{1}{3.09\times10^{16}}$ pc $= 1.80\times10^5$ pc [1]

(ii) By $\frac{GMm}{r^2} = \frac{mv^2}{r}$ [1]

$\therefore M = \frac{v^2 r}{G} = \frac{(2.5\times10^5)^2(5.57\times10^{21})}{(6.67\times10^{-11})} = 5.22\times10^{42}$ kg [1]

(c) By $\theta = \frac{2r}{d}$

$\therefore (0.245°\times\frac{\pi}{180°}) = \frac{2(1.80\times10^5)}{d}$ [1]

$\therefore d = 8.42\times10^7$ pc [1]

(d) (i) By $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $\quad \therefore v \propto \frac{1}{\sqrt{r}}$

$\therefore$ The radial velocity of star B should be greater than that of A. [1]

(ii) There may be the existence of dark matter in the outer region of the galaxy [1]

Section B : Atomic World

2.1 C

× (1) Protons and neutrons have not been discovered at that time, thus cannot be deduced.

× (2) Electron in orbits of specific energy (energy level) is proposed by Bohr, not by Rutherford.

(3) Since most of the mass is concentrated in the tiny nucleus, the nucleus has extremely high density.

2.2 B

By $E = \phi + K_{max}$

$\therefore \frac{hc}{\lambda} = \phi + K_{max}$

For the green light of wavelength 550 nm :

$\therefore \frac{(6.63\times10^{-34})(3\times10^{8})}{(550\times10^{-9})}\times\frac{1}{1.6\times10^{-19}} = \varphi + (0.65) \qquad \therefore \varphi = 1.61 \text{ eV}$

For the blue light of wavelength 450 nm :

$\therefore \frac{(6.63\times10^{-34})(3\times10^{8})}{(450\times10^{-9})}\times\frac{1}{1.6\times10^{-19}} = (1.61) + K_{max} \qquad \therefore K_{max} = 1.15 \text{ eV}$

2.3 A

A. The maximum speed of the photoelectrons is not affected by the intensity of the incident light.

B. Different types of metal have different work function ϕ.
By Einstein's photoelectric equation : $E = \phi + K_{max}$
For the same energy of photon, K_{max} and v_{max} is affected by ϕ.

C. K_{max} and maximum speed of the photoelectrons depend on the voltage applied to the photocell.
If the anode voltage is positive, the photoelectrons accelerate towards the anode.
If the anode voltage is negative, the photoelectrons decelerate towards the anode.

D. By Einstein's photoelectric equation : $hf = \phi + K_{max}$
Although the maximum kinetic energy K_{max} and maximum speed increases if the frequency f increases, but they not proportional

2.4 A

Power of light incident onto the cathode surface : $P = IA = (0.075)(4.5\times10^{-4}) = 3.375\times10^{-5}$ W

By $P = \frac{N}{t}E$ where $\frac{N}{t}$ is the number of photons incident onto the cathode surface per second

$\therefore (3.375\times10^{-5}) = \frac{N}{t}(2.8\times1.6\times10^{-19}) \qquad \therefore \frac{N}{t} = 7.53\times10^{13}\text{ s}^{-1}$

Each photon gives one photoelectrons. Number of electrons emitted per second is equal to number of photons per second.

Number of photoelectrons emitted per second : $\frac{n}{t} = 7.53\times10^{13}\text{ s}^{-1}$

Saturation current : $i = \frac{n}{t}e = (7.53\times10^{13})(1.6\times10^{-19}) = 1.2\times10^{-5}\text{ A} = 12\times10^{-6}\text{ A} = 12\ \mu\text{A}$

2.5 D

Initial kinetic energy of electron = Final kinetic energy of electron + energy of the photon

$(4.5 \times 1.6 \times 10^{-19}) = \frac{1}{2} \times (9.11 \times 10^{-31})\, v^2 + (6.63 \times 10^{-34}) \times (6.5 \times 10^{14})$

$\therefore\ v = 8.0 \times 10^5\ \text{m s}^{-1}$

2.6 A

$KE = QV \quad \therefore\ QV = \frac{1}{2} m v^2 = \frac{m^2 v^2}{2m} = \frac{(mv)^2}{2m} = \frac{p^2}{2m} \quad \therefore\ p = \sqrt{2mQV}$

