HONG KONG DIPLOMA OF SECONDARY EDUCATION

2020 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.

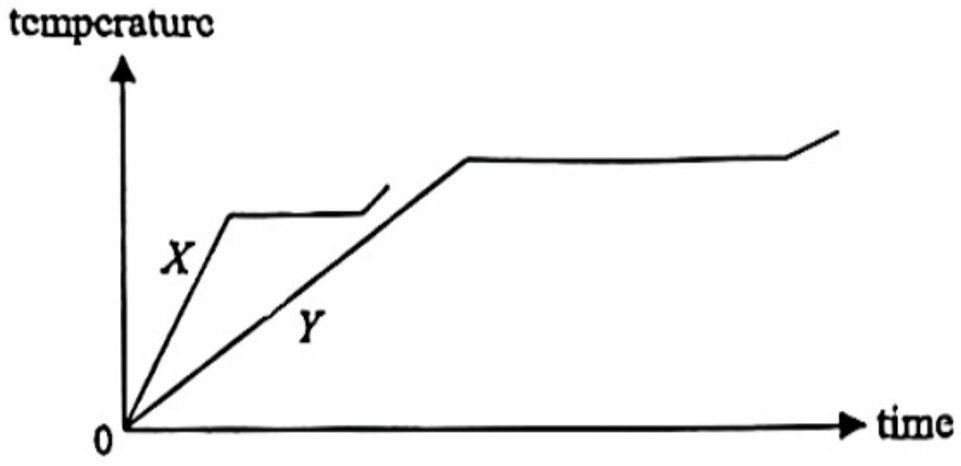
5. You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARKS** for that question.

6. No marks will be deducted for wrong answers.

Section A

There are 33 questions.

1.



Two solid substances X and Y are separately heated by two identical heaters. The figure shows the variation of the temperature of the substances with time. Which of the following deductions are correct ?

(1) The melting point of Y is higher than that of X.
(2) The heat capacity of solid Y is greater than that of Y.
(3) The specific latent heat of fusion of Y is greater than that of X.

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

2. When a cup of hot water is blown, water at the surface evaporates. This causes a drop of temperature of the water in the cup. Which of the following is/are the correct explanation(s) ?

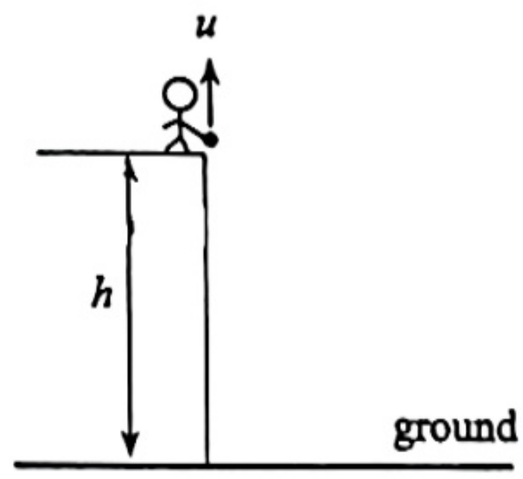
(1) The evaporated water absorbs latent heat of fusion from the remaining water in the cup.
(2) Water molecules of greater kinetic energy escape from the water surface.
(3) The average potential energy of water molecules in the cup decreases.

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

3. If the temperature of an ideal gas increases from 100 °C to 200 °C, the root-mean-square speed of the gas molecules will

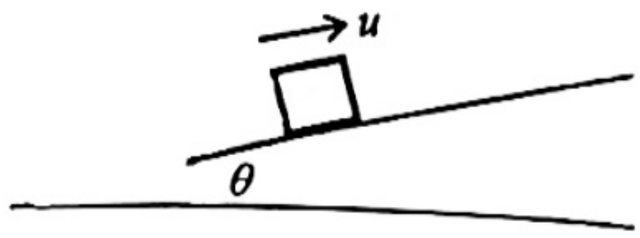
A. increase by 13%
B. increase by 27%
C increase by 33%
D. increase by 41%

4. A boy throws a small ball upwards with an initial velocity u of 12 m s^{-1} at the top of a building. The ball finally reaches the ground after a time of 5.4 s. If air resistance is negligible, what is the height h of the building ?



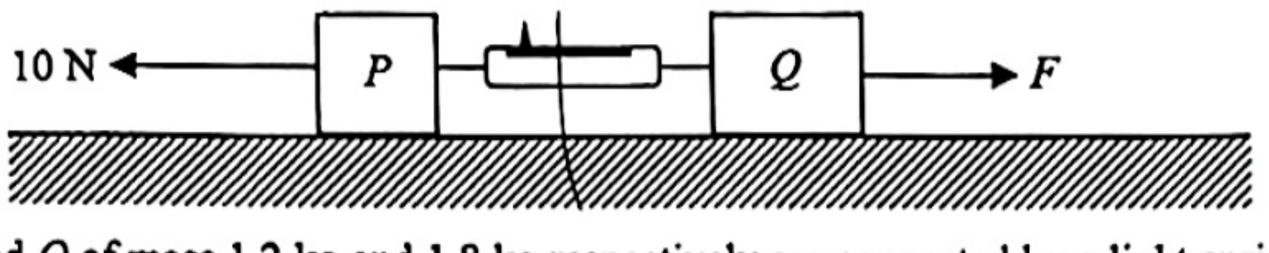
A 78 m
B. 128 m
C. 156 m
D. 208 m

5. A small block is projected up with an initial velocity u along a rough plane inclined at an angle of θ to the horizontal. It then moves up with a deceleration of 4.5 m s^{-2}. If the mass of the small block is 50 g and the friction acting on the block is 0.12 N, what is the angle θ?



A. 12.4°
B. 24.5°
C. 33.6°
D. 44.7°

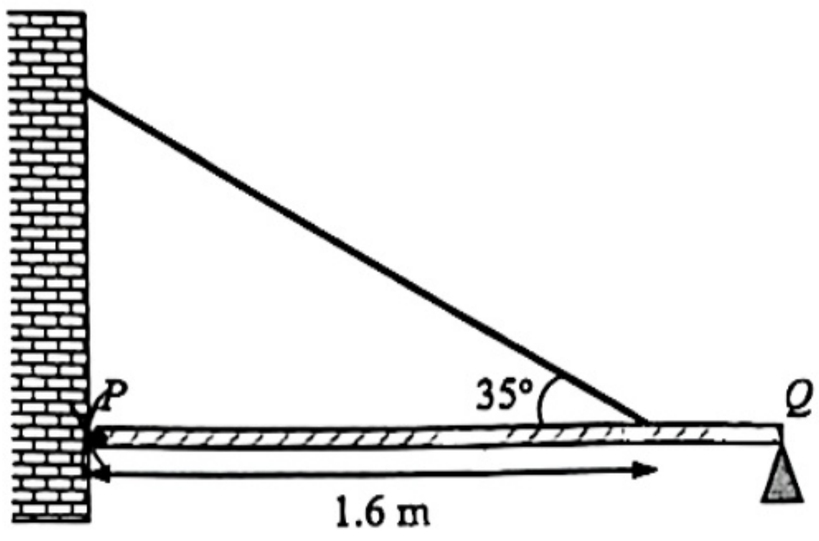
6.



Two blocks P and Q of mass 1.2 kg and 1.8 kg respectively are connected by a light spring balance and placed on a smooth horizontal surface as shown. When horizontal forces 10 N and F act on P and Q respectively, the whole system moves to the right with constant acceleration. If the reading of the spring balance is 11.8 N, what is the force F?

A. 5.5 N
B. 8.5 N
C. 12.5 N
D 14.5 N

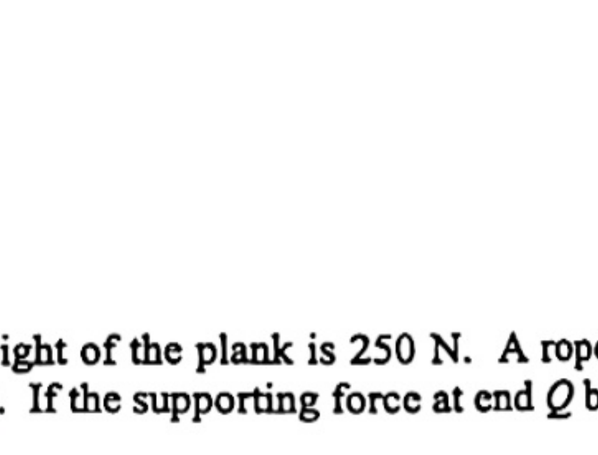
7.



A uniform plank PQ of length 2 m is hinged at end P and rests horizontally. The weight of the plank is 250 N. A rope is attached to the plank at a point 1.6 m from P and makes an angle of 35° with the plank. If the supporting force at end Q by a trestle is 80 N, find the tension of the rope.

A. 56 N
B. 69 N
C. 78 N
D. 98 N

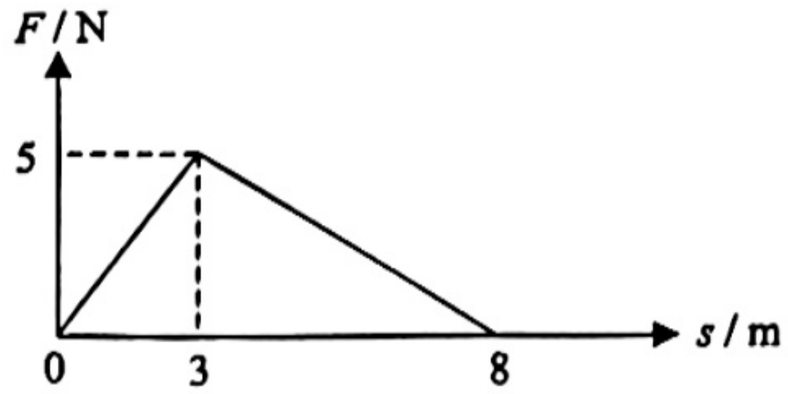
8. Billy is riding the 'Ferris Wheel' in an amusement park. The wheel is rotating at a uniform speed. Which of the following statements concerning the motion of Billy is/are correct?



(1) The mechanical energy of Billy is conserved.
(2) The momentum of Billy is conserved.
(3) The magnitude of centripetal force acting on Billy is constant.

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

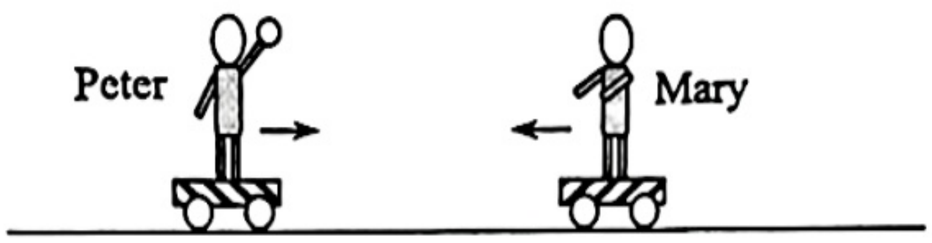
9.



A block of mass 2.5 kg is initially at rest on a smooth horizontal surface. A horizontal force F is applied to the block and the variation of the force with the displacement s is shown in the figure. What is the momentum of the block after the block has moved 8 m ?

A. 10 N s
B. 15 N s
C. 20 N s
D. 40 N s

10.

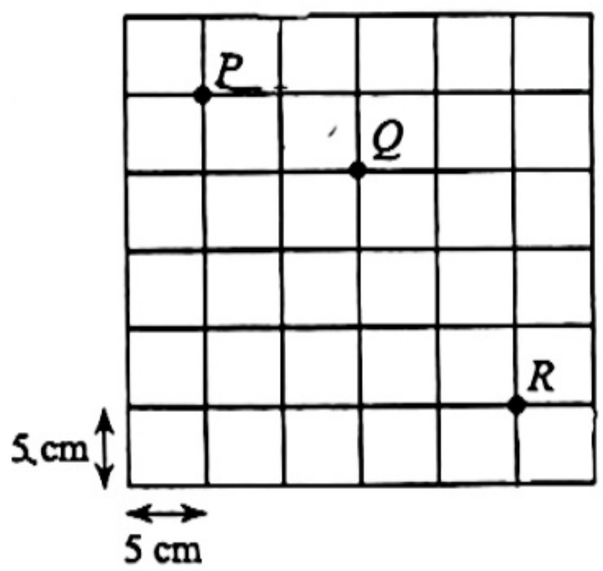


Two children, Peter and Mary, standing on light skateboards with frictionless rollers are moving towards each other as shown above. Both of them have the same mass of 24 kg and move at a speed of 1.2 m s^{-1}. Initially Peter holds a ball of mass 1.0 kg. He then throws the ball towards Mary and Mary catches the ball. The final velocity of Peter becomes 0.9 m s^{-1} towards the right after throwing the ball. Which of the following statements is/are correct ?

(1) The final velocity of Mary is 0.816 m s^{-1} after she catches the ball.
(2) The momentum of the ball is conserved throughout the motion.
(3) The mechanical energy of Peter, Mary and the ball is conserved.

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

11. The stroboscopic picture shows a particle projected horizontally at position P into the air in a vertical plane. Subsequently the particle reaches positions Q and R such that the time interval between P and Q is equal to that between Q and R. Each square of the grid measures 5 cm × 5 cm. Find the speed of the particle at R. Neglect air resistance. Take g to be 10 m s^{-2}.



A. 1.25 m s^{-1}
B 2.24 m s^{-1}
C. 2.84 m s^{-1}
D. 3.38 m s^{-1}

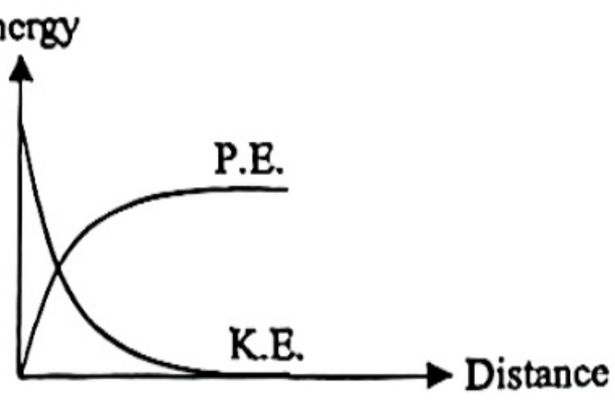
12. An aircraft of mass 6500 kg flies with a constant speed in a horizontal circle. Its wings slant an angle of 22.5° to the horizontal. What is the centripetal force acting on the aircraft ?

A. 24400 N
B. 26400 N
C. 36500 N
D. 58900 N

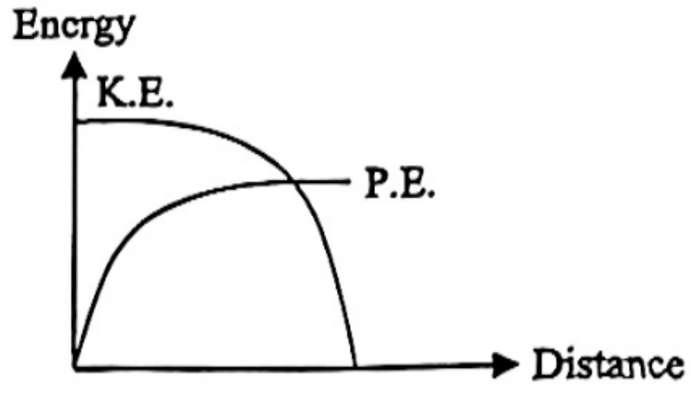
13.

A small block is given an initial velocity to move upwards along a rough inclined plane. Assume the friction is constant along the plane, which of the following graphs best represents the change of energy of the block during its upward motion ?

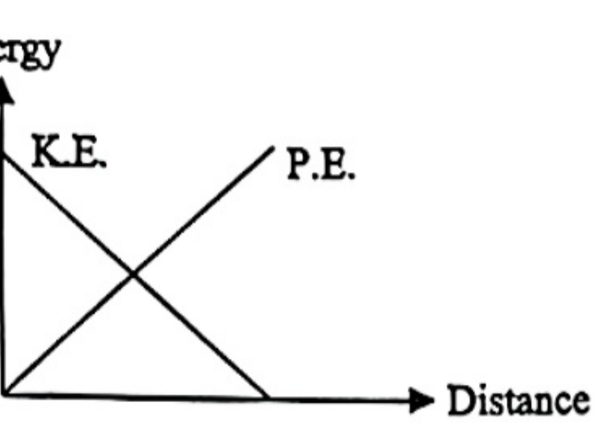
A.



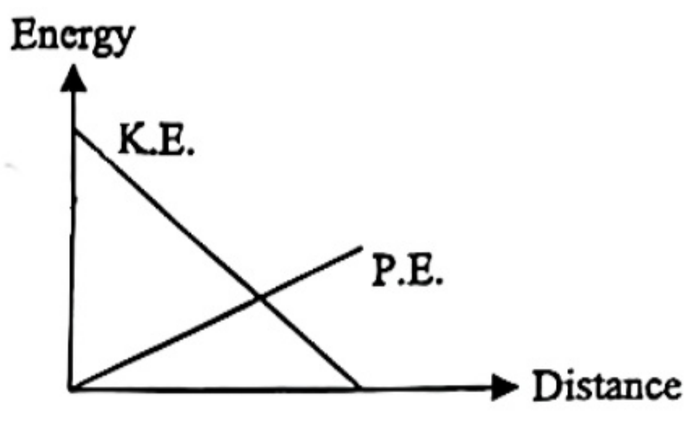
B.



C.

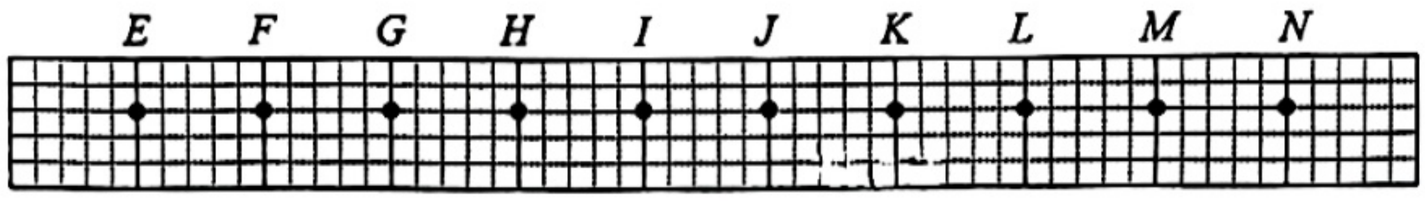


D.



