

PHYSICS PAPER 1

8.30 am – 11.00 am (2½ hours)

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 the Question-Answer Book. **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 two 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)

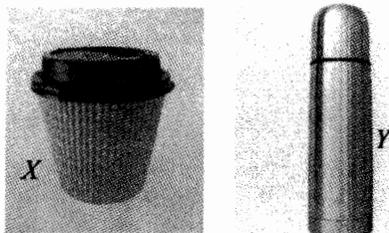
- (1) Read carefully the instructions on the Answer Sheet. After the announcement of the start of the examination, you should first stick a barcode label and insert the information required in the spaces provided. No extra time will be given for sticking on the barcode label after the 'Time is up' announcement.
- (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 the Answer Sheet, so that wrong marks can be completely erased with a 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.

Not to be taken away before the
end of the examination session

Section A

There are 33 questions. Questions marked with * involve knowledge of the extension component.

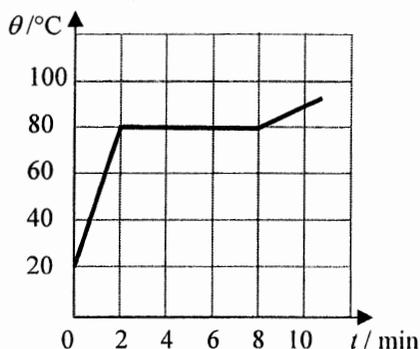
1.



Two identical scoops of ice-cream are transferred from a refrigerator into paper cup X and vacuum flask Y shown above. Under room temperature, the time required for the ice-cream in the containers to melt completely is t_X and t_Y respectively. What is the expected result and explanation?

- A. $t_X > t_Y$ as the vacuum flask reduces heat loss to the surroundings.
- B. $t_X > t_Y$ as the vacuum flask retains the heat.
- C. $t_Y > t_X$ as the vacuum flask keeps things cold by releasing heat into the surroundings.
- D. $t_Y > t_X$ as the vacuum flask reduces the rate of heat gain from the surroundings.

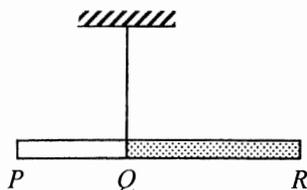
2.



An electric heater of constant power is used to heat a solid substance X which is insulated from the surroundings. The variation of its temperature θ with time t is shown above. X has a specific heat capacity of $800 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$ in its solid state. What is the specific latent heat of fusion of X ?

- A. 144 kJ kg^{-1}
- B. 192 kJ kg^{-1}
- C. 202 kJ kg^{-1}
- D. Answer cannot be found as both the mass of X and the power of the heater are not known.

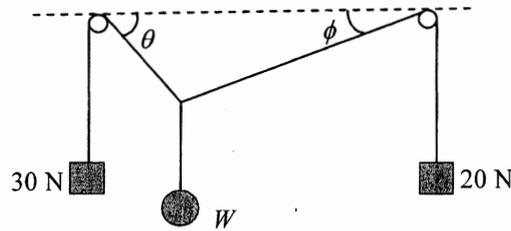
3.



PQR is a composite rod having a uniform cross-section but with portions PQ and QR made of different materials, each of uniform density. The ratio of the length of PQ to that of QR is $2 : 3$. When the rod is suspended at Q , it remains horizontal as shown. What is the ratio of the mass of PQ to that of QR ?

- A. $2 : 3$
- B. $1 : 1$
- C. $3 : 2$
- D. Answer cannot be found as the ratio of their densities is not given.

4.



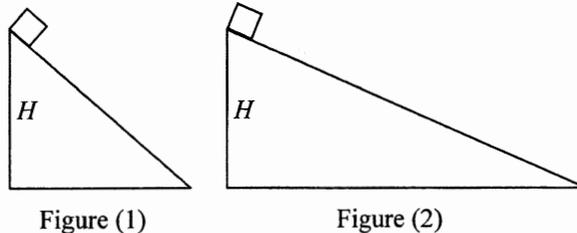
The figure shows a weight W attached to two light strings which pass over two smooth pegs at the same height and with weights 30 N and 20 N attached to the respective ends of each string. The system is at equilibrium. Which deduction about W is correct?