The de Broglie wavelength of the electron is given by : $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mQV}}$

✓ (1) $m\uparrow \Rightarrow \lambda\downarrow$ ∴ de Broglie wavelength decreases with the mass m

✓ (2) $Q\uparrow \Rightarrow \lambda\downarrow$ ∴ de Broglie wavelength decreases with the charge Q

✗ (3) $V\uparrow \Rightarrow \lambda\downarrow$ ∴ de Broglie wavelength should decrease with the voltage V

2.7 B

For the first excited state, principal quantum number : $n = 2$

By $r_n = n^2 r_1 \quad \therefore\ r_2 = (2)^2 (5.3 \times 10^{-11}) = 2.12 \times 10^{-10}\ \text{m}$

By $2\pi r = n\lambda \quad \therefore\ 2\pi (2.12 \times 10^{-10}) = (2)\lambda \quad \therefore\ \lambda = 6.7 \times 10^{-10}\ \text{m}$

OR

Angular momentum of the electron : $mvr = n\frac{h}{2\pi} = (2) \times \frac{(6.63\times10^{-34})}{2\pi} = 2.11 \times 10^{-34}\ \text{kg m}^2\ \text{s}^{-1}$

Linear momentum p of the electron :

$\therefore\ mv \times (2.12 \times 10^{-10}) = 2.11 \times 10^{-34}$

$\therefore\ p = mv = 9.953 \times 10^{-25}\ \text{kg m s}^{-1}$

De Broglie wavelength of the electron :

$$\lambda = \frac{h}{mv} = \frac{(6.63\times10^{-34})}{(9.953\times10^{-25})} = 6.7 \times 10^{-10}\ \text{m}$$

2.8 D

By $eV = \frac{1}{2} m v^2 = \frac{p^2}{2m} \quad \therefore p = \sqrt{2meV}$

De Broglie wavelength : $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}} = \frac{(6.63\times10^{-34})}{\sqrt{2(9.11\times10^{-31})(1.6\times10^{-19})(12\times10^{3})}} = 1.12 \times 10^{-11}\ \text{m}$

By Rayleigh criterion, resolving power : $\theta = 1.22\frac{\lambda}{d} = 1.22 \times \frac{(1.12\times10^{-11})}{(0.025)} \approx 5.5 \times 10^{-10}\ \text{rad}$

Q2. (a) Ionization energy of an atom is the minimum energy required to remove an electron from the atom. [1]

Ionization energy = 10.4 eV [1]

(b) (i) Inelastic collision would occur. [1]

(ii) The atom would be excited to the first excitation state. [1]

(iii) $[(-5.5)-(-10.4)] \times 1.6 \times 10^{-19} = \dfrac{(6.63\times 10^{-34})\times(3\times 10^{8})}{\lambda}$ [1]

$\therefore\ \lambda = 2.54 \times 10^{-7}$ m

It belongs to ultra-violet radiation. [1]

(iv) Loss of kinetic energy of the electron during collision $= (-5.5)-(-10.4) = 4.9$ eV

$\therefore\ (6.0-4.9) \times 1.6 \times 10^{-19} = \frac{1}{2}(9.11 \times 10^{-31})\, v^2$ [1]

$\therefore\ v = 6.22 \times 10^{5}$ m s^{-1} [1]

(c) (i) The photon would not be absorbed since the atom has no difference of energy levels exactly equal to 6 eV. [1]

< Note : "inelastic collision occur" is not accepted >

(ii) The photon would be absorbed by the atom and the atom is ionized. [1]

Section C : Energy and Use of Energy

3.1 D

At the point X : $\cos\theta = \frac{1.8}{3.6} = 0.5$ where θ is the incident angle of light ray onto the floor at X

Illuminance at a point on a surface : $E = \frac{\Phi}{4\pi r^2}\cos\theta$

$\therefore\ (10) = \frac{\Phi}{4\pi(3.6)^2}(0.5)$ $\therefore\ \Phi = 3257\ \text{lm}$

Efficacy of the lamp $= \frac{\Phi}{P} = \frac{(3257)}{(35)} = 93\ \text{lm W}^{-1}$