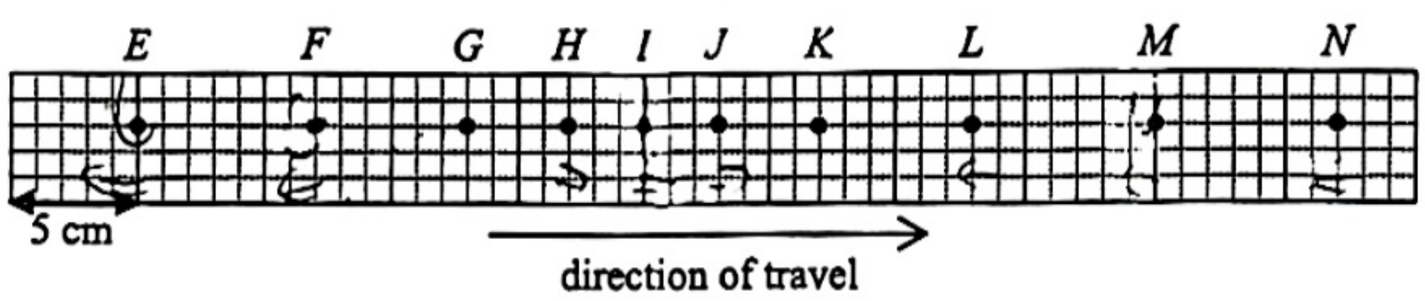
14.

Figure (a)



equilibrium positions

Figure (b)



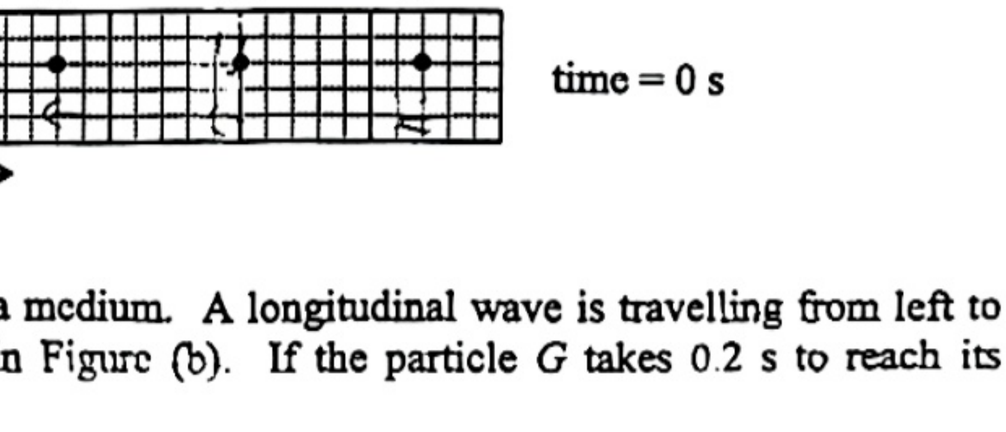
time = 0 s

Figure (a) shows the equilibrium positions of particles E to N in a medium. A longitudinal wave is travelling from left to right. At time = 0 s, the positions of the particles are shown in Figure (b). If the particle G takes 0.2 s to reach its equilibrium position, what is the speed of this longitudinal wave ?

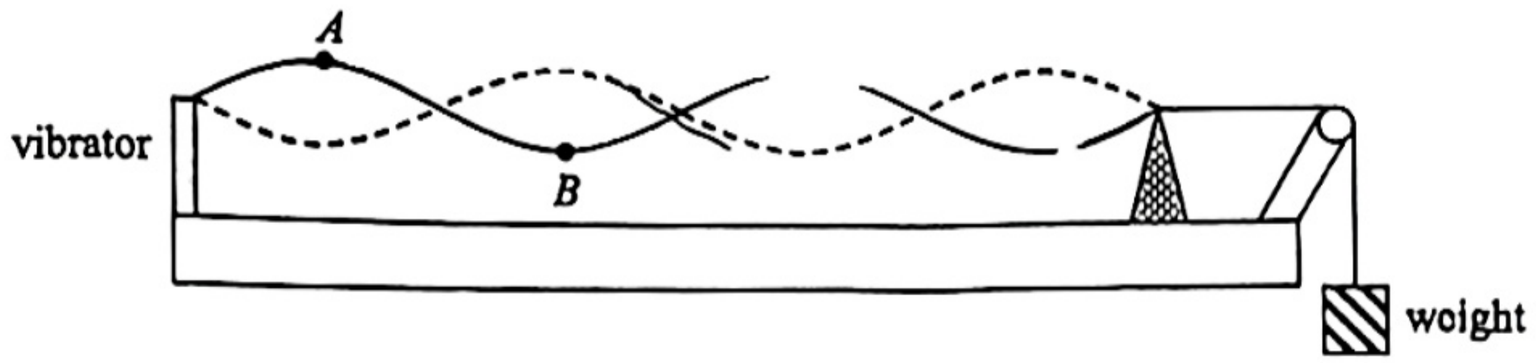
A. $15\ cm\ s^{-1}$
B. $25\ cm\ s^{-1}$
C. $50\ cm\ s^{-1}$
D. $75\ cm\ s^{-1}$

15. 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. On the line joining S_1 and S_2, how many points are undergoing constructive interference ?

A. 3
B 5
C. 7
D. 9



16.

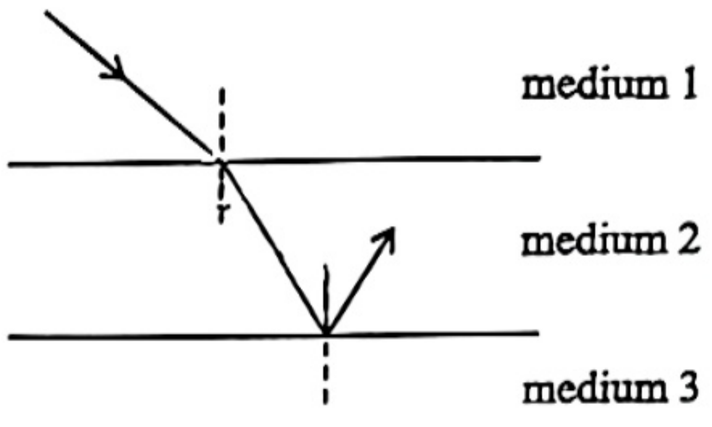


A string is set to vibrate at a fixed frequency by a vibrator attached to one end to form a stationary wave. The other end is attached to a weight to provide the tension. If the tension is increased by adding weights so that the speed of transverse wave along the string is doubled, which of the following statements are correct ?

(1) The wavelength will double.
(2) Particles *A* and *B* will vibrate in opposite phase.
(3) There will be 2 antinodes in the stationary wave.

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

17. A light ray travels from medium 1 to medium 2, and then undergoes total internal reflection when it meets medium 3 as shown in the figure. Arrange the refractive index n of the three media in ascending order.



A. $n_1 < n_2 < n_3$
B. $n_1 < n_3 < n_2$
C. $n_3 < n_1 < n_2$
D. $n_3 < n_2 < n_1$

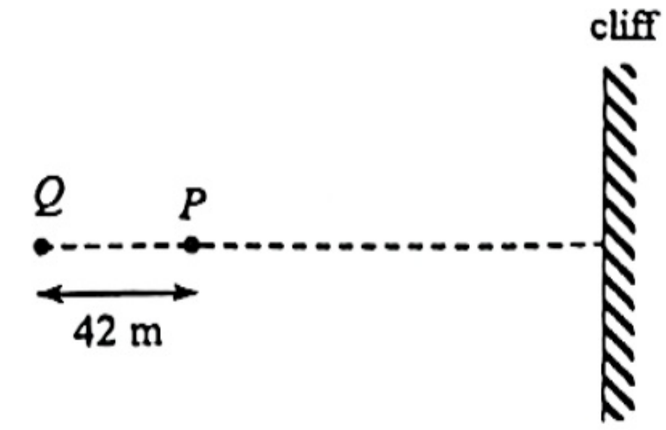
18. An object is placed at 24 cm from a lens. An erect image with magnification of 0.5 is produced. The lens is

A. convex lens of focal length 8 cm.
B. convex lens of focal length 24 cm.
C. concave lens of focal length 8 cm.
D. concave lens of focal length 24 cm.

19. Which of the following is **NOT** an application of the corresponding wave ?

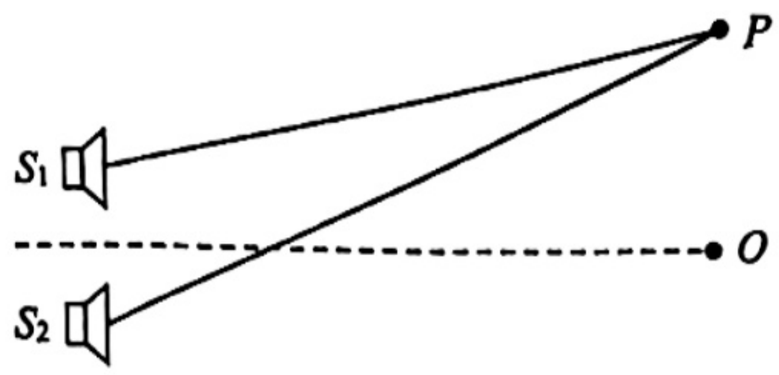
A. microwave for the detection of flying objects
B. infrared for the detection of cracks in metals
C. ultraviolet for the sterilization of drinking water
D. ultrasound for the auto-focusing in camera

20. A boy claps his hands in front of a cliff at the position *P* as shown. He hears the echo 0.5 s later. He then walks a distance of 42 m to the position *Q* and claps again. This time he hears the echo 0.75 s later. The speed of sound in air is



A. 328 m s^{-1}
B. 332 m s^{-1}
C. 336 m s^{-1}
D. 340 m s^{-1}

21.

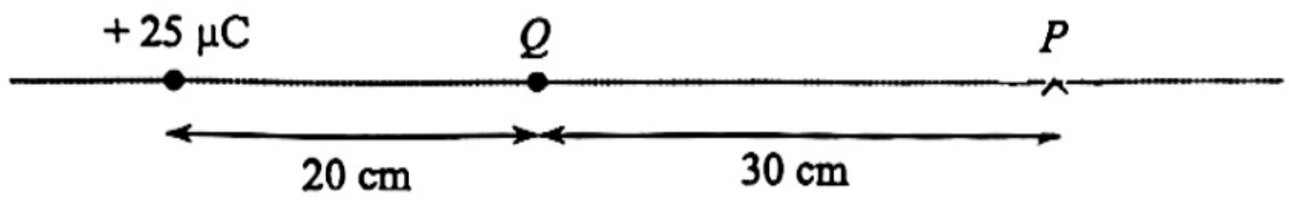


Loudspeakers S_1 and S_2 connected to a signal generator emit sound waves which are in opposite phase. Point O is equidistant from the loudspeakers while at point P minimum loudness is detected. The wavelength of the sound waves is λ. The separation between the two loudspeakers is 2λ. Which of the following statements are correct ?

(1) At O, maximum loudness should be detected.
(2) The path difference at P must be 1λ.
(3) If the frequency emitted by the signal generator is halved, the loudness detected at P will become maximum.

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

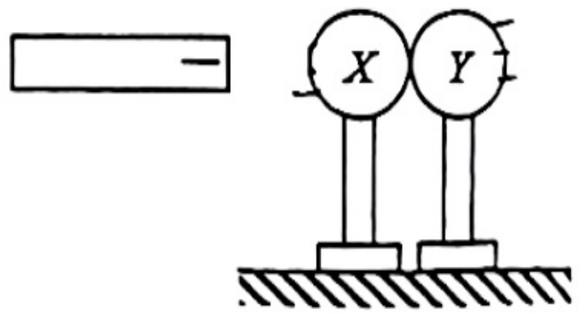
22.



A point charge of + 25 μC and another point charge of Q are separated at 20 cm. The neutral point P is at 30 cm to the right of Q. Find the charge Q.

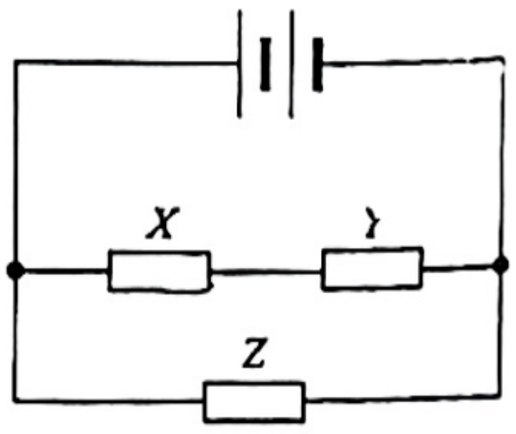
A. + 9 μC
B. + 15 μC
C. − 9 μC
D. − 15 μC

23. Two insulated uncharged metal spheres X and Y are placed in contact as shown. A negatively-charged rod is brought near X. X is then touched by a finger momentarily. The charged rod is then removed afterwards. Finally, two spheres are separated. Which of the following correctly describes the charges on X and Y ?



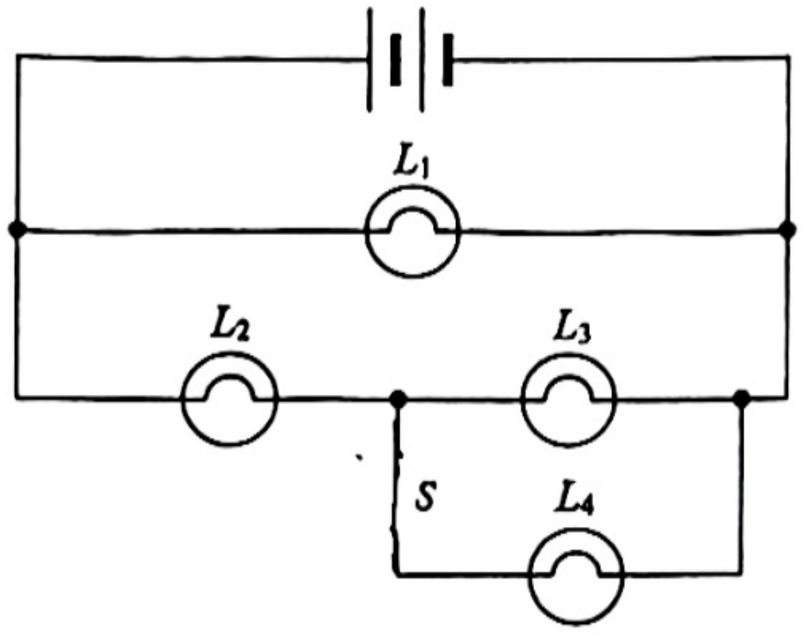
	sphere X	**sphere Y**
A.	uncharged	uncharged
B.	uncharged	negative
C.	positive	uncharged
D.	positive	positive

24. In the circuit, three identical resistors X, Y and Z are connected to a battery of negligible internal resistance. If the power dissipated in resistor X is 12 W, what is the total power supplied by the battery ?



A. 36 W
B. 48 W
C. 60 W
D. 72 W

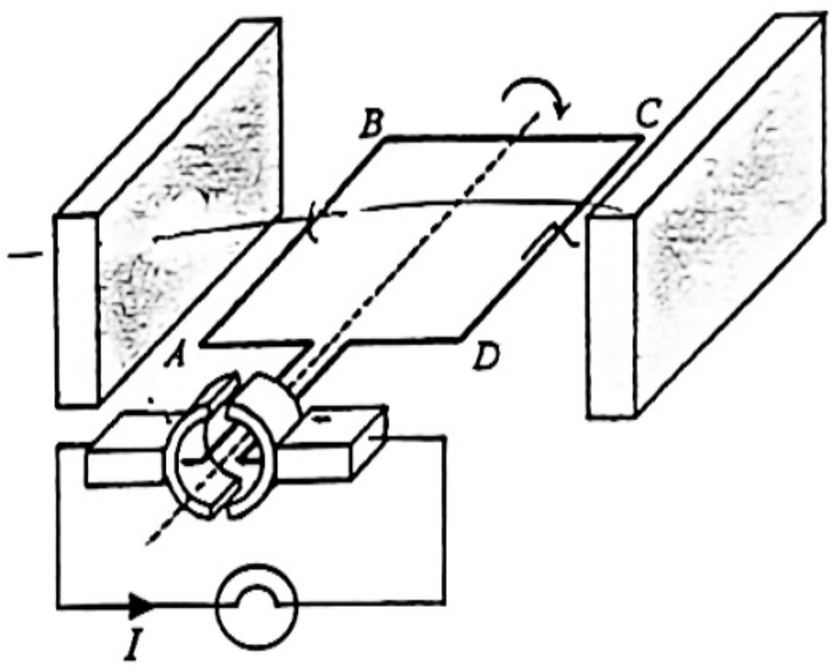
25.



A battery of negligible internal resistance is connected to 4 identical light bulbs L_1, L_2, L_3 and L_4 as shown in the figure. Which of the following statements is NOT correct after the switch S is closed ?

A. The power given out by the battery increases.
B. The current flowing through L_1 increases.
C. The brightness of L_2 increases.
D. The brightness of L_3 decreases.

26.



The figure shows a simple generator consisting of a coil between two slab shaped magnets. The coil $ABCD$ is rotated uniformly in clockwise direction and the current flows through the light bulb is in the direction indicated. Which of the following statements is correct ?

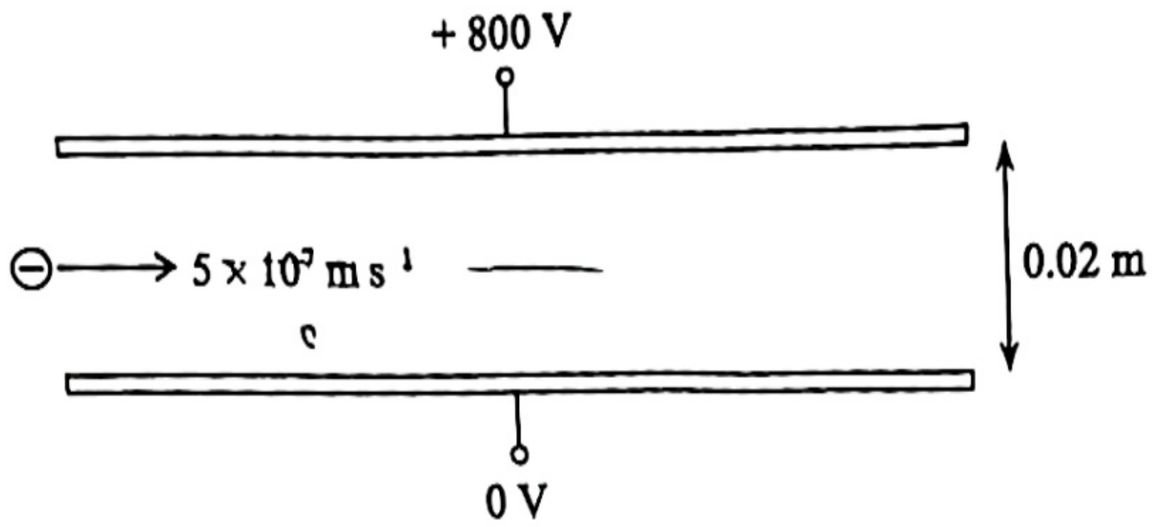
A. The direction of magnetic field produced by the magnets is from left to right.
B. The magnetic force acting on the side AB is in upward direction.
C. The current flowing through the light bulb is a d.c. steady current.
D. The potential at A is higher than the potential at B.