- A. W is less than 50 N.
- B. W is equal to 50 N.
- C. W is greater than 50 N.
- D. No information about W can be obtained as angles θ and ϕ are not known.

5. A particle is moving along a straight line with uniform acceleration. It takes 4 s to travel a distance of 36 m and then 2 s to travel the next 36 m. What is its acceleration?

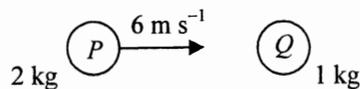
- A. 2.5 m s^{-2}
- B. 3.0 m s^{-2}
- C. 4.0 m s^{-2}
- D. 4.5 m s^{-2}

6. Two small identical blocks slide down from rest on smooth incline planes from the same height H as shown in Figure (1) and Figure (2) below. Their respective speeds at the bottom of the incline planes are denoted by v_1 and v_2 and the respective times taken to reach the bottom are t_1 and t_2 . Which of the following is correct? Neglect air resistance.



- A. $v_1 > v_2$ and $t_1 = t_2$
- B. $v_1 > v_2$ and $t_1 < t_2$
- C. $v_1 = v_2$ and $t_1 = t_2$
- D. $v_1 = v_2$ and $t_1 < t_2$

7.

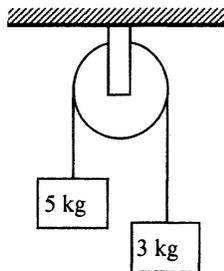


A sphere P of mass 2 kg makes a head-on collision with another sphere Q of mass 1 kg which is initially at rest. The speed of P just before collision is 6 m s^{-1} . If the two spheres move in the same direction after collision, which of the following could be the speed(s) of Q just after collision?

- (1) 2 m s^{-1}
- (2) 4 m s^{-1}
- (3) 6 m s^{-1}

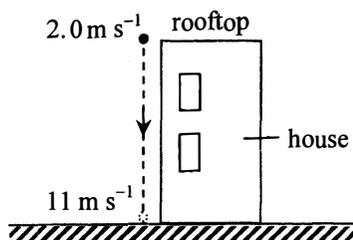
- A. (1) only
- B. (1) and (2) only
- C. (2) and (3) only
- D. (1), (2) and (3)

8. Two blocks of masses 5 kg and 3 kg respectively are connected by a light string passing through a frictionless fixed light pulley. Find the magnitude of the acceleration of the blocks in terms of the acceleration due to gravity g when they are released. Neglect air resistance.



- A. g
 B. $\frac{g}{2}$
 C. $\frac{g}{4}$
 D. $\frac{g}{8}$

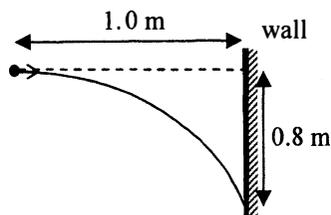
9.



A particle is projected vertically downward with an initial speed of 2.0 m s^{-1} from the rooftop of a house. The particle reaches the ground with a speed of 11 m s^{-1} as shown. Estimate the height of the house. Neglect air resistance. ($g = 9.81 \text{ m s}^{-2}$)

- A. 3.3 m
 B. 6.0 m
 C. 6.5 m
 D. 12 m

*10.



A particle is projected horizontally towards a vertical wall 1.0 m away. It hits the wall at a position 0.8 m vertically below its point of projection. At what speed is it projected? Neglect air resistance. ($g = 9.81 \text{ m s}^{-2}$)

- A. 2.0 m s^{-1}
 B. 2.5 m s^{-1}
 C. 5.0 m s^{-1}
 D. 6.3 m s^{-1}

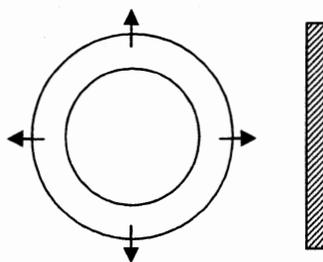
*11. An astronaut inside a spacecraft moving in a circular orbit around the Earth is apparently weightless because

- A. the astronaut is too far from the Earth to feel the Earth's gravitational force.
- B. the astronaut and the spacecraft are both moving with the same acceleration towards the Earth.
- C. the Earth's gravitational force on the astronaut is balanced by the reaction force of the spacecraft's floor.
- D. the Earth's gravitational force on the astronaut is balanced by the centripetal force.