3.2 D

First one : COP $= \frac{Q_C}{W} = 3.5$ $\therefore\ Q_C = 3.5\,W$

$\therefore\ Q_H = Q_C + W = 3.5\,W + W = 4.5\,W$

Second one : COP $= \frac{Q_C'}{2W} = 3.5$ $\therefore\ Q_C' = 7\,W$

$\therefore\ Q_H' = Q_C' + W = 7\,W + W = 8\,W$

Ratio of thermal energy released to environment $= 4.5 : 8 = 9 : 16$

3.3 C

(1) The compressor C compresses the vapour refrigerant into liquid to release latent heat of vaporization. The heat Q_H is then released to indoor to give warm air, thus, flow of refrigerant : $C \rightarrow B \rightarrow A \rightarrow D$

(2) When the vapour refrigerant flows from C to B, it undergoes condensation in component B to release latent heat of vaporization, thus B is the condenser.

(3) When the liquid refrigerant flows from A to D, it undergoes evaporation at the evaporator D to absorb heat or give cold. Thus, D has the lowest temperature.

3.4 C

For the outside temperature at 30 °C :

Rate of heat transfer by conduction $= UA\,\Delta T = UA\,(30 - 25) = 5\,UA$

Rate of heat transfer by radiation = rate of heat transfer by conduction $\times \frac{1}{2} = (5\,UA) \times \frac{1}{2} = 2.5\,UA$

Cooling capacity of air-conditioner = total rate of heat transfer into the room by conduction and radiation

$\therefore\ P = 5\,UA + 2.5\,UA = 7.5\,UA$

If the outside temperature changes to 35 °C :

Rate of heat transfer by conduction $= UA\,\Delta T = UA\,(35 - 25) = 10\,UA$

Rate of heat transfer by radiation is still $2.5\,UA$

$\therefore\ P' = 10\,UA + 2.5\,UA = 12.5\,UA = \frac{12.5}{7.5}P = 1.7\,P$

3.5 B

Work done by the car engine = gain of $K.E.$ of the car

$\therefore W = \frac{1}{2}mv^2 = \frac{1}{2}(2000)(100 \times \frac{1000}{3600})^2 = 771600$ J

Power output of the car engine : $P_{out} = \frac{W}{t} = \frac{(771600)}{(3.8)} = 203$ kW

Efficiency $= \frac{203}{450} \times 100\% = 45\%$

3.6 A

Mass defect = (235.0439 + 1.0087) − (143.9139 + 89.8973 + 2 × 1.0087) = 0.224 u

Energy release = 0.224 × 931 = 208.544 MeV

1 mole of U-235 consists of 6.02×10^{23} U-235

Total energy release by 1 mole of U-235 = $(6.02 \times 10^{23})(208.544 \times 10^6 \times 1.6 \times 10^{-19}) = 2.0 \times 10^{13}$ J

3.7 D

By $E_{out} = P_{out}\,t = \frac{1}{2}\rho A v^3 \times \eta \times t$

For the first 2 hours : $E_1 = \frac{1}{2}(1.2)(\pi \times 15^2) \times (20)^3 \times 30\% \times (2 \times 3600) = 7.33$ GJ

For the next 3 hours : $E_2 = \frac{1}{2}(1.2)(\pi \times 15^2) \times (10)^3 \times 30\% \times (3 \times 3600) = 1.37$ GJ

Total energy output = 7.33 + 1.37 = 8.7 GJ

3.8 C

By $P_{out} = \frac{m}{t}gh \times \eta$ where $\frac{m}{t} = \rho\frac{V}{t}$

$\therefore (230 \times 10^6) = (1000) \times \frac{(2.5 \times 10^6)}{(3600)} \times (9.81) \times (75) \times \eta$

$\therefore \eta = 45\%$

Q3. (a) Mass defect $= 1.00728 \times 92 + 1.00867 \times (235 - 92) - 235.04396 = 1.86561$ u [1]

Binding energy per nucleon of ${}^{235}_{92}U = 1.86561 \times 931 \times \frac{1}{235} = 7.39$ MeV / nucleon [1]

(b) (i) Uncontrolled chain reaction occurs and the reactor would be overheated and burnt. [1]

(ii) The chain reaction cannot be maintained and the reactor would finally shut down. [1]

(c) (i) All the fission neutrons would be absorbed and the reactor would shut down. [1]