27. A portable transformer can give variable output voltage by varying the turns ratio of the primary coil and secondary coil. Assume that the efficiency of the transformer remains unchanged. If now the transformer is connected to a heating element of fixed resistance, which of the following is/are correct if the output voltage changes from 12 V to 24 V ?

(1) The power output by the transformer will double.
(2) The primary current of the transformer will become 4 times as before.
(3) The power loss of the transformer remains unchanged.

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

28.



An electron moving at a velocity of 5×10^7 m s^{-1} enters a region of cross fields consisting of an electric field and a magnetic field (not indicated) as shown. The electric field is set up by applying a potential difference of 800 V across the two parallel plates separated at 0.02 m. If the electron travels through the cross fields without deflection, what is the direction and the magnitude of the magnetic field within the parallel plates ? (Neglect the effect of gravity.)

	direction	magnitude
A	into paper	0.8 mT
B.	into paper	1.6 mT
C.	out of paper	0.8 mT
D	out of paper	1.6 mT

29.

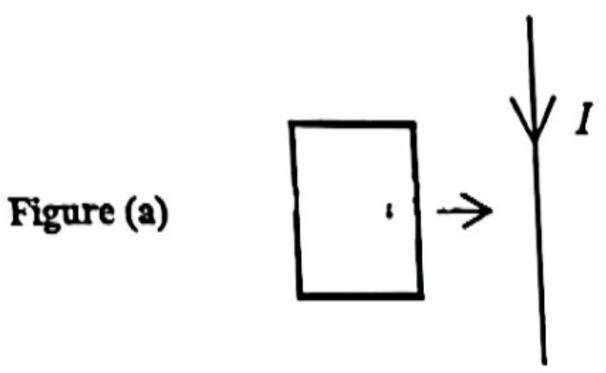


Figure (a)

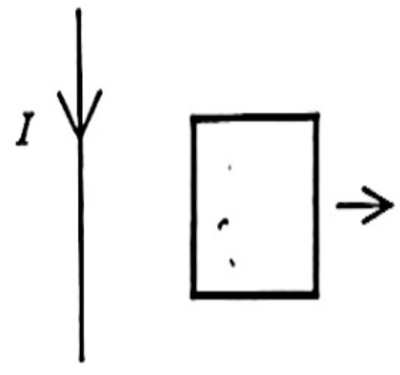
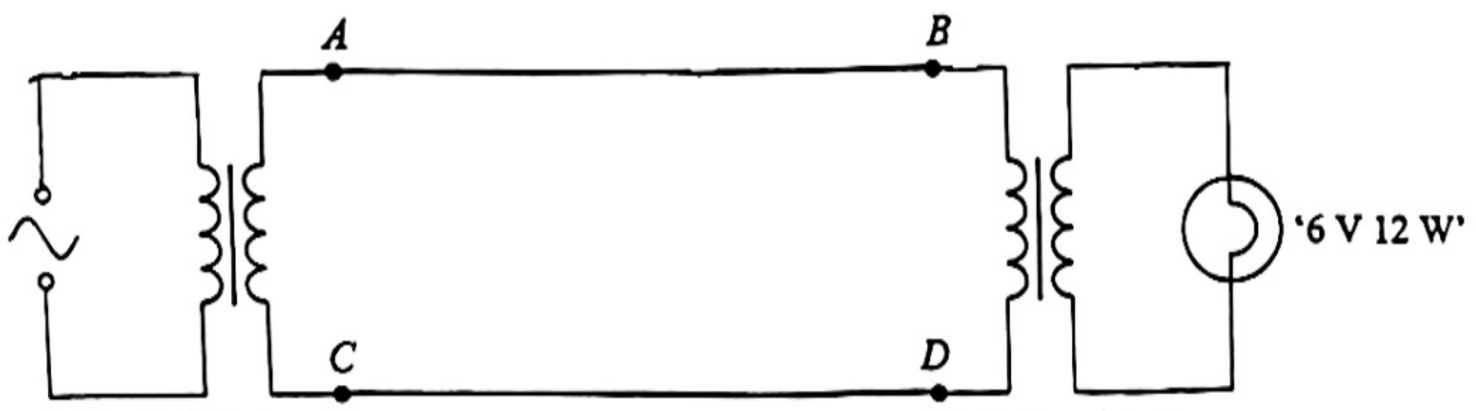


Figure (b)

The two figures above shows a rectangular metal coil moving from left to right with a uniform speed across an insulated metal wire carrying a steady current I in downward direction. Which of the following correctly describes the induced current at the positions shown in the two figures ?

	Figure (a)	Figure (b)
A.	clockwise	clockwise
B.	clockwise	anticlockwise
C.	anticlockwise	clockwise
D.	anticlockwise	anticlockwise

30



A.	1 : 10 step-up transformer
B.	10 : 1 step-down transformer

The figure shows a simple power transmission system. An a.c. supply and two ideal transformers are used to operate a lamp of rating '6 V, 12 W' by transmission of electrical power through 2 cables AB and CD, each has a resistance of 10 Ω. If the lamp works at its rated values, what is the efficiency in this power transmission system ?

A.	3%
B.	6%
C	94%
D.	97%

31. The initial activity of two radioactive sources, X and Y, are in the ratio of 1 : 2. Both X and Y decay to give stable daughter nuclei. The ratio of the half-life of X to that of Y is 2 : 3. What is the ratio of their activities after 6 hours ?

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

32. A medical tracer can be injected into the human body to reveal the function of a particular organ. Which of the following sources is most suitable for this purpose ?

A. β source with a half-life of 6 hours
B. β source with a half-life of 5 years
C. γ source with a half-life of 6 hours
D. γ source with a half-life of 5 years

33. Uranium-238 ($^{238}_{92}\mathrm{U}$) decays to thorium-234 ($^{234}_{90}\mathrm{Th}$) by emitting an alpha particle.

$$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

Given that : mass of $^{238}_{92}\mathrm{U} = 3.954096 \times 10^{-25}$ kg
mass of $^{234}_{90}\mathrm{Th} = 3.887521 \times 10^{-25}$ kg
mass of $^{4}_{2}\mathrm{He} = 6.6483 \times 10^{-27}$ kg

What is the energy released in this decay process ?

A. 4.8 MeV
B. 5.0 MeV
C. 5.2 MeV
D. 5.4 MeV

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	$u = 1.661 \times 10^{-27}\ \text{kg}$	(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 :

$$v = u + at$$

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

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

Mathematics

Equation of a straight line	$y = mx + c$
Arc length	$= r\theta$
Surface area of cylinder	$= 2\pi rh + 2\pi r^2$
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
$\left\|\dfrac{\Delta f}{f_0}\right\| \approx \dfrac{v}{c} \approx \left\|\dfrac{\Delta\lambda}{\lambda_0}\right\|$	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

$\frac{1}{2}m_e v_{max}^2 = hf - \phi$	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.	moment $= F \times d$	moment of a force
B3.	$E_p = mgh$	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.	$\frac{V_s}{V_p} = \frac{N_s}{N_p}$	ratio of secondary voltage to primary voltage in a transformer

E1.	$N = N_0e^{-\lambda t}$	law of radioactive decay
E2.	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$	half-life and decay constant
E3.	$A = kN$	activity and the number of undecayed nuclei
E4.	$E = mc^2$	mass-energy relationship

Hong Kong Diploma of Secondary Education Examination

2020

Mock Examination

PHYSICS PAPER 1

SECTION B : Question-Answer Book B

This paper must be answered in English

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.

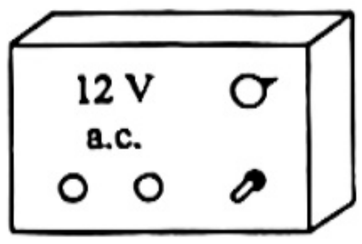
Please stick the barcode label here.

Candidate Number

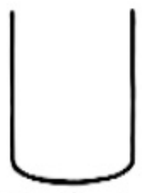
Question No.	Marks
1	6
2	6
3	8
4	9
5	9
6	8
7	9
8	11
9	9
10	9

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

1.

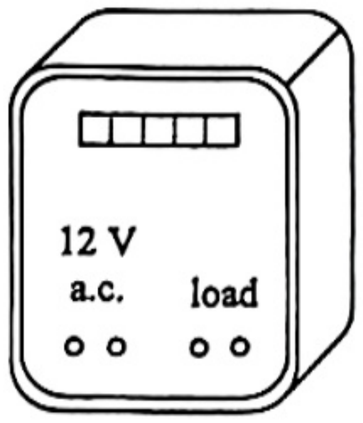


Low voltage power supply



Beaker

Funnel



Joulemeter

Crushed ice

Immersion heater

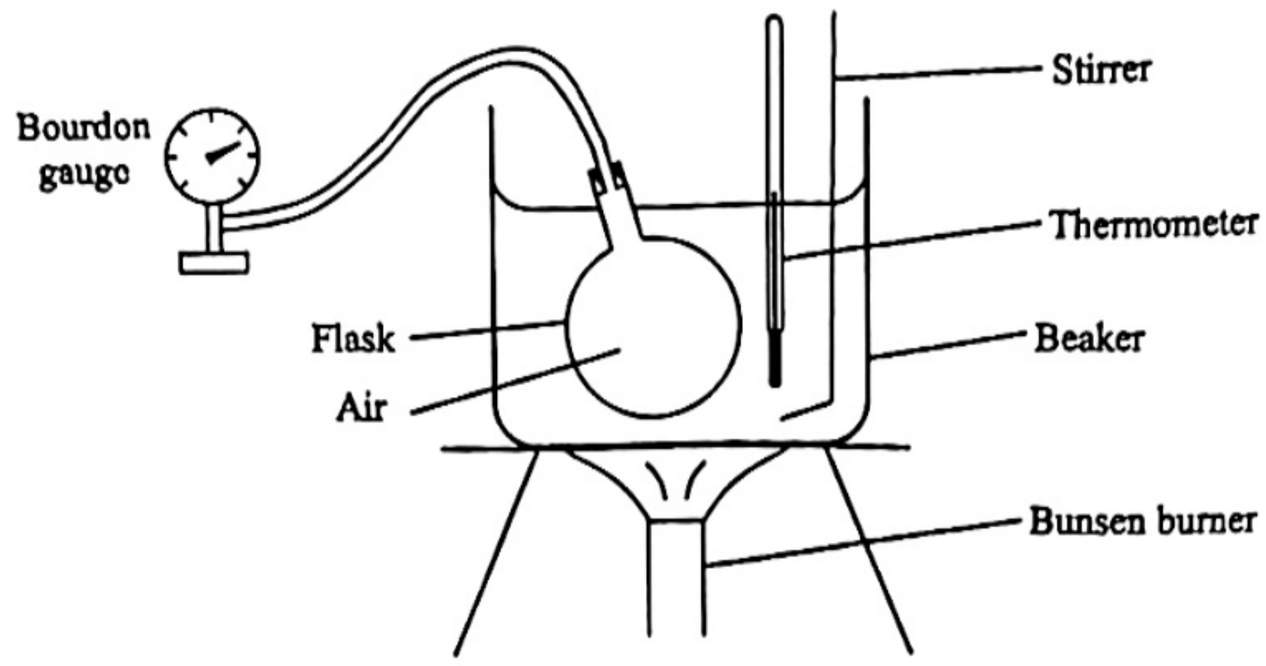
(a) Describe how the above apparatus can be set up to perform an experiment to measure the specific latent heat of fusion of ice L. State the physical quantities to be measured and an equation for finding L. (4 marks)

(b) (i) State a reason why crushed ice should be used instead of a lump of ice. (1 mark)

(ii) The result obtained in this experiment is found to be lower than the actual value of the specific latent heat of fusion of ice. Give a reason. (1 mark)

Answers written in the margins will not be marked.

2.



Donny uses the above set-up to study the relationship between pressure P and temperature θ of air inside a flask. He found that the pressure is 105 kPa at room temperature of 25 °C. When the water is heated up by the Bunsen burner to a temperature of 70 °C, the pressure increases to 120 kPa.

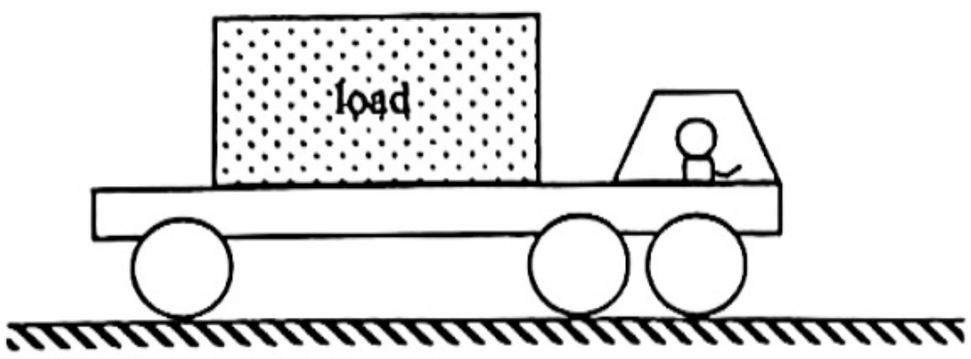
(a) Use the above result, determine the temperature of absolute zero in °C obtained in this experiment. Assume that the volume of the flask remains constant during the heating. (2 marks)

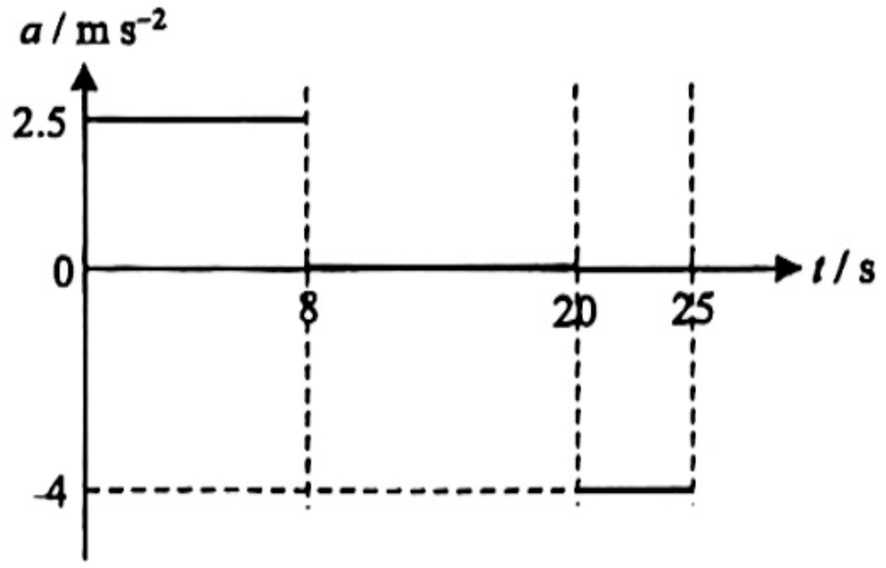
(b) If the molar mass of air is 28.8 g/mol, calculate the root-mean-square speed of air molecules at the temperature of 70 °C. Assume air is an ideal gas. (2 marks)

(c) When the temperature of air drops from 25 °C to 0 °C, the air pressure decreases. Use kinetic theory to explain such a change. (2 marks)

Answers written in the margins will not be marked.

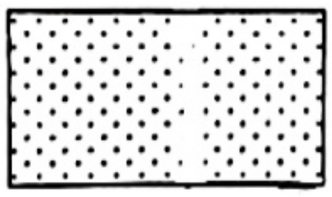
3.





A lorry of mass 2000 kg carrying a heavy load of mass 500 kg travels on a straight horizontal road. At time = 0, the lorry accelerates from rest with an acceleration of 2.5 m s^{-2} for 8 s as shown in the above a - t graph. The whole journey lasts for 25 s and the lorry finally comes to a rest. During the whole journey, the load moves together with the lorry without slipping.

(a) Draw and name the forces acting on the load during the first 8 s of acceleration. (2 marks)



(b) Calculate the friction acting on the load during the time interval from 20 s to 25 s. State the direction of friction during this time interval (forward or backward). (2 marks)

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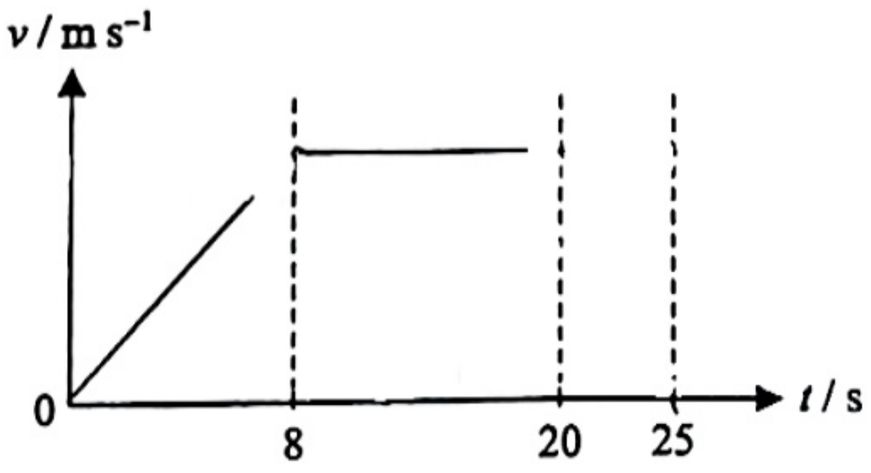
(c) Draw the time variation of the velocity of the lorry in the whole journey in the following v - t graph. Mark down the value of the maximum velocity of the lorry in the graph. (2 marks)



(d) Calculate the average velocity of the lorry during the whole journey. (2 marks)

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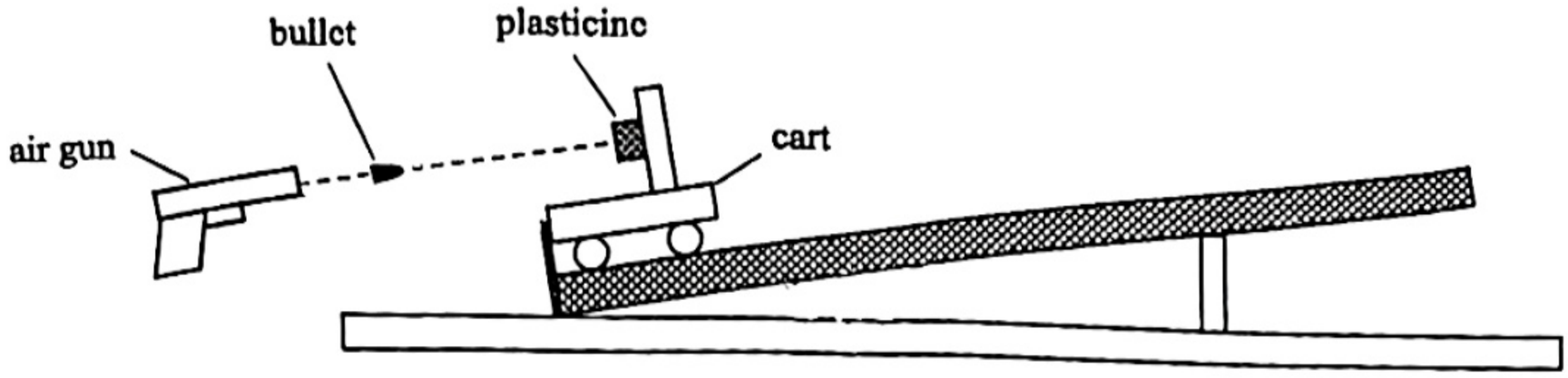
Answers written in the margins will not be marked.