*12. An artificial satellite revolves in a circular orbit above the Earth's surface at a height equal to the radius of the Earth. Find the acceleration of the satellite in terms of the acceleration due to gravity g on the Earth's surface.

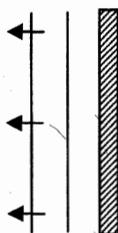
- A. $\frac{g}{8}$
- B. $\frac{g}{4}$
- C. $\frac{g}{2}$
- D. g

13.



The above figure shows two circular pulses produced by drops of water falling on a ripple tank. The pulses are then reflected by a straight barrier. Which diagram best shows the reflected pulses?

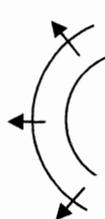
A.



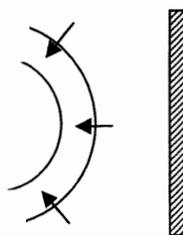
B.



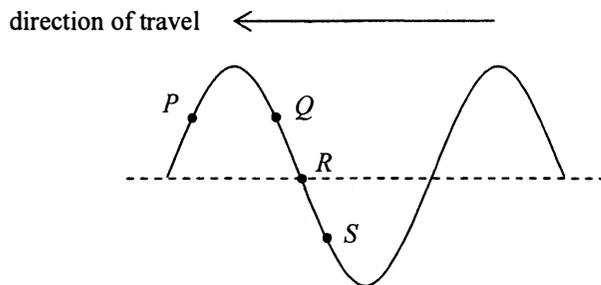
C.



D.



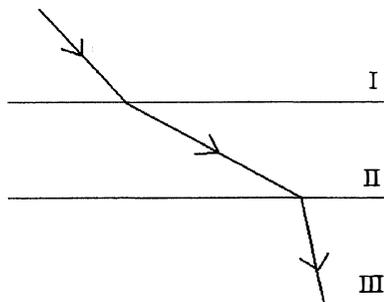
14. A transverse wave travels towards the left on a long string. P , Q , R and S are particles on the string. Which of the following statements correctly describe(s) their motions at the instant shown?



- (1) P is moving upwards.
 (2) Q and S are moving in opposite directions.
 (3) R is momentarily at rest.

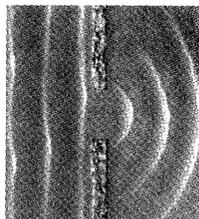
- A. (1) only
 B. (3) only
 C. (1) and (2) only
 D. (2) and (3) only

15. The figure shows the path of a light ray travelling from medium I to medium III separated by parallel boundaries. Arrange in **ascending order** the speed of light in the respective media.



- A. $I < III < II$
 B. $II < III < I$
 C. $III < I < II$
 D. $III < II < I$

16.



The photograph shows a series of plane sea waves travelling through a gap in a sea wall which exhibits diffraction. Assuming that the frequency of the waves remains unchanged, which of the following will increase the degree of diffraction ?

- (1) The gap in the sea wall becomes narrower.
- (2) The wavelength of the waves increases.
- (3) The amplitude of the waves becomes larger.

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

17.

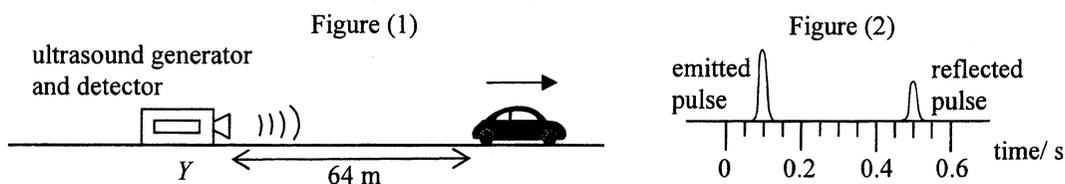
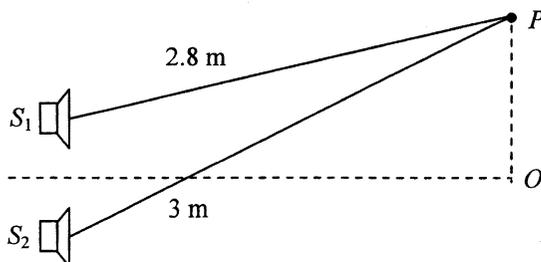