(ii) The fast fission neutrons cannot be slowed down and captured by the U-235 nuclei. The chain reaction would stop eventually. [1]

(d) (i) Energy release $= 8.35 \times 142 + 8.57 \times 91 - 7.39 \times 235 = 228.92$ MeV < accept 229 MeV > [1]

Mass defect $= \frac{(228.92)}{931} = 0.246$ u [1]

(ii) $\frac{N}{t} = \frac{45 \times 10^{-6}}{235} \times (6.02 \times 10^{23}) = 1.153 \times 10^{17}\ s^{-1}$

$P = (1.153 \times 10^{17}) \times (228.92 \times 10^{6} \times 1.6 \times 10^{-19}) \times 35\% = 1.48 \times 10^{6}$ W < accept 1.48 MW >

Section D : Medical Physics

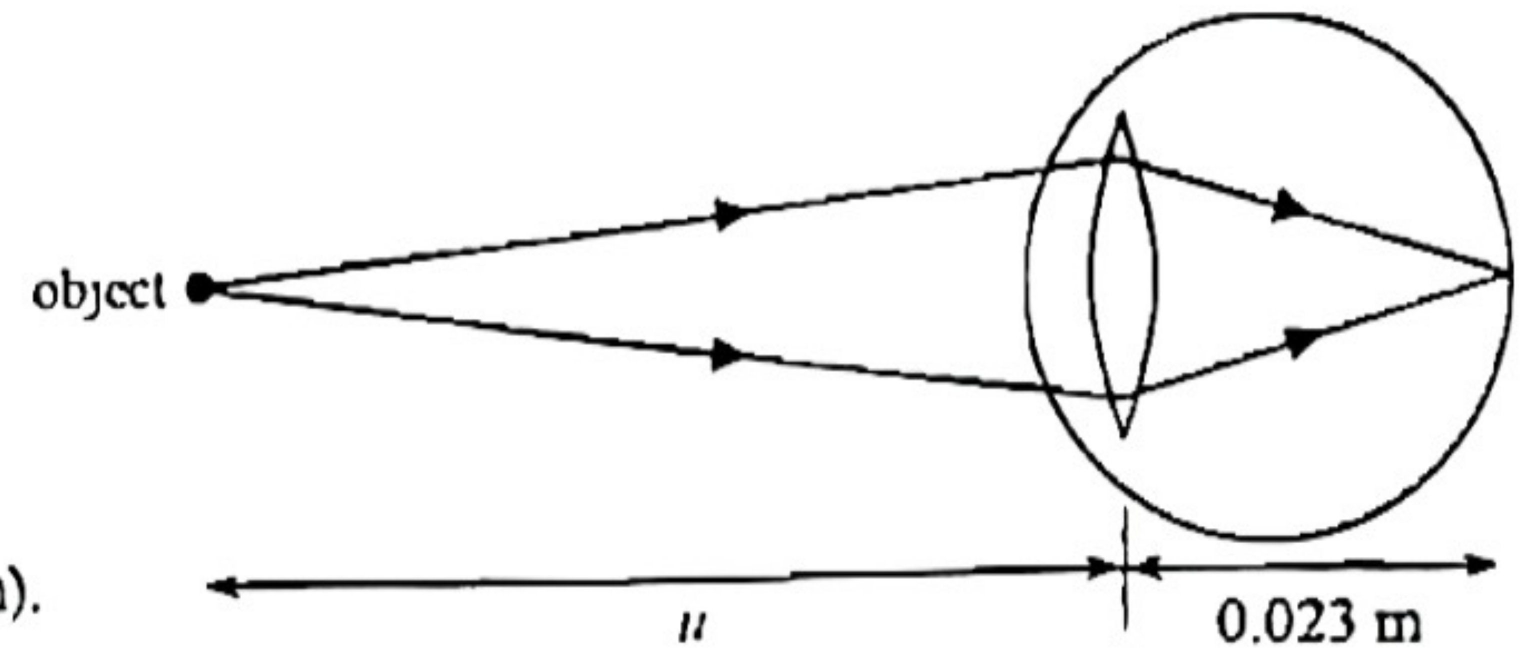
4.1 C

For the eye-lens to have maximum power, the eye-lens is the thickest and it is used to view closest object.