4.



A small cart with a piece of fixed plasticine is initially at rest on a smooth inclined plane that makes an angle of 15° with the horizontal. The total mass of the cart is 72.5 g. A bullet of mass 2.5 g is fired from an air gun towards the cart as shown in the above figure. The air gun takes 5 ms to give the bullet a muzzle speed of 90 m s^{-1}. Neglect air resistance and take g to be 9.81 m s^{-2}.

(a) Find the average force exerted on the bullet by the gun during the firing of the bullet. (2 marks)

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(b) Assume the bullet embeds into the plasticine, calculate the speed of the cart after the collision. (2 marks)

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(c) After the collision, the cart moves up the inclined plane. Calculate the distance that the cart can travel before it comes to momentary rest at the maximum height. (2 marks)

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(d) A student states that all the initial kinetic energy of the bullet changes to the potential energy of the cart and bullet at the maximum height. Explain why his claim is not correct. (1 mark)

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(e) If now the plasticine on the cart is removed and the experiment is repeated, the bullet hits the cart and rebounds backward. Explain how the maximum distance travelled by the cart on the inclined plane would be affected compared to the previous case. (2 marks)

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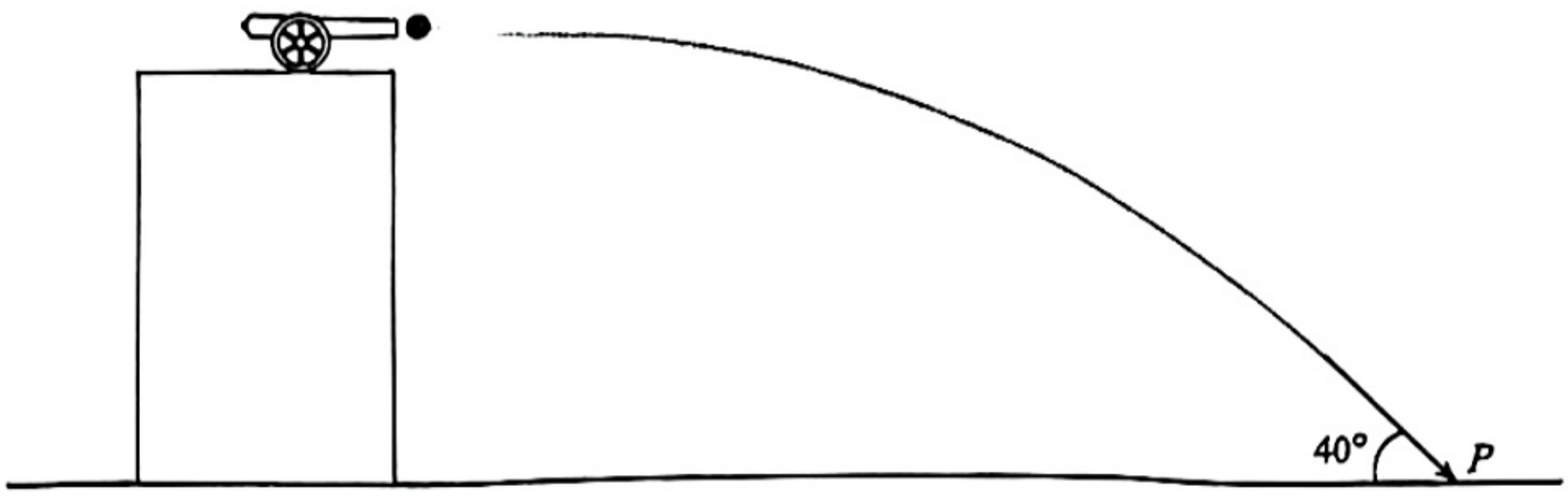
Answers written in the margins will not be marked.

5. (a)



A cannon fires a metal ball with an initial horizontal velocity from the top of a building. It reaches the ground at P with a final velocity v of 85 m s^{-1} making an angle of 40° with the horizontal ground as shown in the figure.

(i) Determine the height of the building above the ground. (3 marks)

(ii) Calculate the horizontal distance of point P from the building. (2 marks)

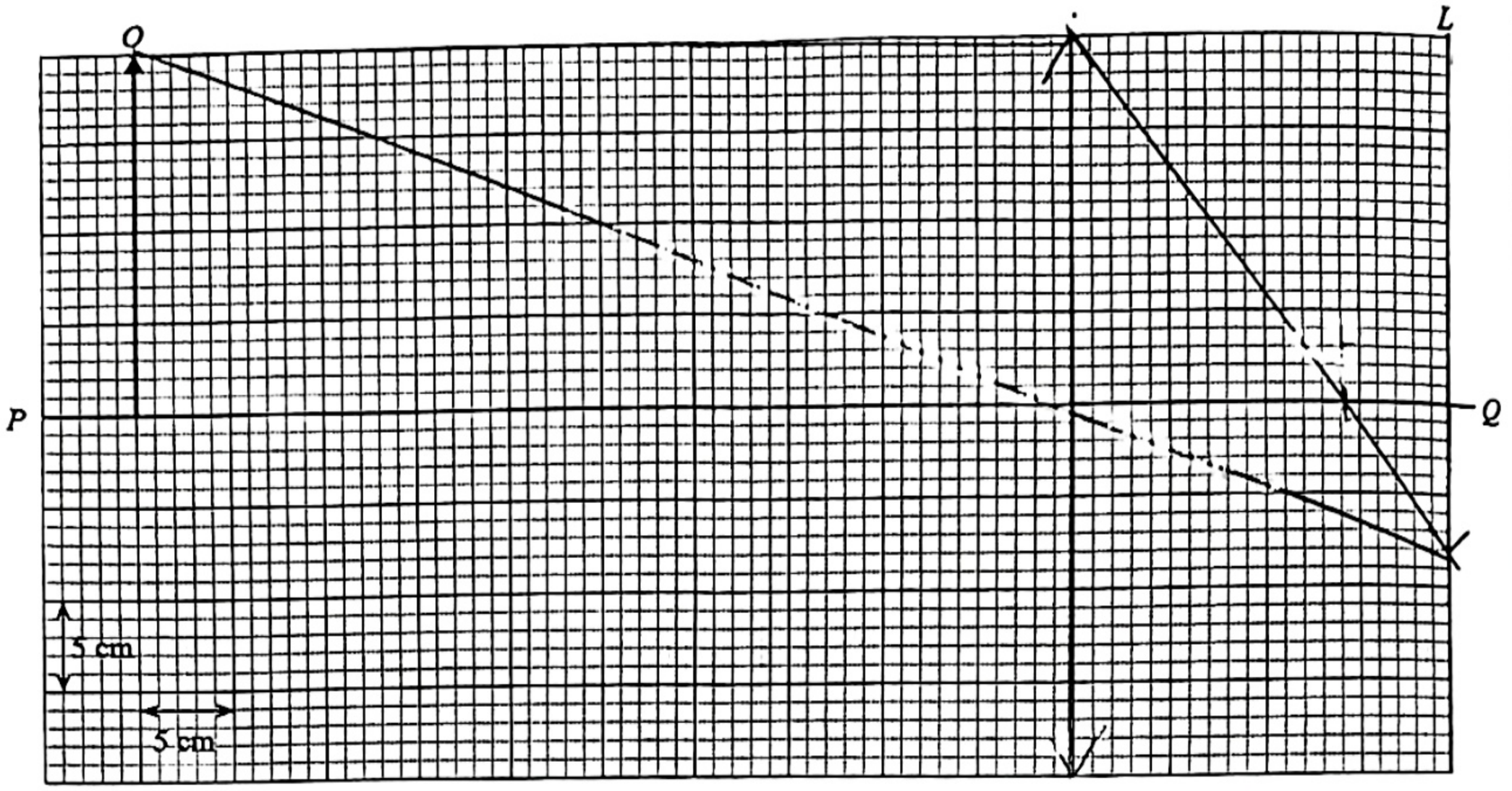
(b) Newton has argued that if a cannon-ball were fired horizontally at high enough speed from the top of a building, it would finally return to the same point and hit the cannon after revolving around the Earth. Given that the radius of the Earth is 6400 km. Neglect air resistance.

(i) Calculate the minimum speed of the cannon-ball to return to the original firing point. Assume the ball moves close to the Earth's surface. (2 marks)

(ii) Hence, or otherwise, determine the time taken for the cannon-ball to return to the cannon again. (2 marks)

Answers written in the margins will not be marked.

6.



In the above figure, PQ is the principal axis of a lens L that has not been drawn. An object O placed on the axis gives an image captured by the screen L as shown. It is known that the magnification of the image is 0.4.

(a) What type of lens is L ? Explain. (2 marks)

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(b) (i) Draw the image I on the screen. (1 mark)

(ii) By drawing a construction line, draw the lens L in the figure. (1 mark)

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

(c) Without changing the position of the object and the screen, by moving the lens a certain distance towards the object O, another sharp image can also be formed on the screen L.

(i) State the object distance u of this new position of the lens. (1 mark)

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(ii) Hence write down the magnification of the new image formed on the screen. (1 mark)

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(d) It is found that if the lens L is placed at a distance of 10 cm from the object O, no sharp image can be captured by the screen, no matter where the screen is placed. Explain. (1 mark)

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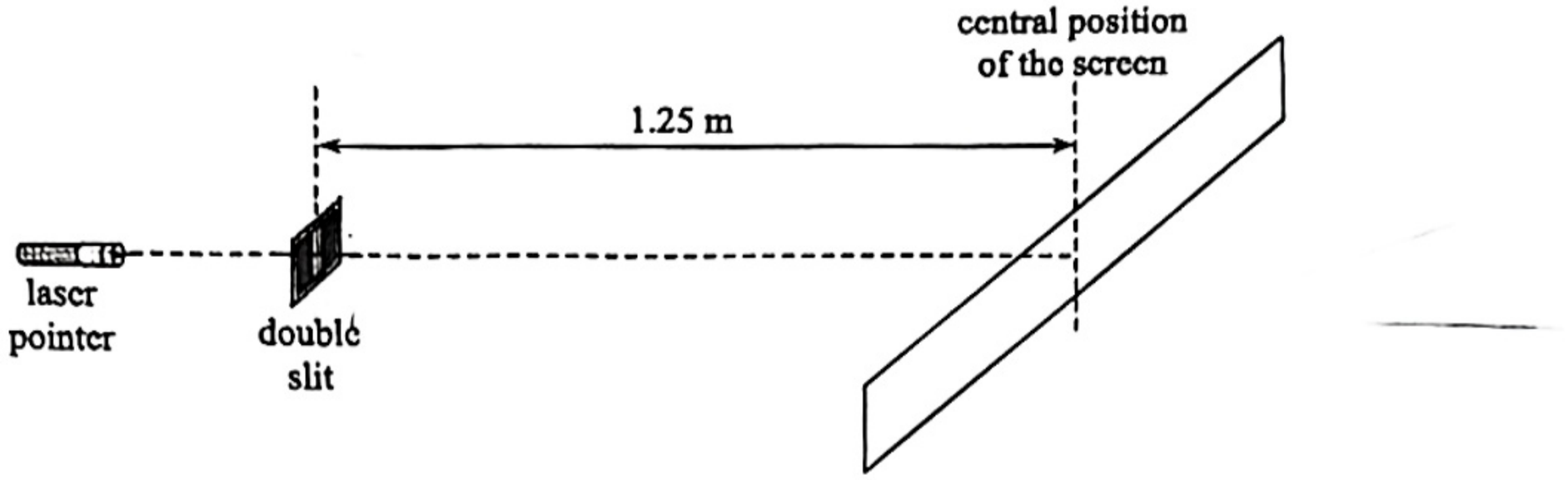
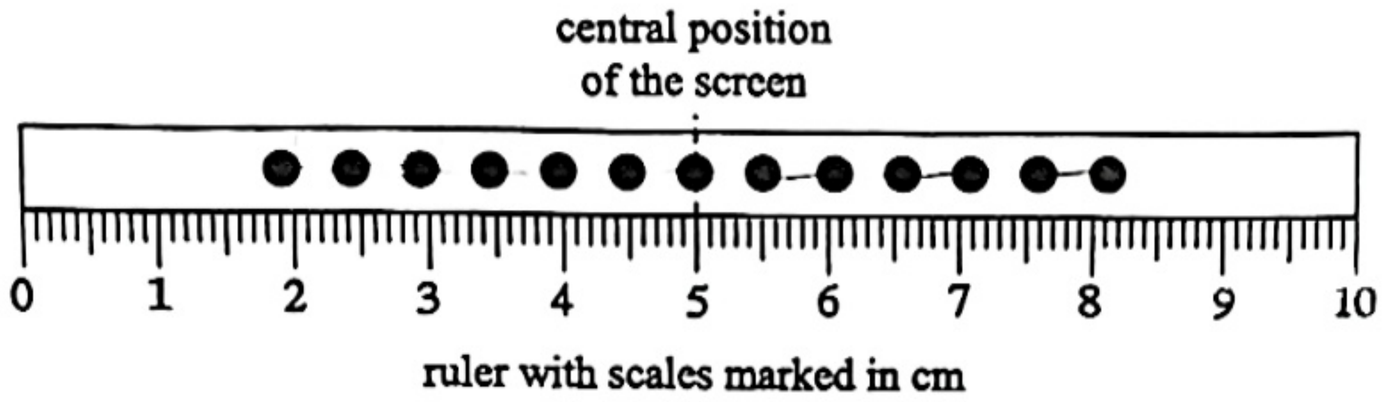
Answers written in the margins will not be marked.

7.



A laser beam emitting red light of wavelength 675 nm is directed perpendicularly towards a double slit as shown. A screen is placed at 1.25 m from the double slit. Only 13 bright spot can be seen on the screen as shown below :



ruler with scales marked in cm

(a) Find the slit separation a of the double slit from the above information. (3 marks)

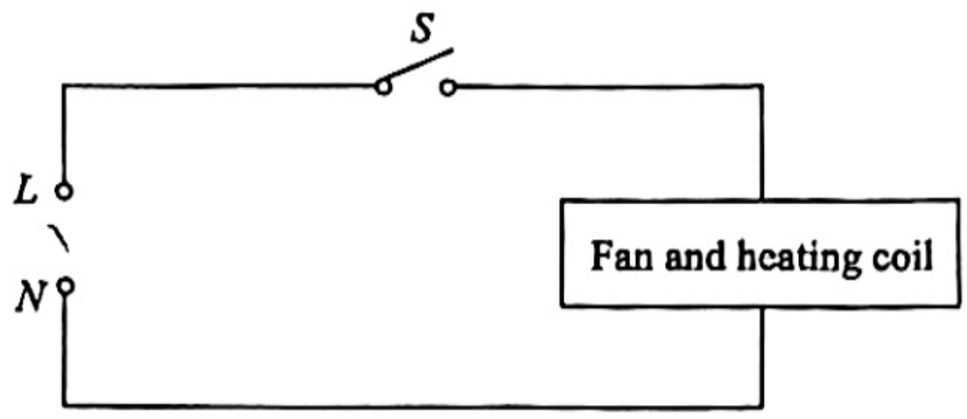
(b) If another double slit with the same slit separation a but smaller slit width is used, state **TWO** changes that can be observed concerning the bright spots projected on the screen. (2 marks)

(c) If another laser pointer emitting green light is used instead, explain the change of the separation between two adjacent spots projected on the screen. (1 mark)

(d) The double slit is then replaced by a diffraction grating of 2500 lines per cm. Calculate the separation between the two second-order bright spots projected on the screen for the same experimental settings. (3 marks)

Answers written in the margins will not be marked.

8.



A hair dryer with plastic cover consists of a fan and a heating coil. It is connected to the mains supply of 220 V. Switch *S* is installed on the live (*L*) wire as shown. The rating values of the heating coil is "800 W, 220 V". When switch *S* is closed, both the fan and the heating coil operate normally.

(a) Explain whether the fan and heating coil are connected in series or in parallel. (2 marks)

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(b) When the hair dryer operates normally, the current drawn from the mains supply is 4.5 A. Calculate the power rating of the fan. (2 marks)

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(c) A student argues that if the switch *S* is incorrectly connected to the neutral (*N*) wire, the hair dryer still operates even when the switch is off. Comment and state the potential hazard of this connection. (2 marks)

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(d) Explain whether the hair dryer requires the connection of earth wire. (1 mark)

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(e) If this hair dryer is brought to another country with mains supply of 120 V, what would be the power dissipated by the heating coil ? (2 marks)

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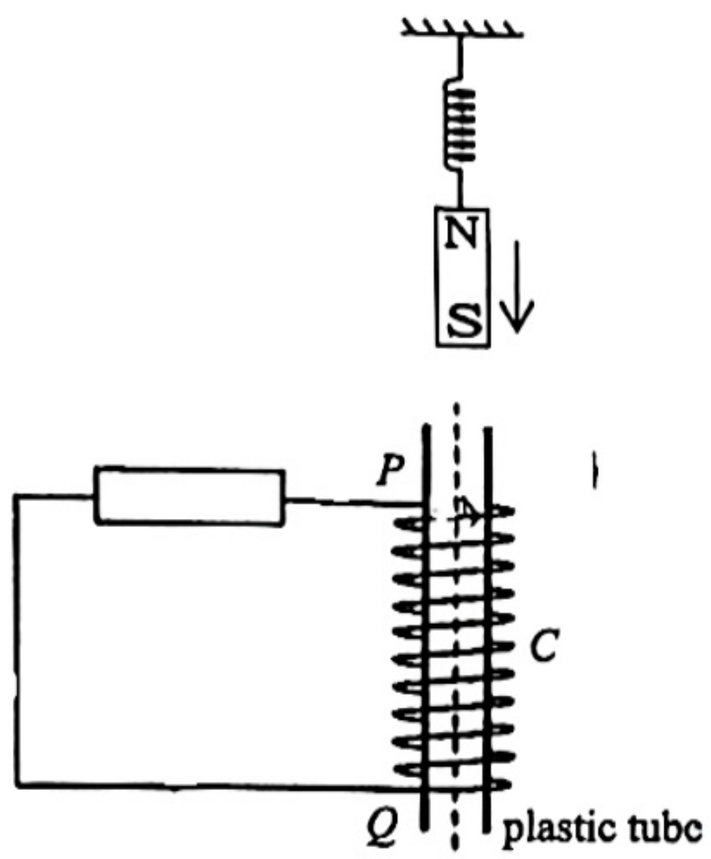
Answers written in the margins will not be marked.