Figure (1) shows a car travelling with a uniform speed along a straight road away from a stationary ultrasound generator and detector at Y . When the car is 64 m from Y , the generator emits an ultrasound pulse towards the car. The pulse is then reflected back to the detector at Y and displayed on a CRO as shown in Figure (2). Estimate the speed of the car. Given: speed of ultrasound in air is 340 m s^{-1}

- A. 16 m s^{-1}
- B. 20 m s^{-1}
- C. 24 m s^{-1}
- D. 32 m s^{-1}

18.



S_1 and S_2 are two loudspeakers connected to a signal generator but the sound waves produced by them are in anti-phase. Point O is equidistant from the loudspeakers while point P is at the distances shown in the figure from the loudspeakers. What type of interference occurs at O and P if the wavelength of the sound waves is 10 cm ?

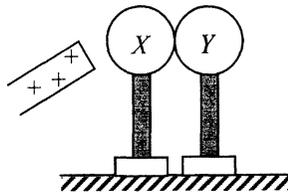
- | | O | P |
|----|--------------|--------------|
| A. | destructive | constructive |
| B. | constructive | constructive |
| C. | destructive | destructive |
| D. | constructive | destructive |

19. Which of the following statements about sound waves is/are correct ?

- (1) Sound waves are electromagnetic waves.
- (2) Sound waves cannot travel in a vacuum.
- (3) Sound waves cannot form stationary waves.

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

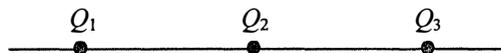
20.



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

- | | sphere X | sphere Y |
|----|------------|------------|
| A. | uncharged | uncharged |
| B. | uncharged | positive |
| C. | negative | uncharged |
| D. | negative | negative |

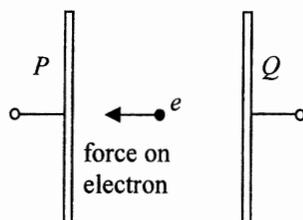
21.



Three point charges Q_1 , Q_2 and Q_3 are fixed on a straight line with Q_2 at the mid-point of Q_1 and Q_3 . The resultant electrostatic force on each charge is zero. Which of the following can be the sign and magnitude (in the same arbitrary units) of Q_1 , Q_2 and Q_3 ?

- | | Q_1 | Q_2 | Q_3 |
|----|-------|-------|-------|
| A. | +2 | +1 | +2 |
| B. | +2 | -1 | +2 |
| C. | -4 | +1 | +4 |
| D. | -4 | +1 | -4 |

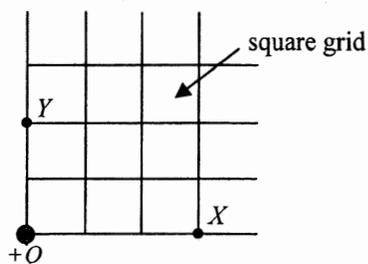
22.



Two parallel metal plates P and Q are maintained at a certain p.d. by a battery (not shown in the figure). An electron placed between the plates would experience an electrostatic force of 8.0×10^{-18} N towards P . Which of the following descriptions about the electric field E between the plates is correct?

- A. $E = 0.02 \text{ N C}^{-1}$ from Q to P .
- B. $E = 0.02 \text{ N C}^{-1}$ from P to Q .
- C. $E = 50 \text{ N C}^{-1}$ from Q to P .
- D. $E = 50 \text{ N C}^{-1}$ from P to Q .

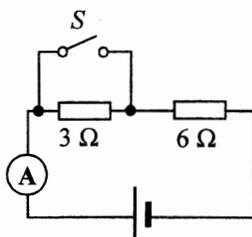
*23.