By $P = \frac{1}{u} + \frac{1}{v}$

$\therefore \quad (+45) = \frac{1}{u} + \frac{1}{(0.023)}$

$\therefore \; u = 0.657$ m



The closest point that the eye can see is 0.657 m (65.7 cm).

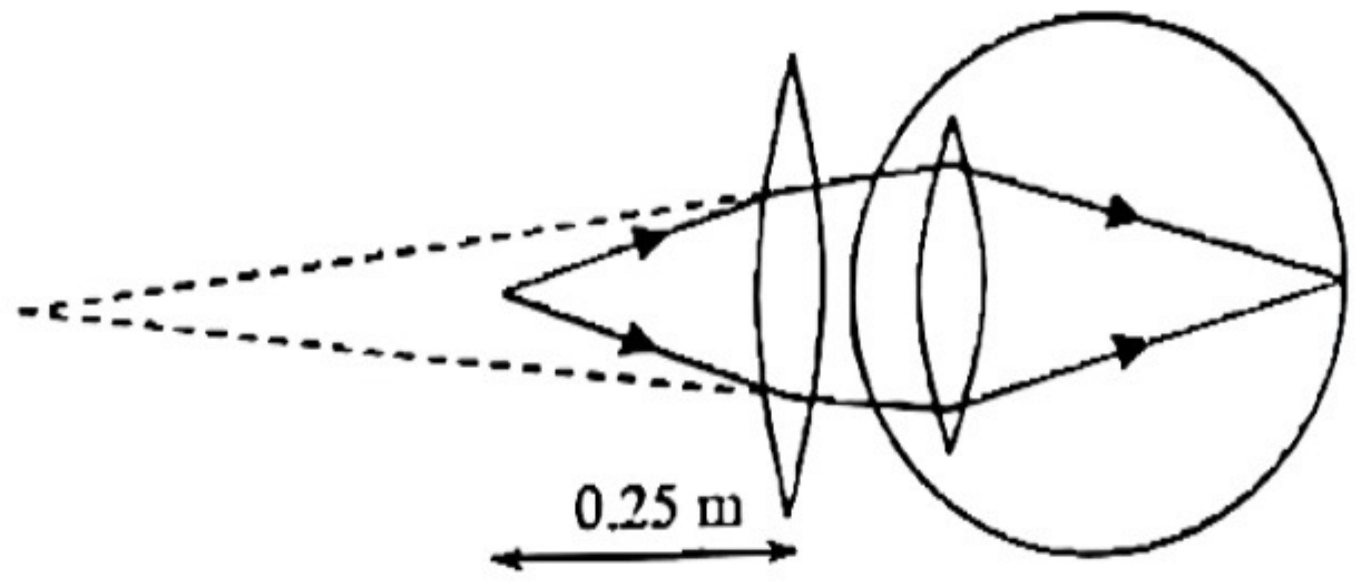
He is suffering from long-sight.

To correct this defect, he should wear convex lens.

To view a close object at 25 cm,

the image should be seemed to be at 65.7 cm

$P = \frac{1}{u} + \frac{1}{v} = \frac{1}{(0.25)} + \frac{1}{(-0.657)} \approx +2.5$ D



4.2 C

The angular separation of the two objects : $\theta = \frac{a}{L}$ $\quad \therefore \; \theta = \frac{(4 \times 10^{-3})}{(25)} = 1.6 \times 10^{-4}$ rad

This angle is equal to the resolving power of the eye if he can just resolve them.

By Rayleigh criterion : $\theta = \frac{1.22\lambda}{d}$

$\therefore \quad (1.6 \times 10^{-4}) = 1.22 \times \frac{(450 \times 10^{-9})}{d}$ $\qquad \therefore \; d = 3.43 \times 10^{-3}$ m $= 3.43$ mm ≈ 3.4 mm

4.3 B

By $\frac{I_2}{I_1} = (\frac{d_1}{d_2})^2 = (\frac{10}{8})^2 = \frac{25}{16}$

By $L_2 - L_1 = 10 \log (\frac{I_2}{I_1})$ $\qquad \therefore \; L_2 - (50) = 10 \log (\frac{25}{16})$ $\qquad \therefore \; L_2 = 51.9$ dB

When the power is doubled, the intensity is also doubled.