9. (a)



A magnet connected to a spring with its upper end attached to a fixed point is placed above a plastic tube. A coil C_1 is wound around the plastic tube and connected to a resistor R as shown in the figure.

(i) At a certain instant, the magnet is moving downwards. A current is induced in the coil C. State which point (P or Q) is at a higher potential. (1 mark)

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(ii) As the magnet oscillates up and down, a student states that the magnetic force acting on the magnet must always be repulsive. Comment on his statement. (1 mark)

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(iii) When the magnet is given an initial displacement and oscillates above the plastic tube, the oscillation quickly comes to rest. State the change of energy in this process. (1 mark)

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(iv) If the resistor R is now disconnected and the circuit becomes open, the magnet that oscillates above the plastic tube takes a much longer time to come to rest. Explain. (2 marks)

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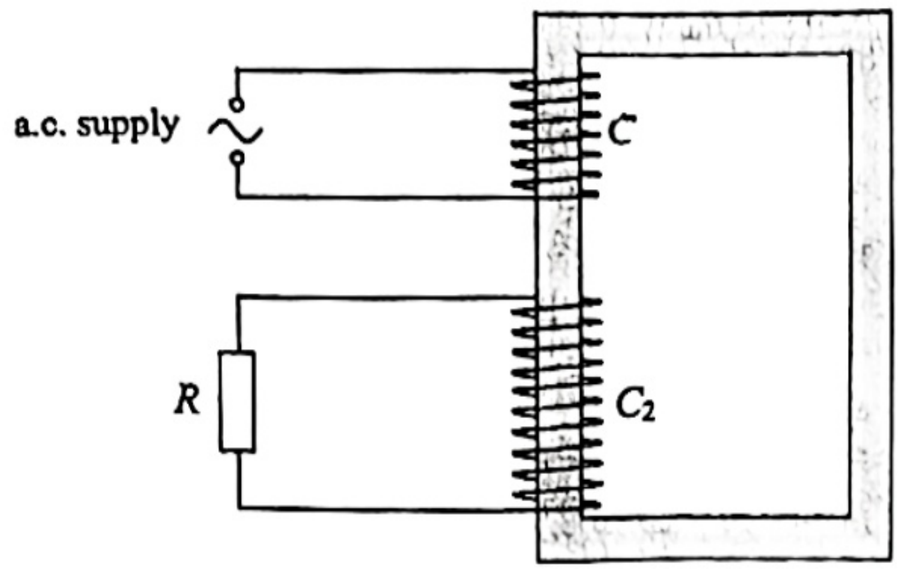
Answers written in the margins will not be marked.

9. (b)



NOT DRAWN TO SCALE

In the above figure, coils C_1 and C_2 are wound on a soft iron core to make a transformer. The number of turns in C_1 is 48 while that in C_2 is 120. The resistor R connected in C_2 has a resistance of 25 Ω. The root-mean-square voltage of the a.c. supply is 15 V. The efficiency of the transformer is 90%.

(i) State **TWO** reasons of the use of the soft iron core in the transformer. (2 marks)

(ii) Calculate the average power dissipated in the resistor R. (2 marks)

(iii) Determine the peak current flowing in the coil C_1. (2 marks)

Answers written in the margins will not be marked.

10. In a special situation, polonium-210 is used as an energy source to generate thermal energy. Po-210 decays by mitting alpha-particles, each decay gives out 5.32 MeV of energy. The half-life of Po-210 is 138 days. Assume the daughter nucleus of polonium-210 is stable. At a certain moment, the power delivered by the source is 240 kW.

(a) Calculate decay constant of polonium-210, express the answer in s^{-1}. (2 marks)

(b) Find the activity of the source at this moment. (2 marks)

(c) Given that the mass of one mole of polonium-210 is 210 g. Determine the mass of the active polonium-210 at this moment. (3 marks)

(d) Determine the time taken for the power delivered by the source to drop to 100 kW. (2 marks)

END OF PAPER

Answers written in the margins will not be marked.

Section A : Astronomy and Space Science

Q.1 : Multiple-choice questions

1.1 In a spherical galaxy, the average separation between two neighbouring stars is 1.5 pc. If the diameter of this galaxy is 30000 pc, estimate the number of stars inside this galaxy, assuming that the stars are uniformly distributed.

A. 3.4×10^{12}
B. 4.2×10^{12}
C. 4.6×10^{12}
D. 5.8×10^{12}

A	B	C	D
○	◉	○	○

1.2 Which of the following concerning Ptolemy's geocentric model is correct ?

A. The distance between the Earth and the Sun is always less than the distance between the Mars and the Sun.
B. Venus has a complete cycle of phases.
C. Mars perform retrograde motion when it is close to the Earth.
D. Jupiter cannot be observed in mid-night.

A	B	C	D
○	○	◉	○

1.3 Which of the following deductions are correct according to Kepler's laws of planetary motion ?

(1) The speed of each planet is not constant throughout the orbit.
(2) The distance of each planet from the Sun varies periodically.
(3) The gravitational force acting on each planet by the Sun is always perpendicular to the velocity of the planet.

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

A	B	C	D
◉	○	○	○

1.4

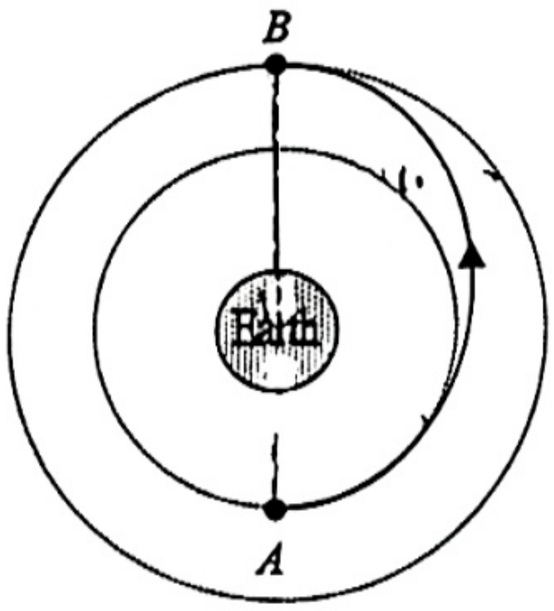


Diagram NOT drawn to scale

A satellite is moving in a circular orbit of radius 9600 km. The satellite's engine is now fired at A to give it a boost so that it can enter another higher orbit of radius 12000 km at B through an elliptical transfer orbit from A to B, with AB as the major axis of the elliptical orbit as shown in the figure. Find the time taken for the satellite to transfer from A to B ?
Given : $GM = 4.0 \times 10^{14}$ N m^2 kg^{-1}, where G is the universal gravitational constant and M is the mass of the Earth.

A. 78 minutes
B. 93 minutes
C. 109 minutes
D. 186 minutes

A	B	C	D
○	○	○	◉

1.5 Given that mass of Earth is 6×10^{24} kg. A space probe is moving away from the Earth. At a distance of 8000 km from the centre of the Earth, it has a speed of 12 km s^{-1}. What is its speed when it is far away from the Earth ? Neglect air resistance and the effect of other celestial bodies.

A. 3630 m s^{-1}
B. 4320 m s^{-1}
C. 5580 m s^{-1}
D. 6630 m s^{-1}

A	B	C	D
○	○	○	○

1.6 A star is observed to have an angular shift of 0.05" across the background distant stars taken six months apart. If the luminosity of the star is 4.8×10^{28} W, what is the brightness of this star observed at the Earth ?

A. 1.5×10^{-9} W m^{-2}
B. 2.9×10^{-9} W m^{-2}
C. 4.5×10^{-9} W m^{-2}
D. 5.8×10^{-9} W m^{-2}

A	B	C	D
○	◉	–	○

1.7 The table below shows the apparent magnitudes and absolute magnitudes of four stars, *P*, *Q*, *R* and *S*.

star	apparent magnitude	absolute magnitude
P	0	–2.5
Q	–0.5	2
R	2.5	–1.5
S	–1.5	0

Which of the following are correct ?

(1) Star *S* is the brightest as seen from the Earth.
(2) Star *P* has the greatest luminosity.
(3) Star *Q* is the closest star from the Earth.

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

A	B	C	D
◉	○	○	○

1.8 Star *X* orbits around star *S* approximately in a circular orbit. An observer on the Earth viewing a spectral line emitted from star *X* found that its wavelength varies between 589.2 nm and 590.6 nm. Find the linear speed of the star *X* around star *S*.

A. 306 km s^{-1}
B. 356 km s^{-1}
C. 407 km s^{-1}
D. 485 km s^{-1}

A	B	C	D
○	◉	○	○

Q.1 : Structured question

(a) Stars are divided into seven major spectral classes according to their surface temperatures. List these seven classes in ascending order of temperature. State the class that the Sun belongs to. (2 marks)

(b) Star X has a luminosity 5000 times that of the Sun, and its surface temperature is 3000 K. Given that the radius of the Sun R_S is 7×10^8 m and surface temperature of the Sun is 6000 K.

(i) Calculate the radius of X in terms of R_S. (2 marks)

(ii) State the type of stars that X belongs to. (1 mark)

(iii) If the angular size of X is 0.052 arcsecond, calculate the distance of star X from the Earth. (2 marks)

(iv) Determine the parallax of star X. (1 mark)

(c) Nowadays, astronomers believe that our universe is expanding. Explain what evidence leads to this conclusion. (2 marks)

Section B : Atomic World

Q.2 : Multiple-choice questions

2.1 According to the Rutherford's atomic model, which of the following deductions is **NOT** correct ?

A. Electromagnetic radiation would be emitted continuously by atoms.
B. Atoms would collapse eventually
C. There must be energy levels in an atom.
D. The spectrum emitted by atoms must be continuous.

A	B	C	D
○	○	◉	○

2.2 An electron is accelerated from rest by a voltage of 10 V. It then bombards an atom and excites the atom from ground s to a higher energy state. The electron then rebounds with a velocity of 6×10^5 m s^{-1}, and the excited atom subsequ transits to the ground state with the emission of a photon. What is the wavelength of the photon emitted ?

A. 1.39×10^{-7} m
B. 3.56×10^{-7} m
C. 5.48×10^{-7} m
D. 6.24×10^{-7} m

A	B	C	D
)	○	○	○

2 3 According to the Bohr model, the electron in a hydrogen atom can be excited to a higher energy level by absorbin photon. Which of the following concerning this transition are correct ?

(1) The momentum of the electron increases.
(2) The angular momentum of the electron increases.
(3) The de Broglie wavelength of the electron increases.

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

A	B	C	D
)	○	)	○

2.4 In a hydrogen atom, the transition of electron from the 3rd excited state to the 2nd excited state gives a wavelength of What is the wavelength of light emitted if the transition is from the 1st excited state to the ground state ?

A. $\frac{5}{27}\lambda$
B. $\frac{7}{108}\lambda$
C. $\frac{7}{144}\lambda$
D. $\frac{27}{124}\lambda$

A	B	C	D
○	)	○	○

2.5 In a transmission electron microscope (TEM), the electrons emitted from the cathode are accelerated by the anode voltage t give a de Broglie wavelength of 7.5×10^{-11} m. The anode voltage should be

A. 189 V
B. 268 V
C. 37) V
D. 536 V

A	B	C	D
○	◉	○	○

2.6 The electron in a hydrogen atom is excited to the third excited state. Which of the following radiation may be emitted in the subsequent transition(s) ?

(1) infra-red radiation
(2) visible light
(3) ultra-violet radiation

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 A magnifying glass is made of a convex lens with focal length 10 cm. It has an aperture of 5 cm. It is used to observe two point objects separated at 0.1 mm. What is the maximum distance that the two objects can be resolved ? Assume that the average wavelength of light reflected by the objects is 550 nm.

A. 3.73 m
B. 7.45 m
C. 10.5 m
D. 14.9 m

A	B	C	D
○	◔	○	○

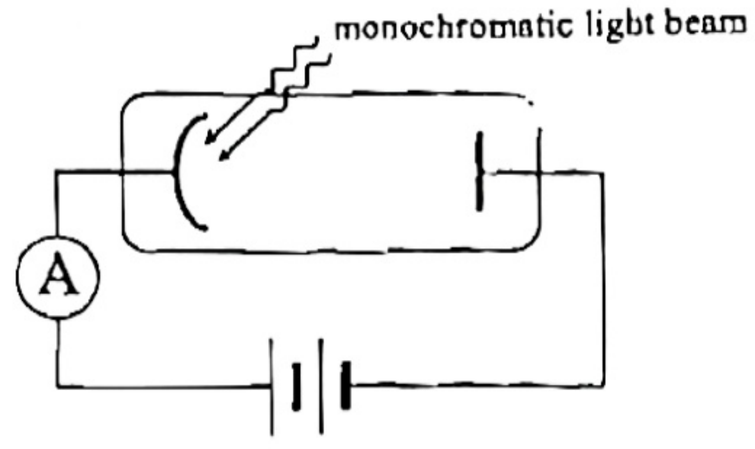
2.8 The surface of a lotus leaf consists of waxy material with nano-sized tiny bumps. These contribute to the well-known Lotus effect of surface. Which of the following statements are correct ?

(1) The tiny bumps can be observed by scientists by using optical microscope.
(2) Water droplets will roll off easily on the surface of a lotus leaf.
(3) Fabric made use of Lotus effect can keep dry under the falling of rain.

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.2 : Structured question



In a photoelectric experiment, the cathode of the photocell is illuminated by a parallel beam of monochromatic blue light of wavelength 480 nm as shown. The work function of the cathode metal is 1.56 eV. The surface area of the cathode is 6 cm^2.

(a) Explain the meaning of the work function of a metal. (1 mark)

(b) Calculate the energy of each photon of the incident light, express the answer in eV. (1 mark)

(c) Calculate the stopping potential in the photocell. (2 marks)

(d) State the direction of the current in the photocell (clockwise or anticlockwise). (1 mark)

(e) Explain why not all photoelectron are emitted with the same maximum kinetic energy although the energy of each incident photon is the same. (1 mark)

(f) If the intensity of the incident light beam is 2.5 W m^{-2}, what is the number of photons incident onto the cathode in a second ? (2 marks)

(g) If another beam of green light with the same intensity is incident onto the cathode of the photocell, state the change

(1) the number of photons incident onto the cathode per second, and

(2) the stopping potential. (2 marks)

Section C : Energy and Use of Energy

Q.3 : Multiple-choice questions

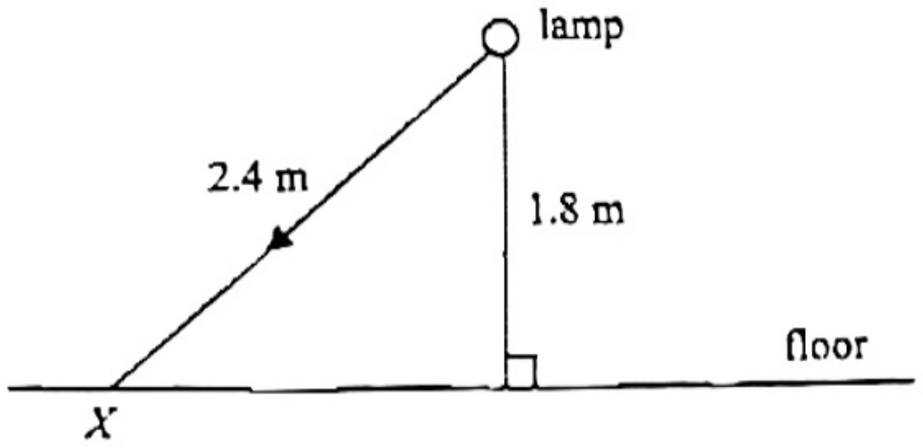
3.1 Which of the following concerning the cooking with an induction cooker is/are correct ?

(1) The cooking utensil must consist of magnetic material.
(2) Eddy current is induced in the induction cooker.
(3) The surface of the induction cooker will never get hot when the cooker is operating.

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

A	B	C	D
○	○	○	○

3.2



A lamp is fixed on the ceiling of a room as the only light source. The illuminance on the floor at point X is 20 lux. Assuming that the lamp emits light uniformly in all directions and the reflection by walls or ceiling is neglected. If the efficacy of the lamp is 48 lm m^{-2}, estimate the power rating of the lamp.

A. 30 W
B. 40 W
C. 50 W
D. 60 W

A	B	C	D
○	○	○	○

3.3 An air-conditioner has a coefficient of performance (COP) of 2.5 in normal working condition. During operation, thermal energy is continuously released to the environment at a rate of 5250 W. The cooling capacity of this air-conditioner is

A. 1500 W
B. 2250 W
C. 3750 W
D. 6750 W

A	B	C	D
○	○	○	○

3.4 A hybrid car consists of a device that can be used as a motor or a dynamo. Which of the following situations correctly describes the proper usage of this device ?

(1) When the car is cruising at a constant speed by the engine, the device is used as a motor.
(2) When the car is accelerating with full power, the device is used as a motor.
(3) When the car is under braking, the device is used as a dynamo.

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

A	B	C	D
○	○	○	○

3.5 Suppose each fission of uranium-235 gives out 200 MeV of nuclear energy. The efficiency of converting nuclear energy to electrical energy is 30%. In a nuclear power plant, a mass of 0.03 kg uranium-235 is required per hour for steady power generation. Estimate the electrical power generated by this power plant. (Molar mass of uranium-235 is 0.235 kg.)

A. 205 MW
B. 410 MW
C. 513 MW
D. 683 MW

A	B	C	D
○	○	○	○

3.6 A pump storage system is usually built near a power plant running continuously to give out steady power. At low demand period, the excess power is used to pump water from a low reservoir to a high reservoir. The vertical height between the two reservoirs is 200 m. The efficiency of this pump storage system is 35%. If the excess electrical power is 500 MW, what is the volume flow rate of water driven by this system ? (Given : density of water = 1000 kg m^{-3})

A. 89 $m^3 s^{-1}$
B. 126 $m^3 s^{-1}$
C. 178 $m^3 s^{-1}$
D. 255 $m^3 s^{-1}$

A	B	C	D
○	○	○	○

3.7 A wind turbine generator is designed to give out a certain electrical power when wind blowing normally at a certain designed speed. In another design, if the length of the turbine blades is increased by 20%, and the efficiency is increased from 30% to 40%, what is the percentage increase of the electrical power for the same wind speed ?

A. 44%
B. 54%
C. 60%
D. 92%

A	B	C	D
○	○	○	○

3.8 A solar panel of area 25 m^2 is installed on the roof of a building. When direct sunlight makes an angle of 15° to the normal of the panel, the panel generates an electrical power of 2150 W. If the solar constant is 1370 W m^{-2} and 45% of radiation is absorbed by the atmosphere, what is the efficiency of the solar panel ?

A. 11.8%
B. 14.4%
C. 44.1%
D. 53.9%

A	B	C	D
○	○	○	○

Q.3 : **Structured question**

A house consists of walls, roof and windows. The following table lists out the thermal transmittance and the total area of each building part.