The figure shows the location of an isolated point charge $+Q$. If the electric potential at X is V , what is the electric potential at Y ?

- A. $\frac{2}{3}V$
- B. $\frac{3}{2}V$
- C. $\frac{4}{9}V$
- D. $\frac{9}{4}V$

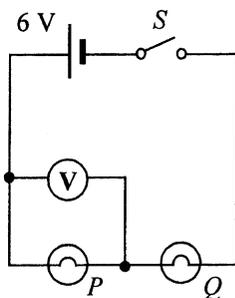
24.



In the above circuit, the cell has constant e.m.f. and a fixed internal resistance. When S is closed, the ammeter reads 3.0 A. When S is open, which of the following is a possible reading of the ammeter?

- A. 1.6 A
- B. 2.0 A
- C. 2.4 A
- D. 3.2 A

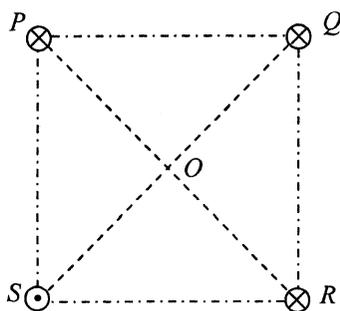
25.



The figure shows two light bulbs P and Q connected to a cell of e.m.f. 6 V and negligible internal resistance. The voltmeter reads 6 V when the switch S is closed. Which of the following is possible?

- A. Both P and Q are short-circuited.
- B. Both P and Q are burnt out and become open circuit.
- C. P is short-circuited or Q is burnt out and becomes open circuit.
- D. P is burnt out and becomes open circuit or Q is short-circuited.

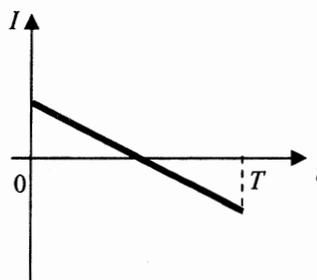
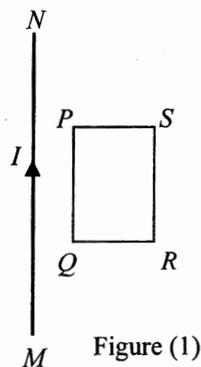
26.



Four long straight parallel wires P , Q , R and S carrying currents of equal magnitude are situated at the vertices of a square as shown. P , Q and R each carries a current directed into the paper while S carries a current directed out of the paper. The direction of the resultant magnetic field at the centre O of the square is along

- A. OP .
- B. OQ .
- C. OR .
- D. OS .

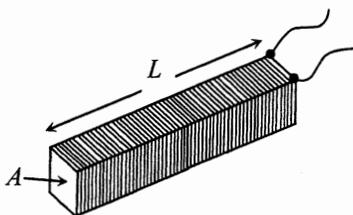
27.



A long straight current-carrying wire MN and a rectangular coil $PQRS$ are fixed in the same plane as shown in Figure (1). The current I is taken as positive when it flows from M to N and it varies with time t as shown in Figure (2). The direction of the induced current in the coil during the time interval $0 - T$ is

- A. first anti-clockwise and then clockwise.
- B. first clockwise and then anti-clockwise.
- C. anti-clockwise throughout.
- D. clockwise throughout.

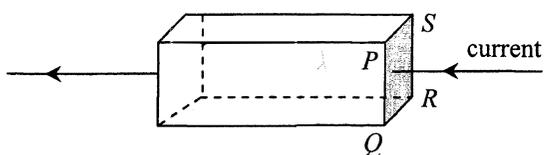
28.



The figure shows a closely packed long solenoid of cross-sectional area A and length L having a total of N turns. If the solenoid carries a constant direct current throughout, which of the following changes can increase the magnetic flux density B at its central cross-section?

	length	cross-sectional area	total number of turns
A.	$2L$	$2A$	$2N$
B.	L	$2A$	N
C.	$2L$	A	N
D.	L	A	$2N$

*29.