By $L_2 - L_1 = 10 \log (\frac{I_2}{I_1})$ $\qquad \therefore \; L_2 - (51.9) = 10 \log (2)$ $\qquad \therefore \; L_2 = 54.9 \approx 55$ dB

4.4 B

By $d = \frac{1}{2} v t$ $\qquad \therefore \; v \propto \frac{d}{t}$ $\qquad \therefore \; \frac{v_b}{v_s} = \frac{d_b}{d_s} \times \frac{t_s}{t_b}$

The time travelled in soft tissue is 2 units and that in bone is 3 units, they are in the ratio of 2 : 3.

$\therefore \quad \frac{v_b}{(1510)} = \frac{6.5}{2.0} \times \frac{2}{3}$ $\qquad \therefore \; v_b = 3270 \text{ m s}^{-1}$

4.5 C

Acoustic impedance of tissue X : $Z_1 = \rho_1 c_1 = (932) \times (1470) = 1.37$ MRayl

Acoustic impedance of tissue Y : $Z_2 = \rho_2 c_2 = (1085) \times (1580) = 1.71$ MRayl

Intensity reflection coefficient between X and Y : $\alpha = \dfrac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} = \dfrac{(1.71 - 1.37)^2}{(1.71 + 1.37)^2} = 0.0122$

Intensity of ultrasound transmitted through the interface : $I = (1 - \alpha) I_o = (1 - 0.0122) \times (25) = 24.7$ mW cm^{-2}

4.6 A

$$I = I_o \times \left(\frac{1}{2}\right)^{\frac{(1.5)}{(2.8)}} \times \left(\frac{1}{2}\right)^{\frac{(2.5)}{(3.6)}} = 0.43\, I_o$$

OR

$$I = I_o\, e^{-\frac{\ln 2}{(2.8)} \times (1.5)} \times e^{-\frac{\ln 2}{(3.6)} \times (2.5)} = 0.43\, I_o$$

4.7 B

By $\dfrac{1}{T_e} = \dfrac{1}{T_b} + \dfrac{1}{T_p}$

$\therefore \dfrac{1}{T_e} = \dfrac{1}{(2 \times 24)} + \dfrac{1}{(8)}$ $\qquad \therefore T_e = 6.857$ hours

By $\dfrac{A}{A_o} = \left(\dfrac{1}{2}\right)^{t/T_e}$

$\therefore \dfrac{A}{A_o} = \left(\dfrac{1}{2}\right)^{(12)/(6.857)} = 0.297 \approx 30\%$

4.8 A

(1) Both of them uses X-rays that make use of the degree of attenuation of the radiation through body tissue.

(2) Both of them uses X-rays that are ionizing radiation.

(3) CT scan can give high resolution image of various body tissues
but radiographic imaging cannot give high resolution or contrast for soft tissues.

Q4. (a) $\sin\theta_c = \dfrac{n_{clad}}{n_{core}} = \dfrac{(1.35)}{(1.58)}$ $\quad\therefore\ \theta_c = 58.7°$ [1]

$\theta_1 = 90° - 58.7° = 31.3°$

By $\sin\theta_{max} = n_1 \sin\theta_1$ $\quad\therefore\ \sin\theta_{max} = (1.58)\sin 31.3°$ $\quad\therefore\ \theta_{max} = 55.2°$ [1]

Since the incident angle 60° of the light ray is larger than θ_{max}, the light ray cannot be transmitted to the other end. [1]

(b) refractive index of cladding should decrease [1]

($\theta_{max}\uparrow \Rightarrow \theta_1\uparrow \Rightarrow \theta_c\downarrow \Rightarrow n_{clad}\downarrow$)

(c) The non-coherent bundle is used to transmit light into the organ for illumination. [1]

The coherent bundle is used to transmit images from the organ to the body outside for observation. [1]

(d) (i) The endoscope is inserted into the large intestine of the patient through his anus.

The doctor can then view through the endoscope to examine the polyp position. [1]

A tiny forceps can be placed through the endoscope to cut the polyp. [1]

(ii) Any **TWO** of the following : [2]

* The procedure is non-ionizing and does not cause harmful effect to the human body.
* The patients can rapidly recover with little discomfort after the operation.
* The endoscope can provide a clear view inside the organ.
* Tissues inside the organ can be cut and taken out for biopsy by using small forcep.