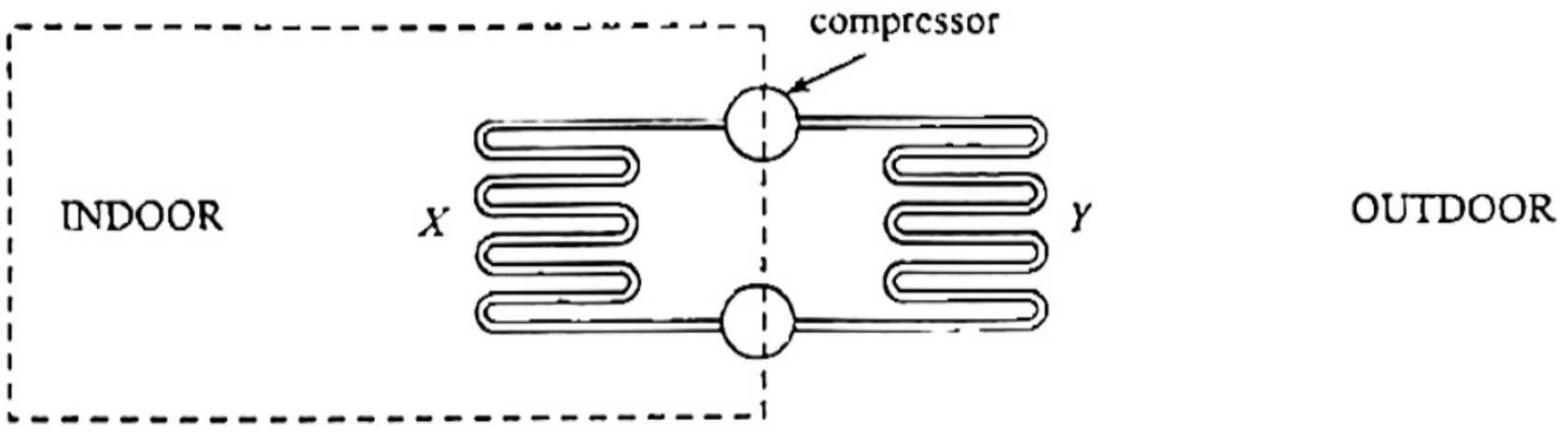
	Walls	**Roof**	**Windows**
Thermal transmittance / W m^{-2} K^{-1}	1.6	1.2	5.4
Total area / m^2	840	150	240

(a) State **TWO** factors that affect the thermal transmittance of a building material. (2 marks)

(b) Suppose the average temperature difference between the house and the environment is 7.5 °C. Use the above table, determine the OTTV of the house. (3 marks)

(c) The engineer decides to change the window material of the house from double glazing clear glass to double glazing low-emissivity glass. Explain how this change can reduce the OTTV of the house. (1 mark)

(d) Air-conditioning system is to be installed in every room of the house. The schematic diagram of an air-conditioner is shown below :



(i) In summer, outdoor has a higher temperature than indoor. State the direction of the flow of the refrigerant through the compressor (from X to Y or from Y to X). (1 mark)

(ii) What is the physical process occurring in the component X for the refrigerant ? (1 mark)

(iii) The coefficient of performance (COP) of the air-conditioner is 2.75. Calculate the cost of electrical energy to remove 550 MJ of heat from indoor. Given that the cost of electrical energy is $1.26 per unit. (2 marks)

Section D : Medical Physics

Q.4 : Multiple-choice questions

4.1 After an eye check, Billy finds that he has to wear corrective spectacles with power −0.5 D. Which of the follo deductions are correct ?

(1) The eye lenses of Billy are too thick.
(2) The far point of Billy before correction is 2 m.
(3) After wearing spectacles, the near point of Billy decreases.

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

A	B	C	D
○	○	○	○

4.2 Two point objects reflecting green light can just be resolved by Mary when she is standing 5 m from the objects. average wavelength of green light is 550 nm. If the diameter of the pupils of Mary is 3.5 mm, what is the separation of t two objects ?

A. 0.48 mm
B. 0.72 mm
C. 0.96 mm
D. 1.92 mm

A	B	C	D
○	○	○	○

4.3 The sound intensity level emitted by a small machine is 90 dB. The sound level of background noise is 85 dB. What is total noise level ?

A. 91.2 dB
B. 91.8 dB
C. 92.3 dB
D. 92.8 dB

A	B	C	D
○	○	○	○

4.4 An ultrasound of intensity 20 mW cm^{-2} is incident normally at a muscle-fat interface. The speed and density of these media are shown below :

Tissue	Speed of sound in / m s^{-1}	Density / kg m^{-3}
Muscle	1580	1076
Fat	1450	952

What is the intensity of the ultrasound reflected from the interface ?

A. 0.108 mW cm^{-2}
B. 0.216 mW cm^{-2}
C. 1.04 mW cm^{-2}
D. 2.08 mW cm^{-2}

A	B	C	D
○	○	○	○

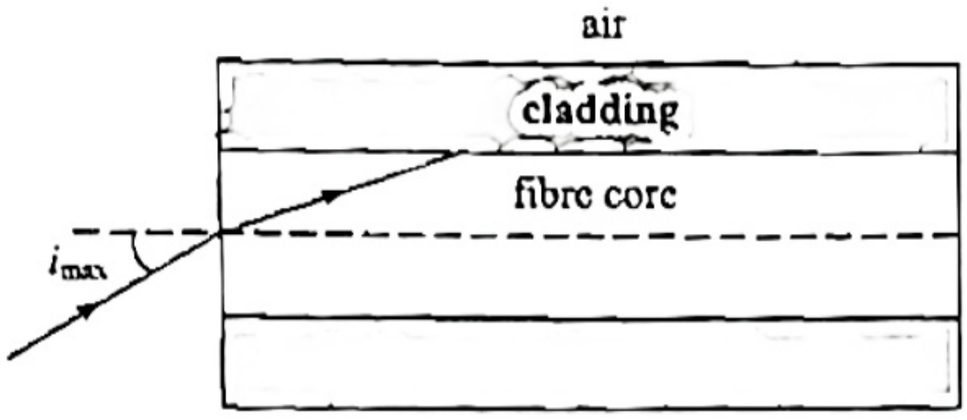
45 Before ultrasonic scanning, an acoustic gel has to be applied between the scanner and the skin. Which of the following correctly describe(s) the reason(s) ?

(1) The gel is used to reduce the attenuation of ultrasound when it passes from the scanner to the skin.
(2) The gel is used to increase the reflection of ultrasound from the skin.
(3) The gel is used to eliminate the air between the transducer and the skin.

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

A	B	C	D
○	○	○	○

46



An optical fibre used for endoscopy is cladded with material of refractive index of 1.38. The refractive index of the fibre core is 1.56. The maximum angle of incidence i_{max} for the guided mode without leakage of light is

A. 27.8°
B. 38.5°
C. 46.7°
D. 62.2°

A	B	C	D
○	○	○	○

47 Before taking radiographic image of the digestive system, an artificial contrast medium (ACM) is swallowed by the patient and time is allowed for the medium to reach the target organs. What is the function of the use of the ACM ?

(1) ACM inside the organ decreases the average density of the organ.
(2) ACM inside the organ decreases the half-value thickness of the organ for X-ray.
(3) ACM gives a larger contrast between the organ and the surrounding tissues.

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

A	B	C	D
○	○	○	○

48 Which of the following statements concerning the use of computed tomography (CT) is **NOT** correct ?

A. CT scan employs ionizing radiation for operation.
B. CT scan produces images of high resolution between tissues with close values of attenuation coefficients.
C. The reconstruction of CT image makes use of the back projection of X-ray intensity through a cross-section around the patient.
D. CT scan is an invasive operation.

A	B	C	D
○	○	○	○

Q.4 : Structured question

Technetium-99*m* emits γ radiation only and its physical half-life is 6 hours. It is used as a medical tracer in radionuclide imaging. When it is injected into the human body of a patient to test the proper function of the kidney, the effective half-life becomes 2 hours.

(a) Explain why the effective half-life in human body is not equal to the physical half-life. (1 mark)

(b) If 60 mg of this tracer is injected into the body of the patient, find the mass of the tracer left in the body after 2 hours. (3 marks)

(c) After the test, state a method that can decrease the mass of the tracer in the body of the patient in a shorter time. (1 mark)

(d) When the tracer reaches the target organ, explain how the radionuclide image can be formed. (2 marks)

(e) Another radioisotope emitting both β and γ radiation can also be used as medical tracer. State ONE disadvantage if this type of tracer is used. (1 mark)

(f) State the main difference between the radionuclide image and the X-ray radiographic image. (2 marks)

END OF PAPER

Section A

Answers

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

Solution

1 A

✓ (1) The horizontal line represents the process of melting at which the temperature is the melting point
The melting point of Y is higher than that of X as shown in the figure.

✓ (2) By $Pt = C\Delta T$, slope of the graph $= \frac{\Delta T}{t} = \frac{P}{C}$
Since the two heaters have same power, slope is inversely proportional to the heat capacity C.
As solid Y has smaller slope, solid Y has greater heat capacity than X.

✓ (3) By $Pt = ml_f$, since the mass of X and Y may not be equal,
the times of heating during fusion are different,
there is no deduction concerning the specific latent heat of fusion l_f

2 B

× (1) The evaporated water should absorb latent heat of vaporization from the remaining water.

✓ (2) Water molecules of greater kinetic energy escapes from the water surface,
thus the average kinetic energy of the remaining water molecules decreases,
and this results in a drop of temperature of the remaining water.

× (3) Since the water in the cup remains in liquid state,
the average potential energy of the water molecules should remain unchanged.

3 A

By $E_K = \frac{3}{2}\cdot\frac{R}{N_A}T = \frac{1}{2}mc^2$ $\quad c \propto \sqrt{T}$

$\frac{c_2}{c_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{(200+273)}{(100+273)}} = 1.13 = 113\%$

Root-mean-square speed increases by 13%.

4 A

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

$\therefore s = (12)(5.4) + \frac{1}{2}(-9.81)(5.4)^2 = -78$ m

Height of the building $= 78$ m

5. A

Since the block moves up with deceleration, the direction of a is downwards

Both the $mg\sin\theta$ and friction f are downwards, the resultant force is the sum of these two forces.

By $mg\sin\theta + f = ma$

$\therefore (0.05)(9.81)\sin\theta + (0.12) = (0.05)(4.5)$

$\therefore \theta = 12.4°$

6. D

Reading of spring balance is the tension of the string connecting P and Q

Consider P: $(11.8) - (10) = (1.2)a$ $\quad \therefore a = 1.5\ m\ s^{-2}$

Consider Q: $F - (11.8) = (1.8)(1.5)$ $\quad F = 14.5$ N

7 D

The weight of the plank is 250 N acting at the centre of gravity which is at 1 m from P.

Take moment at point P.

Moment of tension of the rope + moment of the supporting force at Q = moment of the weight of the plank

$\therefore (T\sin 35°) \times (1.6) = (80) \times (2) = (250) \times (1)$

$\therefore T = 98$ N

8. B

× (1) Since the speed of Billy is constant, the kinetic energy of Billy is constant.
However, the potential energy of Billy changes when he moves up and down.
Therefore, the mechanical energy ($KE + PE$) of Billy is not conserved.
The change of mechanical energy of Billy is due to the work done of the machine.

× (2) As the direction of velocity of Billy is changing, the momentum of Billy is not conserved.

✓ (3) The magnitude of the centripetal force, $F = mv^2/r$
As the speed v and radius r are constant, the magnitude of centripetal force is constant.

9 A

Area under the graph = work done by F on the block = gain of kinetic energy of the block

$\therefore \frac{1}{2}(8)(5) = \frac{1}{2}(2.5)v^2$

$\therefore v = 4\ m\ s^{-1}$

Momentum of the block $= mv = (2.5)(4) = 10$ N s

10 A

✓ (1) The total momentum of Peter, Mary and ball is conserved.

$(24 + 1)(1.2) + (24)(-1.2) = (24)(0.9) + (24 + 1)v$

$v = -0.816$ m s^{-1}

The final velocity of Mary and the ball is 0.816 m s^{-1} towards the left

× (2) During the throwing motion, there is external force acting on the ball by Peter.
During the receiving motion, there is external force acting on the ball by Mary
The momentum of the ball is not conserved in these two motions.

× (3) During the throwing motion by Peter, there is work done by Peter.
For the receiving motion, it is an inelastic collision, and the kinetic energy must decrease
Thus, mechanical energy is not conserved throughout the motion.

11. B

As the particle is projected horizontally at P, the initial vertical velocity is zero.

Assume the time interval between two images be T

For the first two images, vertical displacement s_1 is 5 cm and horizontal displacement s_2 is 10 cm.

By $s_1 = \frac{1}{2}gt^2$ $\quad 0.05 = \frac{1}{2}(10)T^2$ $\quad T = 0.1$ s

By $s_2 = ut$ $\quad 0.10 = u(0.1)$ $\quad u = 1$ m s^{-1}

From P to R, by Conservation of energy :

$\frac{1}{2}mu^2 + mgh = \frac{1}{2}mv^2$

$\frac{1}{2}(1)^2 + (10)(4 \times 0.05) = \frac{1}{2}v^2$

$v = 2.24$ m s^{-1}

12 B

There is two forces acting on the aircraft : weight mg and lift force L.

Since the vertical forces are balanced :

$L\cos\theta = mg$ $\quad L = \frac{mg}{\cos\theta}$

The horizontal component of the lift force provides the centripetal force

Thus, the centripetal force on the aircraft :

$F = L\sin\theta = \frac{mg}{\cos\theta} \times \sin\theta = mg\tan\theta$

$F = (6500)(9.81)\tan 22.5^\circ = 26400$ N

13 D

The graph of energy against distance must be straight lines.

Since there is friction, there is work done against friction when the block travels up the incline

Loss of kinetic energy = gain of potential energy + work done against friction

Thus, the gain of potential energy must be less than the loss of kinetic energy

14 C

Wavelength of the wave : $\lambda = 5 \times 8 = 40$ cm

Since particle G is at the extreme position, it performs $\frac{1}{4}$ cycle to reach its equilibrium position

Thus, the time taken is $\frac{1}{4}$ period.

$\therefore \frac{1}{4}T = 0.2$ $\quad T = 0.8$ s

Speed of the wave $= \frac{\lambda}{T} = \frac{40}{0.8} = 50$ cm s^{-1}

15. B

Since the distance between crest and trough is 0.5λ, the separation between the two sources S_1 and S_2 is 2.5λ

Between the two sources, there are points which have path difference : $0\lambda, +1\lambda, -1\lambda, -2\lambda, 2\lambda$

These 5 points will undergo constructive interference

16 B

✓ (1) As the frequency is fixed, by $v = f\lambda$, wavelength will double as speed is doubled.

× (2) When wavelength doubles, the number of loops will change from 4 to 2.
Particles A and B will be in the same loop and should vibrate in phase.

✓ (3) As there is 2 loops, there are 2 antinodes in the stationary wave.

17. C

From the figure, incident angle θ_1 in medium 1 is greater than θ_2 in medium 2.

Since total internal reflection occurs, the refracted angle θ_3 in medium 3 does not exist, thus, $\sin\theta_3 > 1$

$\therefore \sin\theta_1 > \sin\theta_2 > \sin\theta_3$

For parallel sided media : $n_1\sin\theta_1 = n_2\sin\theta_2 = n_3\sin\theta_3$

$\therefore$

18. D

By $v = mu = (0.5)(24) = 12$ cm

Since the image is erect, it is a virtual image, v is (−) in the lens formula.

By $\frac{1}{f} = \frac{1}{u} - \frac{1}{v}$ $\quad \therefore \frac{1}{f} = \frac{1}{(24)} + \frac{1}{(-12)}$ $\quad f = -24$ cm

The lens is concave with focal length 24 cm

19 B

✓ A Microwave is used in radar to detect flying objects.

× B To detect cracks in metals, ultrasound or X rays should be used, infrared cannot be

✓ C Ultraviolet can be used to sterilize drinking water by killing bacteria.

✓ D Ultrasound can be used for auto focusing in camera, and infrared can also be used

20. C

Assume the distance between P and the cliff is d and the speed of sound is c.

At P: $2d = c(0.5)$

At Q: $2(42 + d) = c(0.75)$

Combine the two equations: $c = 336\ m\ s^{-1}$

21. C

✗ (1) The path difference at O is zero. Since the sources are in opposite phase, destructive interference occurs and the loudness detected should be minimum.

✓ (2) Since minimum loudness is detected at P, path difference $= n\lambda$ (for sources in opposite phase)
The separation between the two sources $= a = 2\lambda$
Since the path difference must be less than a, i.e. 2λ, thus, the path difference at P must be 1λ

✓ (3) If the frequency is halved, the new wavelength λ' will become doubled, i.e. $\lambda' = 2\lambda$
Path difference at P will become $\frac{1}{2}\lambda'$, thus, constructive interference occurs and loudness is maximum.

22. C

At neutral point, the magnitude of electric field due to each charge must be equal.

$E_1 = E_2$

$$\frac{(25)}{4\pi\varepsilon_0 (20-30)^2} = \frac{Q}{4\pi\varepsilon_0 (30)^2}$$

$Q = 9\ \mu C$

The direction of E due to $+25\ \mu C$ at P is rightwards.

Therefore, the direction of E due to Q must be leftwards, thus Q must be negative.

23. D

When the negatively charged rod is brought near X, X has induced positive charge and Y has induced negative charge.

When X is touched by the finger to earth, the induced positive charge in X does not charge but Y becomes uncharged.

When the charged rod is removed, X shares some positive charge to Y.

Finally, both X and Y are positively charged.

24. D

Let the voltage across X be V. Voltage across Y will also be V.

Thus the voltage across Z is $2V$.

The power dissipated by X: $P = \frac{V^2}{R} = 12\ W$

Total power dissipated by X, Y and Z: $P = \frac{V^2}{R} + \frac{V^2}{R} + \frac{(2V)^2}{R}$

$P = 6\frac{V^2}{R} = 6 \times 12 = 72\ W$

25. B

✓ A. As the equivalent resistance of the whole circuit decreases, current from the battery increases.
Thus, power given out by the battery increases.

× B. As the voltage across L_1 remains unchanged, current flowing through L_1 should be unchanged.

✓ C. As the equivalent resistance L_3 and L_4 decreases, voltage across them decreases.
Thus, voltage across L_2 increases. Thus, brightness of L_2 increases.

✓ D. As voltage across L_3 decreases, brightness of L_3 decreases.

26. D

× A. Consider side AB. the direction of induced current is from B to A and AB is moving upwards.
By Right hand rule, the direction of magnetic field should be from right to left.

× B. Whenever there is induced current, there is opposing magnetic force.
Thus, the magnetic force on AB should be in downward direction, opposite to upward motion.

× C. The generator consists of a commutator, thus the induced current is d.c.
The induced current is maximum when the coil is horizontal and minimum when the coil is vertical.
Thus, the induced current is an unsteady d.c.