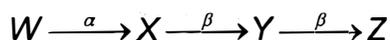
The figure shows a current flowing from right to left in a metal block with cross-section $PQRS$. When a uniform magnetic field is applied to the block, the electric potential of the side PQ is found to be higher than that of the side SR . In which direction can the magnetic field be applied ?

- A. from P to Q
- B. from Q to P
- C. from P to S
- D. from S to P

*30. When a heater is connected to a d.c. voltage of 10 V , the power dissipated is P . If the heater is connected to a sinusoidal a.c., the power dissipated becomes $\frac{1}{2}P$. What is the **r.m.s. voltage** of this a.c. source ? Assume that the resistance of the heater is constant.

- A. 5 V
- B. $5\sqrt{2}\text{ V}$
- C. 10 V
- D. $10\sqrt{2}\text{ V}$

31. Nucleus W decays to nucleus Z as shown below:



Which of the following statements is/are correct ?

- (1) Nucleus X has 1 more proton than nucleus Y .
 - (2) Nucleus W has 2 more neutrons than nucleus X .
 - (3) W and Z are isotopes of the same element.
- A. (1) only
 - B. (2) only
 - C. (1) and (3) only
 - D. (2) and (3) only

32. A GM counter is placed close to and in front of a radioactive source which emits both α and γ radiations. The count rate recorded is 450 counts per minute while the background count rate is 50 counts per minute. Three different materials are placed in turn between the source and the counter. The following results are obtained.

Material	Recorded count rate / counts per minute
(Nil)	450
cardboard	x
1 mm of aluminium	y
2 mm of lead	z

Which of the following is the most suitable set of values for x , y and z ?

- | | x | y | z |
|----|-----|-----|-----|
| A. | 300 | 300 | 100 |
| B. | 300 | 100 | 50 |
| C. | 100 | 100 | 0 |
| D. | 100 | 50 | 50 |
- *33. A radium nucleus decays to a radon nucleus by emitting an α -particle. The energy released in the process is 4.9 MeV. Compared to the mass of a radium nucleus, the total mass of a radon nucleus and an α -particle is
- A. 5.4×10^{-11} kg less.
 - B. 5.4×10^{-11} kg more.
 - C. 8.7×10^{-30} kg less.
 - D. 8.7×10^{-30} kg more.

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	$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$	
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 :

$$v = u + at$$

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

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

Mathematics

Equation of a straight line $y = mx + c$

Arc length $= r\theta$

Surface area of cylinder $= 2\pi rh + 2\pi r^2$

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 radians)

<p>Astronomy and Space Science</p> <p>$U = -\frac{GMm}{r}$ gravitational potential energy</p> <p>$P = \sigma AT^4$ Stefan's law</p> <p>$\left \frac{\Delta f}{f_0} \right \approx \frac{v}{c} \approx \left \frac{\Delta \lambda}{\lambda_0} \right$ Doppler effect</p>	<p>Energy and Use of Energy</p> <p>$E = \frac{\Phi}{A}$ illuminance</p> <p>$\frac{Q}{t} = \kappa \frac{A(T_H - T_C)}{d}$ rate of energy transfer by conduction</p> <p>$U = \frac{\kappa}{d}$ thermal transmittance U-value</p> <p>$P = \frac{1}{2} \rho A v^3$ maximum power by wind turbine</p>
<p>Atomic World</p> <p>$\frac{1}{2} m_e v_{\max}^2 = hf - \phi$ Einstein's photoelectric equation</p> <p>$E_n = -\frac{1}{n^2} \left\{ \frac{m_e e^4}{8h^2 \epsilon_0^2} \right\} = -\frac{13.6}{n^2} \text{ eV}$ energy level equation for hydrogen atom</p> <p>$\lambda = \frac{h}{p} = \frac{h}{mv}$ de Broglie formula</p> <p>$\theta \approx \frac{1.22\lambda}{d}$ Rayleigh criterion (resolving power)</p>	<p>Medical Physics</p> <p>$\theta \approx \frac{1.22\lambda}{d}$ Rayleigh criterion (resolving power)</p> <p>power $= \frac{1}{f}$ power of a lens</p> <p>$L = 10 \log \frac{I}{I_0}$ intensity level (dB)</p> <p>$Z = \rho c$ acoustic impedance</p> <p>$\alpha = \frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ intensity reflection coefficient</p> <p>$I = I_0 e^{-\mu x}$ transmitted intensity through a medium</p>