✓ D. The induced e.m.f. along AB is from B to A, thus, the potential at A is higher than B.

27. B

× (1) By $P_{out} = \frac{V_S^2}{R}$, when V_S is double, the power output should become 4 times as before.

✓ (2) Since the efficiency is unchanged, if P_{out} is 4 times, then power input P_{in} will also be 4 times.
By $P_{in} = V_P I_P$, the primary current is increased to 4 times as before.

× (3) Since the efficiency is unchanged, a constant fraction of power input becomes power loss.
Therefore, when power input increases, the power loss should increase.

28. A

Since the direction of electric field is downwards, electric force acting on the electron (negative charge) is upwards.

Since the electron is undeflected, the magnetic force acting on the electron balances the electric force.

Thus, the magnetic force acting on the electron must be downwards.

By Left hand rule, the direction of the magnetic field is into the paper.

Since magnetic force balances the electric force,

$Bqv = qE$ and $E = \frac{V}{d}$

$\therefore Bv = \frac{V}{d}$

$B(5 \times 10^7) = \frac{(800)}{(0.02)}$

$B = 8 \times 10^{-4}\ T = 0.8\ mT$

29. D

At the left hand side of the current I, the magnetic field produced by I is into paper by use of Right hand grip rule.

The strength of the magnetic field increases when the coil is closer to the current.

As the coil moves towards the current in Figure (a), it experiences an increase of magnetic field

Thus, a current is induced in anticlockwise direction to give a magnetic field out of paper to oppose the change.

At the right hand side of the current I, the magnetic field produced by I is out of paper by use of Right hand grip rule.

The strength of the magnetic field decreases when the coil is further away from the current

As the coil moves away from the current in Figure (b), it experiences a decrease of magnetic field.

Thus, a current is induced in anticlockwise direction to give a magnetic field out of paper to oppose the change

30 C

For the step-down transformer

Secondary current should be the rated current of the lamp to work normally $\therefore I_s = \frac{12}{6} = 2\ A$

Primary current $I_p = 2 \times \frac{1}{10} = 0.2\ A$

The current through the cables is equal to the primary current of the step-down transformer

Power loss in the cables $= I^2R = (0.2)^2(10 \times 10) = 0.8\ W$

Power input by the supply $= 12 + 0.8 = 12.8\ W$

Efficiency of the power transmission $\eta = \frac{P_{out}}{P_{in}} = \frac{12}{12.8} \times 100\% = 93.75\% \approx 94\%$

31 A

By $A = A_0(\frac{1}{2})^{\frac{t}{T}}$

$A_1 : A_2 = (A_0)(\frac{1}{2})^{\frac{t}{T}} : (2A_0)(\frac{1}{2})^{\frac{2t}{T}} = \frac{1}{8} : \frac{1}{2} = 1 : 4$

32. C

To reveal an organ well inside the human body, γ source should be used since it can penetrate the human body.

For the use of radioactive source inside human body, the half-life should not be too long to reduce the harmful effect.

33 C

Mass defect : $\Delta m = (3.954096 \times 10^{-25}) - (3.887521 \times 10^{-25} + 6.5483 \times 10^{-27}) = 9.2 \times 10^{-29}\ kg$

Energy released : $E = \Delta m \times c^2 = (9.2 \times 10^{-29}) \times (3 \times 10^8)^2 = 8.28 \times 10^{-12}\ J$

$\therefore E = 8.28 \times 10^{-12} \times \frac{1}{1.6 \times 10^{-19}} = 51750000\ eV \approx 52\ MeV$

OR

$\Delta m = 9.2 \times 10^{-29}\ kg = \frac{9.2 \times 10^{-29}}{1.661 \times 10^{-27}}\ u = 5.5388 \times 10^{-2}\ u$

$E = 5.5388 \times 10^{-2} \times 931 = 52\ MeV$

Section B

1 (a) Put the crushed ice and heater into the funnel, and place the funnel above the beaker [1]

Connect the heater to the power supply via the joulemeter. [1]

Switch on the power supply.

Record the energy E given out by the power supply and the mass of water m collected in the beaker. [1]

The specific latent heat of fusion is found by : $L = E / m$ [1]

(b) (i) Any ONE of the following : [1]

- To enable the temperature of ice to be close to 0°C
- To ensure a good contact between the ice and the heater
- To increase the surface area of contact between the ice and the heater.

(ii) There is heat gained from the surrounding air. [1]

2. (a) By P - T relation $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{(105)}{(25-\theta)} = \frac{(120)}{(70-\theta)}$ [1]

$\theta = -290\ ^\circ C$ [1]

OR

By $\frac{(120-105)}{(70-75)} = \frac{(105-0)}{(25-\theta)}$ [1]

$\therefore \theta = -290\ ^\circ C$ [1]

(b) By $c = \sqrt{\frac{3RT}{M_0}}$

$c = \sqrt{\frac{3(8.31)(70+290)}{(0.0288)}}$ [1]

$c = 558\ m\ s^{-1}$ < accept $545\ m\ s^{-1}$ by using absolute zero of $-273\ ^\circ C$ > [1]

OR

By $E_k = \frac{3RT}{2N_A} = \frac{1}{2}mc^2$

$\frac{3(8.31)(70+290)}{2(6.02 \times 10^{23})} = \frac{1}{2} \times \frac{(0.0288)}{(6.02 \times 10^{23})} c^2$ [1]

$c = 558\ m\ s^{-1}$ < accept $545\ m\ s^{-1}$ by using absolute zero of $-273\ ^\circ C$ > [1]

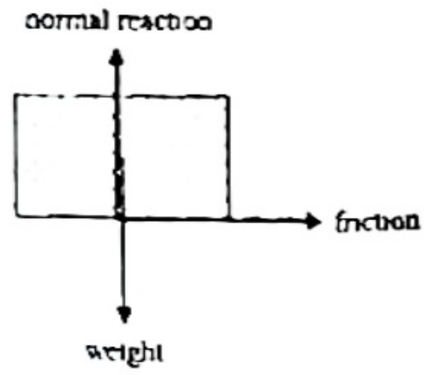
(c) When the temperature drops, the average kinetic energy of gas molecules decreases and move slower

They hit the walls of container less violently < OR momentum decreases > [1]

and less frequently, < OR frequency decreases > [1]

thus, the pressure decreases

3 (a)



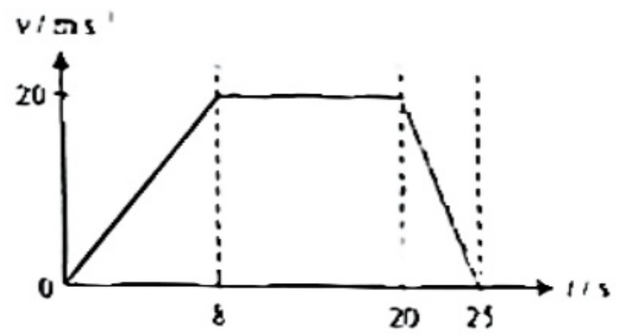
< normal reaction and weight correctly drawn, with correct spelling > [1]

< friction correctly drawn, with correct spelling > [1]

(b) By $f = ma = (500)(4) = 2000$ N < accept -2000 N > [1]

Direction of f : backward [1]

(c)



< correct shape of the graph > [1]

< maximum velocity of 20 m s^{-1} correctly indicated > [1]

(d) Total distance travelled = area under the graph = $\frac{(12+25)(20)}{2} = 370$ m [1]

Average velocity = $\frac{370}{25} = 14.8$ m s^{-1} [1]

4 (a) Average force :

$F = \frac{mv - mu}{t} = \frac{(0.0025)(90)-(0)}{(5\times10^{-3})}$ [1]

$F = 45$ N [1]

(b) By Conservation of momentum :

$m_1 u = (m_1 + m_2) v$

$\therefore (2.5)(90) = (2.5 + 72.5) v$ OR $(0.0025)(90) = (0.0025 + 0.0725) v$ [1]

$v = 3$ m s^{-1} [1]

(c) By $\frac{1}{2} m v^2 = mgh$

$\frac{1}{2}(3)^2 = (9.81)(d \sin 15°)$ [1]

$d = 1.77$ m < accept 1.76 to 1.80 m > [1]

4 (d) Since the collision is inelastic, mechanical energy (OR kinetic energy) is lost during the collision. [1]

(e) Since the bullet rebounds after the collision, its change of momentum increases. [1]

By the law of conservation of momentum, the momentum of the cart after collision increases.

thus, it can move up with a greater distance [1]

5 (a) (i) Initial horizontal velocity :

$u = 85 \cos 40° = 65.1$ m s^{-1} [1]

By conservation of energy

$\frac{1}{2} m u^2 + mgh = \frac{1}{2} m v^2$

$\therefore \frac{1}{2} m (65.1)^2 + m(9.81)h = \frac{1}{2} m (85)^2$ [1]

$\therefore h = 152$ m < accept 150 m to 155 m > [1]

(ii) Vertical component :

$s_y = \frac{1}{2} g t^2$

$\therefore (152) = \frac{1}{2}(9.81) t^2$

$t = 5.57$ s [1]

Horizontal component

$s_x = vt$

$d = (65.1)(5.57) = 363$ m [1]

(b) (i) The weight provides the centripetal force.

$\therefore mg = \frac{mv^2}{R}$

$\therefore (9.81) = \frac{v^2}{(6400\times10^3)}$ [1]

$\therefore v = 7920$ m s^{-1} < accept 7900 to 7950 m s^{-1} > [1]

(ii) Time to perform 1 cycle is one period T

$T = \frac{2\pi R}{v} = \frac{2\pi(6400\times10^3)}{(7920)}$ [1]

$\therefore T = 5077$ s < accept 5070 to 5080 s > [1]

OR

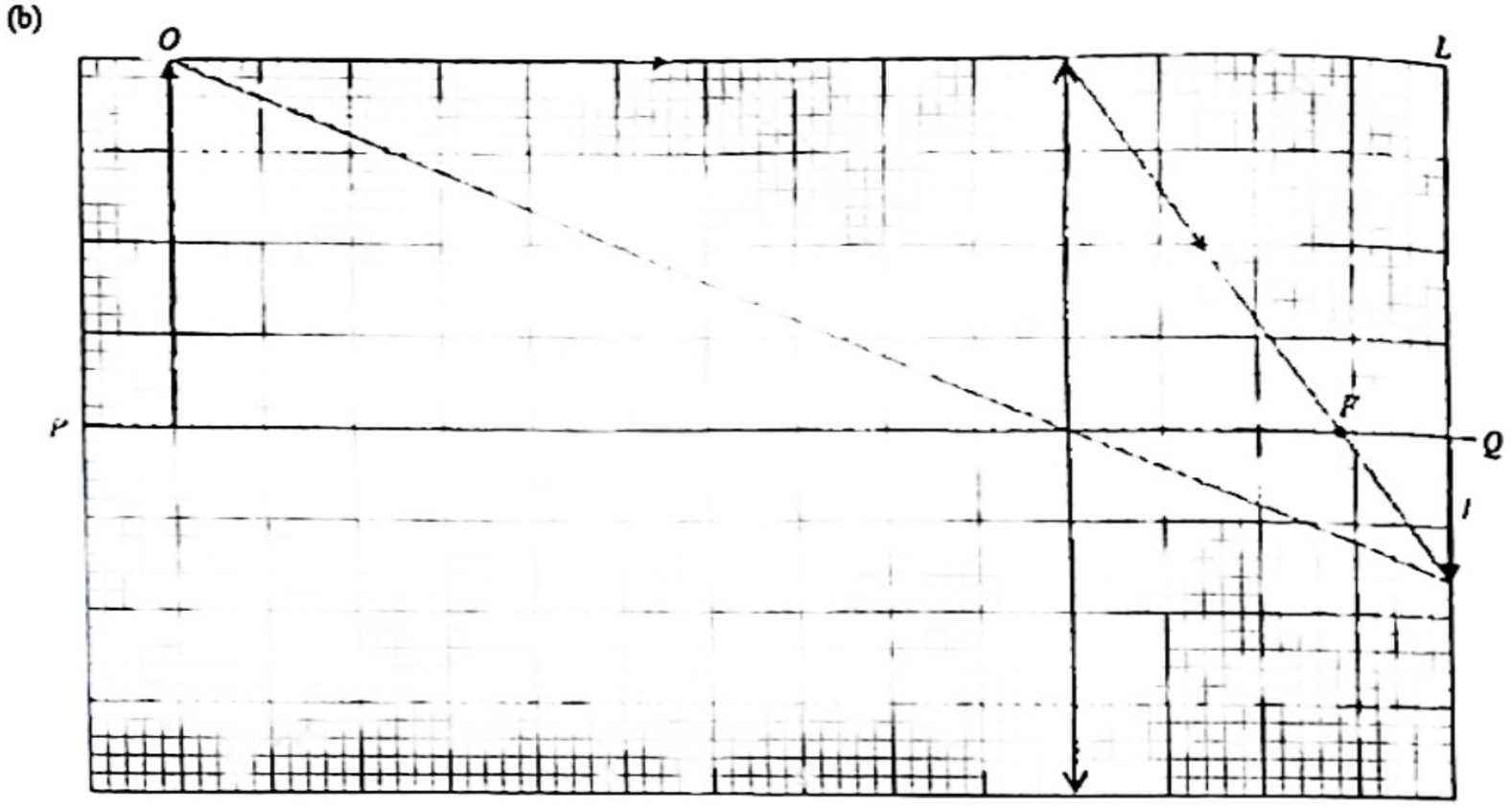
By $mg = mR\omega^2 = mR\left(\frac{2\pi}{T}\right)^2$

$(9.81) = (6400\times10^3)\left(\frac{2\pi}{T}\right)^2$ [1]

$T = 5075$ s < accept 5070 to 5080 s > [1]

6. (a) L is a convex lens (OR converging lens) [1]
since the image that can form on the screen is real. [1]

(b)



(i) < Image I of height 8 cm correctly drawn on the screen > ($h_i = 0.4 \times 20 = 8$ cm) [1]

(ii) < By joining the head of object and head of image, the position of lens L is correctly drawn > [1]

(iii) < By drawing a horizontal light ray towards the lens L, principal focus F is correctly indicated > [1]

(c) (i) $u = 20$ cm [1]
(The original object distance is 50 cm and the original image distance is 20 cm.
Since light is reversible, positions of object and image can be interchanged.
Thus the new object distance is 20 cm and the new image distance is 50 cm.)

(ii) $m = \dfrac{50}{20} = 2.5$ [1]

(d) Since the object distance is less than the focal length (about 14 cm), the image is virtual that cannot form on screen. [1]

7. (a) $\Delta y = \dfrac{(8.1-1.9)}{12} = 0.517$ cm < accept 0.51 to 0.52 cm > [1]

By $\Delta y = \dfrac{\lambda D}{a}$

$\therefore (0.517 \times 10^{-2}) = \dfrac{(675 \times 10^{-9})(1.25)}{a}$ [1]

$\therefore a = 1.63 \times 10^{-4}$ m < accept $1.62 - 1.66 \times 10^{-4}$ m > [1]

7. (b) ① The spots becomes less bright (dimmer). [1]
< since less light is transmitted as slit width decreases >

② More spots can be observed on the screen. [1]
< as slit width decreases, degree of diffraction increases, thus the overlapping region to give interference increases >

(c) Since the wavelength of green light is shorter, the separation between bright spots decreases [1]

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

$\therefore \left(\dfrac{10^{-2}}{2500}\right) \sin\theta = (2)(675 \times 10^{-9})$ [1]

$\therefore \theta = 19.7°$ [1]

By $\tan 19.7° = \dfrac{(s/2)}{(1.25)}$

$\therefore s = 0.896$ m < accept 0.89 to 0.90 m > [1]

8. (a) They are connected in parallel [1]
so that the voltage across the heating coil is the rated voltage. (OR voltage across the heating coil is 220 V) [1]

(b) Total power of fan and heating coil $= 220 \times 4.5 = 990$ W [1]

Power rating of the fan $= 990 - 800 = 190$ W [1]

OR

Current through the heating coil $= \dfrac{(800)}{(220)} = 3.636$ A [1]

Current through the fan $= 4.5 - 3.636 = 0.864$ A

Power rating of the fan $= (220)(0.864) = 190$ W [1]

(c) He is wrong as the switch is off, there is no complete circuit for the hair dryer. [1]
However, the hair dryer is still at high potential (OR high voltage) (OR at live) when the switch is off. [1]

(d) Since the hair dryer has plastic cover, it does not require earth wire. [1]

OR

Since the hair dryer does not have metal case, it does not require earth wire [1]

(e) By $P = (800) \times \left(\dfrac{120}{220}\right)^2$ < accept 238 by [illegible] > [1]

$\therefore P = 238$ W [1]

OR

$k = \dfrac{(220)^2}{(800)} = 60.5\ \Omega$ [1]

$P = \dfrac{(120)^2}{(60.5)} = 238$ W [1]

9. (a) (i) point Q [1]

(ii) He is wrong. The magnetic forces between the magnet and the coil may be repulsive or attractive. [1]

(When the magnet moves downward towards the coil, the magnetic forces between them are repulsive
When the magnet moves upward away from the coil, the magnetic forces between them are attractive)

(iii) The kinetic energy of the magnet changes to electrical energy of the induced current in the coil. [1]

(iv) If the circuit is open, no induced current can flow in the coil. [1]
The magnet then oscillates without any opposing magnetic force. [1]

(b) (i) ① The soft iron guides the magnetic flux from coil C_1 to coil C_2 (with good flux linkage) [1]

② Soft iron increases the strength of the magnetic field. [1]

(ii) Secondary voltage $V_2 = 15 \times \frac{120}{48} = 37.5$ V [1]

Power output : $P_{av} = \frac{(37.5)^2}{(25)} = 56.25$ W < accept 56.3 W > [1]

(iii) By (90%) $= \frac{56.25}{(15)I_1} \times 100\%$ [1]

$I_1 = 4.167$ A

Peak current $= 4.167 \times \sqrt{2} = 5.89$ A [1]

10 (a) By $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{(138 \times 24 \times 3600)}$ [1]

$k = 5.81 \times 10^{-8}\ s^{-1}$ [1]

(b) By $P = EA$

$\therefore (240 \times 10^3) = (5.32 \times 10^{-6} \times 1.6 \times 10^{-9})A$ [1]

$A = 2.82 \times 10^{17}$ Bq [1]

(c) By $A = kN$

$\therefore (2.82 \times 10^{17}) = (5.81 \times 10^{-8})N$ [1]

$N = 4.85 \times 10^{24}$ [1]

$M = \frac{(4.85 \times 10^{24})}{(6.02 \times 10^{23})} \times (0.210) = 1.69$ kg < accept 1690 g > [1]

(d) By $P = P_0 e^{-kt}$ OR By $P = P_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$(100) = (240)\, e^{-(5.81 \times 10^{-8})t}$ $(100) = (240)\left(\frac{1}{2}\right)^{t/(138)}$ [1]

$t = 1.51 \times 10^7$ s $t = 174$ days [1]

Section A : Astronomy and Space Science

1.1 B

Total volume of the galaxy $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{30000}{2}\right)^3 = 1.414 \times 10^{13}$ pc^3

Average volume occupied by each star $= s^3 = (1.5)^3 = 3.375$ pc^3

Number of stars in the galaxy $= \frac{1.414 \times 10^{13}}{3.375} = 4.2 \times 10^{12}$

1.2 C

× A. According to Ptolemy's geocentric model, the Earth is at the centre of the Universe.
The Sun and Mars move around the Earth in circular orbit.
When Sun and Mars are at opposite side of the Earth, Earth-Sun distance is less than Mars-Sun distance.
But when Sun and Mars are at the same side of the Earth, Earth-Sun distance is more than Mars-Sun distance.

× B. According to Ptolemy's model, full phase of Venus can never be observed.

✓ C. Ptolemy's model can explain the retrograde motion of Mars when it is close to the Earth.

× D. When Jupiter and Sun are at opposite side of the Earth, Jupiter can be observed in mid-night.

1.3 A

✓ (1) According to Kepler's second law, the speed of each planet increases when it is closer to the Sun and decreases when it is further away from the Sun.

✓ (2) According to Kepler's first law, each planet revolves around the Sun in elliptical orbit and the Sun is at one of the focus of the orbit.
Thus, the distance between the planet and the Sun varies periodically.

✓ (3) Since each planet moves in elliptical (not circular) orbit,
the velocity that is tangential to the orbit may not be perpendicular to the gravitational force.

1.4 B

Semi-major axis $a = \frac{9600 + 12000}{2} = 10800$ km

Period : $T^2 = \frac{4\pi^2 a^3}{GM} = \frac{4\pi^2 (10800 \times 10^3)^3}{(4.0 \times 10^{14})}$ $\therefore T = 11150$ s

Time taken for half cycle of ellipse : $t = \frac{1}{2}T = \frac{1}{2} \times 11150 = 5575$ s $= 93$ minutes

1.5 D

By conservation of energy, $K + U =$ constant (gravitational PE is zero at infinity)

$\frac{1}{2}mu^2 + \left(-\frac{GMm}{r}\right) = \frac{1}{2}mv^2 + (0)$ $u^2 - \frac{2GM}{r} = v^2$

$\therefore (12000)^2 - \frac{2(6.67 \times 10^{-11})(6 \times 10^{24})}{(8600 \times 10^3)} = v^2$

$\therefore v = 6630$ m s^{-1}

16 B

Parallax : $p = \frac{0.05}{2} = 0.025''$

Distance of the star from the Earth $d = \frac{1}{p} = \frac{1}{0.025} = 40$ pc

Brightness $b = \frac{L}{4\pi d^2} = \frac{(4.8\times10^{28})}{4\pi(40\times3.09\times10^{16})^2} = 2.9\times10^{-9}$ W m^{-2}

17 D

✓ (1) Apparent magnitude m represents the brightness observed on the Earth.
Star S has the smallest apparent magnitude, thus, it is the brightest as seen from the Earth

✓ (2) Absolute magnitude M represents the luminosity of the star.
Star P has the smallest absolute magnitude, thus, it has the greatest luminosity

✓ (3) The value of $(m - M)$ indicates the distance of the star from the Earth.
Star Q has the smallest value of $(m - M)$, thus it is closest to the Earth

18 B

When star X moves directly towards the observer, the shortest apparent wavelength 589.2 nm is observed.

When star X moves directly away from the observer, the longest apparent wavelength 590.6 nm is observed.

Actual wavelength of the spectral line : $\lambda_o = \frac{589.2 + 590.6}{2} = 589.9$ nm.

Doppler shift of wavelength : $\Delta\lambda = \frac{590.6 - 589.2}{2} = 0.7$ nm

By $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ $\quad \frac{0.7}{589.9} = \frac{v}{3\times10^8}$ $\quad v = 356$ km s^{-1}

Q1 (a) Seven classes : M K G F A B O [1]

Sun belongs to class G [1]

(b) (i) By Stefan's Law : $L = 4\pi R^2\sigma T^4$

$\therefore \frac{L}{L_S} = \left(\frac{R}{R_S}\right)^2\times\left(\frac{T}{T_S}\right)^4$ [1]

$\therefore (5000) = \left(\frac{R}{R_S}\right)^2\times\left(\frac{3000}{6000}\right)^4$

$R = 28.3\,R_S$ [1]

(ii) X is a red giant. [1]

(iii) By $\theta = \frac{2R}{d}$

$\therefore (0.052\times\frac{1}{60}\times\frac{1}{60})^\circ\times\frac{\pi}{180^\circ} = \frac{2(28.3\times7\times10^8)}{d}$ [1]

$d = 1.57\times10^{18}$ m [1]

(iv) $d = \frac{1.57\times10^{18}}{3.09\times10^{16}}$ pc $= 50.8$ pc

$p = \frac{1}{d} = \frac{1}{50.8} = 0.020''$ <accept 0.0195 to 0.020 arcsecond> <0.02'' not accepted> [1]

(c) The spectrum emitted from all distant galaxies is found to have red-shift. [1]

By Doppler effect, the distant galaxies must be moving away from us. [1]

Thus the universe should be expanding.

Section B : Atomic World

2.1 C

✓ A According to classical electromagnetic theory,
orbital electrons would emit electromagnetic radiation continuously due to its centripetal acceleration

✓ B As the atoms loses energy continuously, the electrons would spiral towards the nucleus,
and the atoms would collapse eventually.

✗ C The idea of energy levels is proposed by Bohr, not by Rutherford.

✓ D The atom can emit radiation of any energy,
thus the emitted wavelength can be any value, thus the spectrum must be continuous.

2.2 A

During acceleration from rest by potential V, the electron gains kinetic energy where $KE = eV = 10\text{ eV}$

Loss of energy of the bombarding electron = initial kinetic energy − final kinetic energy

$\therefore \Delta E = (10 \times 1.6 \times 10^{-19}) - \frac{1}{2}(9.11 \times 10^{-31})(6 \times 10^5)^2 = 1.436 \times 10^{-18}\text{ J}$

The lost of energy of bombarding electron = excitation energy of the atom = energy of emitted photon

$\Delta E = \frac{hc}{\lambda}$ $(1.436 \times 10^{-18}) = \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{\lambda}$ $\therefore \lambda = 1.39 \times 10^{-7}\text{ m}$

2.3 C

✗ (1) By $mvr = n\frac{h}{2\pi}$ and $r = n^2 r_1$

$\therefore mv(n^2 r_1) = n\frac{h}{2\pi}$ $mvnr_1 = \frac{h}{2\pi}$ $\therefore n\uparrow \Rightarrow v\downarrow \Rightarrow mv\downarrow$

momentum of electron should decrease

(2) By $mvr = n\frac{h}{2\pi}$ $n\uparrow \Rightarrow mvr\uparrow$ angular momentum of electron increases

(3) By $\lambda = \frac{h}{p} = \frac{h}{mv}$ $\therefore mv\downarrow \Rightarrow \lambda\uparrow$ de Broglie wavelength of electron increases

2.4 B

For hydrogen, energy of the nth shell : $E_n = -\frac{E_0}{n^2}$ and $\Delta E = \frac{hc}{\lambda}$

Transition from $n = 4$ (3rd excited state) to $n = 3$ (2nd excited state)

$\frac{hc}{\lambda} = (-\frac{E_0}{16}) - (-\frac{E_0}{9}) = \frac{7}{144}E_0$

Transition from $n = 2$ (1st excited state) to $n = 1$ (ground state) :

$\frac{hc}{\lambda'} = (-\frac{E_0}{4}) - (-\frac{E_0}{1}) = \frac{3}{4}E_0$

$\frac{\lambda'}{\lambda} = \frac{7/144}{3/4} = \frac{7}{108}$ $\therefore \lambda' = \frac{7}{108}\lambda$

2.5 B

De Broglie wavelength : $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE_k}} = \frac{h}{\sqrt{2meV}}$

$(7.5 \times 10^{-11}) = \frac{(6.63 \times 10^{-34})}{\sqrt{2(9.11 \times 10^{-31})(1.6 \times 10^{-19})V}}$

$V = 268\text{ V}$

2.6 D

✓ (1) The transition from E_4 to E_3 will give a photon belonging to infra-red radiation.

✓ (2) The transition from E_3 to E_2 will give a photon belonging to visible light.

✓ (1) The transition from E_2 to E_1 will give a photon belonging to ultra-violet radiation.

2.7 B

By Rayleigh criterion, resolving power :

$\theta = 1.22\frac{\lambda}{d} = 1.22 \times \frac{550 \times 10^{-9}}{0.05} = 1.342 \times 10^{-5}\text{ rad}$

By $\theta = \frac{a}{L}$ $\therefore (1.342 \times 10^{-5}) = \frac{(0.1 \times 10^{-3})}{L}$ $\therefore L = 7.45\text{ m}$

< Note that the focal length would not affect the resolving power >

2.8 C

✗ (1) Since the tiny bumps are nano-sized, they cannot be observed by optical microscope
They can only be observed by electron microscope

✓ (2) Since lotus leaf has highly hydrophobic surface, water droplets will roll off easily from the surface

✓ (3) By using Lotus effect, water cannot stuck to the fabric and can always be dry even under rain falling

Q2. (a) Work function is the minimum energy to remove an electron from the metal surface [1]

(b) $E = h\frac{c}{\lambda}$

$= (6.63\times10^{-34})\cdot\frac{3\times10^{8}}{480\times10^{-9}}\cdot\frac{1}{1.6\times10^{-19}}$

$= 2.59$ eV [1]

(c) By $E = \phi + K_{max}$

$(2.59) = (1.56) + K_{max}$ [1]

$K_{max} = 1.03$ eV

Stopping potential : $V_s = 1.03$ V [1]

(d) anticlockwise [1]

(e) Only the free electrons at the surface can have the maximum kinetic energy [1]

OR

Some electrons are not at the metal surface so they do not have maximum kinetic energy.

(f) $P = IA = \frac{N}{t}E$

$\therefore (2.5)(6\times10^{-4}) = \frac{N}{t}(2.59\times1.6\times10^{-19})$ [1]

$\frac{N}{t} = 3.62\times10^{13}$ s^{-1} [1]

(g) (1) increase [1]

(As frequency of green light is lower, energy of each photon decreases, number of photon increases.)

(2) decrease [1]

(As energy of each photon decreases, for the same work function, K_{max} decreases and thus V_s decreases.)

Section C : Energy and Use of Energy

3.1 A

✓ (1) In order to increase the strength of the magnetic field and guide the magnetic flux to the utensil, the cooking utensil must consist of magnetic material, such as iron or steel.

✗ (2) Eddy current should be induced in the cooking utensil, not in the cooker.

✗ (3) Heat will transfer from the hot cooking utensil to the surface of the induction cooker, thus, the surface of the cooker may get hot when the cooker is working.

3.2 B

At the point X: $\cos\theta = \frac{1.8}{2.4} = 0.75$

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

$\therefore (20) = \frac{\Phi}{4\pi(2.4)^2}\times(0.75)$ $\therefore \Phi = 1930$ lm

Efficacy $= \frac{\Phi}{P}$

$\therefore (48) = \frac{(1930)}{P}$ $\therefore P = 40$ W

3.3 C

Coefficient of performance $= \frac{\text{cooling capacity}}{\text{input electrical power}}$

$\therefore$ COP $= \frac{Q_c/t}{W/t} = 2.5$ $\frac{Q_c}{t} = 2.5\frac{W}{t}$

By $\frac{Q_H}{t} = \frac{Q_C}{t} + \frac{W}{t}$

$\therefore (5250) = 2.5\frac{W}{t} + \frac{W}{t}$ $\frac{W}{t} = 1500$ W

Cooling capacity : $\frac{Q_C}{t} = 2.5\times1500 = 3750$ W

3.4 C

✗ (1) When the hybrid car is cruising at a constant speed by engine, the excess power of the engine drives the dynamo to generate electricity to charge the battery. In this case, the device should be used as a dynamo.

✗ (2) When full power is needed, both the engine and the motor work together. In this case, the device works as a motor.

✓ (3) Under braking, the kinetic energy of the car drives the dynamo to generate electricity for charging. In this case, the device works as a dynamo.

3.5 A

Total fission energy given out by the uranium × efficiency = electrical energy output = Pt

$$\frac{(0.03)}{0.235} \times 6.02 \times 10^{23} \times 200 \times 10^{6} \times 1.6 \times 10^{-19} \times 30\% = P \times (3600)$$

$\therefore P = 2.05 \times 10^{9}\ \text{W} = 205\ \text{MW}$

3.6 A

Electrical power × efficiency = rate of increase of gravitational potential energy of water

$$\therefore \Delta P \times \eta = \frac{m}{t} g h = \rho \frac{V}{t} g h$$

$$(500 \times 10^{6}) \times 35\% = (1000) \times \frac{V}{t} \times (9.81)(200)$$

$$\frac{V}{t} = 89\ \text{m}^3\ \text{s}^{-1}$$

3.7 D

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

$\therefore P_{\text{out}} \propto A \eta \propto L^2 \eta \quad (A = \pi L^2)$

$$\frac{\Delta P_{\text{out}}}{P_{\text{out}}} = (1 + 20\%)^2 \times \left(\frac{40}{30}\right) = 1.92 = 192\%$$

Percentage increase of electrical power = 92%

3.8 A

$P = I A \cos\theta \times \eta$

$\therefore (2150) = 1370 \times (1 - 45\%) \times 25 \times \cos 15^\circ \times \eta$

$\eta = 11.8\%$

Q3 (a) (i) thermal conductivity of the material [1]

(ii) thickness of the material [1]

(b) $\frac{\Delta}{t} = U A \Delta T$

$= [(1.6)(840) + (1.2)(150) + (5.4)(240)] \times (7.5)$ [1]

$= 21150\ \text{W}$

$\text{OTTV} = \frac{Q/t}{A}$

$= \frac{(21150)}{(840 + 150 + 240)}$ [1]

$= 17.2\ \text{W m}^{-2}$ [1]

(c) Low-emissivity windows can transmit visible light and reflect infra-red radiation. [1]

(d) (i) from X to Y [1]

(ii) The refrigerant evaporates in X.

OR

The refrigerant changes from liquid to vapour in X. [1]

(iii) By $\text{COP} = \frac{Q_c}{W}$

$\therefore (2.75) = \frac{(550 \times 10^{6})}{W}$

$\therefore W = 2 \times 10^{8}\ \text{J}$ [1]

$\text{Cost} = \frac{(2 \times 10^{8})}{3600000} \times \$1.26 = \$70$ [1]

Section D : Medical Physics

41 A

✓ (1) Since the corrective spectacles have negative power, they are made of concave lenses.
Concave lens is used to correct short sight. The cause of short sight is due to eye lens too thick.

✓ (2) By $P = \frac{1}{u} + \frac{1}{v}$ $(-0.5) = \frac{1}{\infty} + \frac{1}{v}$ $\therefore v = -2$ m
The far point before correction is 2 m.

× (3) By wearing concave lens, both the far point and near point will increase.

42 C

Resolving power : $\theta = \frac{1.22\lambda}{d} = 1.22 \times \frac{550 \times 10^{-9}}{3.5 \times 10^{-3}} = 1.92 \times 10^{-4}$ rad

By $\theta = \frac{a}{L}$ $(1.92 \times 10^{-4}) = \frac{a}{(5)}$ $\therefore a = 9.6 \times 10^{-4}$ m $= 0.96$ mm

43 A

By $L = 10\log(\frac{I}{I_0})$

(90) $= 10\log\frac{I_1}{I_0}$ $\therefore I_1 = 10^9 I_0$

(85) $= 10\log\frac{I_2}{I_0}$ $\therefore I_2 = 10^{8.5} I_0$

$L = 10\log\frac{I}{I_0}$ dB $= 10\log(\frac{10^9 I_0 + 10^{8.5} I_0}{I_0})$ dB $= 91.2$ dB

44 B

Acoustic impedance of muscle : $Z_1 = 1580 \times 1076 = 1.70$ MRayl

Acoustic impedance of fat : $Z_2 = 1450 \times 952 = 1.38$ MRayl

Intensity reflection coefficient from fat to muscle :

$\alpha = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2} \times 100\% = \frac{(1.38 - 1.70)^2}{(1.38 + 1.70)^2} \times 100\% = 1.08\%$

Intensity of ultrasound reflected from the interface :

$I_1 = \alpha I_0 = 1.08\% \times 20 = 0.216$ mW cm^{-2}

45 B

× (1) The use of gel has no relation with the attenuation of sound.

✓ (2) The use of gel is to decrease the reflection of ultrasound from the skin.

✓ (3) If there is air, ultrasound will almost be completely reflected from the skin
since the reflection coefficient between air and skin is almost equal to 1

46 C

Critical angle of the core-cladding interface

$\sin c = \frac{n_{clad}}{n_{core}} = \frac{(1.38)}{(1.56)}$ $\therefore c = 62.2°$

Refracted angle at the air-core interface :

$\theta_{core} = 90° - 62.2° = 27.8°$

By $n_{air}\sin\theta_{air} = n_{core}\sin\theta_{core}$

$\therefore (1)\sin i_{max} = (1.56)\sin 27.8°$

$\therefore i_{max} = 46.7°$

47 D

× (1) ACM must have high density, thus, the average density of the organ should increase.

✓ (2) ACM has high value of attenuation coefficient μ, thus a low value of half-value thickness.

✓ (3) Organ with ACM has high μ and the surrounding soft tissues have low μ.
This gives a larger contrast for observation.

48 D

✓ A. CT makes use of X-ray which is ionizing radiation.

✓ B. CT image can distinguish soft tissues of close values of attenuation coefficients.

✓ C. After scanning 360° around the patient at a certain cross-section of the patient,
the attenuation intensities at different angles are back projected to reconstruct the CT image.

× D. CT scan is a non-invasive operation, without cutting or inserting instruments into the human body.

Q4 (a) In the human body, the effective half-life has to include the biological half-life. [1]

(b) By $\frac{1}{T_e} = \frac{1}{T_p} + \frac{1}{T_b}$

$\frac{1}{(2)} = \frac{1}{(6)} + \frac{1}{T_b}$

$T_b = 3$ hours [1]

By $M = M_0 (\frac{1}{2})^{t/T_b}$ [1]

$\therefore M = (60) (\frac{1}{2})^{(2)/(3)}$ [1]

$\therefore M = 37.8$ mg

(c) Drink large amount of water. [1]

(d) A gamma camera is placed near the patient. [1]

Gamma rays emitted by the tracer penetrated through the human body recorded by the camera to give the image. [1]

(e) This tracer emits β radiation that will increase the harmful effect to the human body. [1]

(f) Radionuclide planar image reveals the function of an organ function [1]

while X-ray radiographic image shows the structure of an organ. [1]