A1.	$E = mc \Delta T$	energy transfer during heating and cooling	D1.	$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$	Coulomb's law
A2.	$E = l \Delta m$	energy transfer during change of state	D2.	$E = \frac{Q}{4\pi\epsilon_0 r^2}$	electric field strength due to a point charge
A3.	$pV = nRT$	equation of state for an ideal gas	D3.	$V = \frac{Q}{4\pi\epsilon_0 r}$	electric potential due to a point charge
A4.	$pV = \frac{1}{3} Nmc^2$	kinetic theory equation	D4.	$E = \frac{V}{d}$	electric field between parallel plates (numerically)
A5.	$E_K = \frac{3RT}{2N_A}$	molecular kinetic energy	D5.	$I = nAvQ$	general current flow equation
B1.	$F = m \frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$	force	D6.	$R = \frac{\rho l}{A}$	resistance and resistivity
B2.	moment = $F \times d$	moment of a force	D7.	$R = R_1 + R_2$	resistors in series
B3.	$E_p = mgh$	gravitational potential energy	D8.	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	resistors in parallel
B4.	$E_K = \frac{1}{2} mv^2$	kinetic energy	D9.	$P = IV = I^2 R$	power in a circuit
B5.	$P = Fv$	mechanical power	D10.	$F = BQv \sin \theta$	force on a moving charge in a magnetic field
B6.	$a = \frac{v^2}{r} = \omega^2 r$	centripetal acceleration	D11.	$F = BIl \sin \theta$	force on a current-carrying conductor in a magnetic field
B7.	$F = \frac{Gm_1 m_2}{r^2}$	Newton's law of gravitation	D12.	$V = \frac{BI}{nQt}$	Hall voltage
C1.	$\Delta y = \frac{\lambda D}{a}$	fringe width in double-slit interference	D13.	$B = \frac{\mu_0 I}{2\pi r}$	magnetic field due to a long straight wire
C2.	$d \sin \theta = n\lambda$	diffraction grating equation	D14.	$B = \frac{\mu_0 NI}{l}$	magnetic field inside a long solenoid
C3.	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	equation for a single lens	D15.	$\epsilon = N \frac{\Delta \Phi}{\Delta t}$	induced e.m.f.
			D16.	$\frac{V_s}{V_p} \approx \frac{N_s}{N_p}$	ratio of secondary voltage to primary voltage in a transformer
			E1.	$N = N_0 e^{-kt}$	law of radioactive decay
			E2.	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$	half-life and decay constant
			E3.	$A = kN$	activity and the number of undecayed nuclei
			E4.	$\Delta E = \Delta mc^2$	mass-energy relationship

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 your Candidate Number in the space provided on Page 1 and stick barcode labels in the spaces provided on Pages 1, 3, 5, 7 and 9.
- (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 question number 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	7
2	6
3	12
4	9
5	7
6	8
7	7
8	12
9	8
10	8



* A 1 5 0 E 0 1 B *

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Section B: Answer ALL questions. Parts marked with * involve knowledge of the extension component. Write your answers in the spaces provided.

1.

Figure 1.1

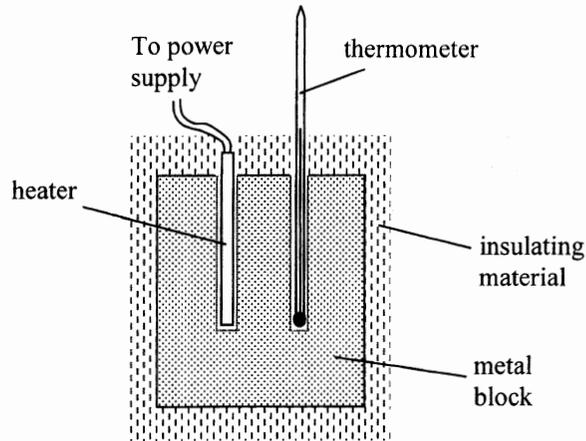
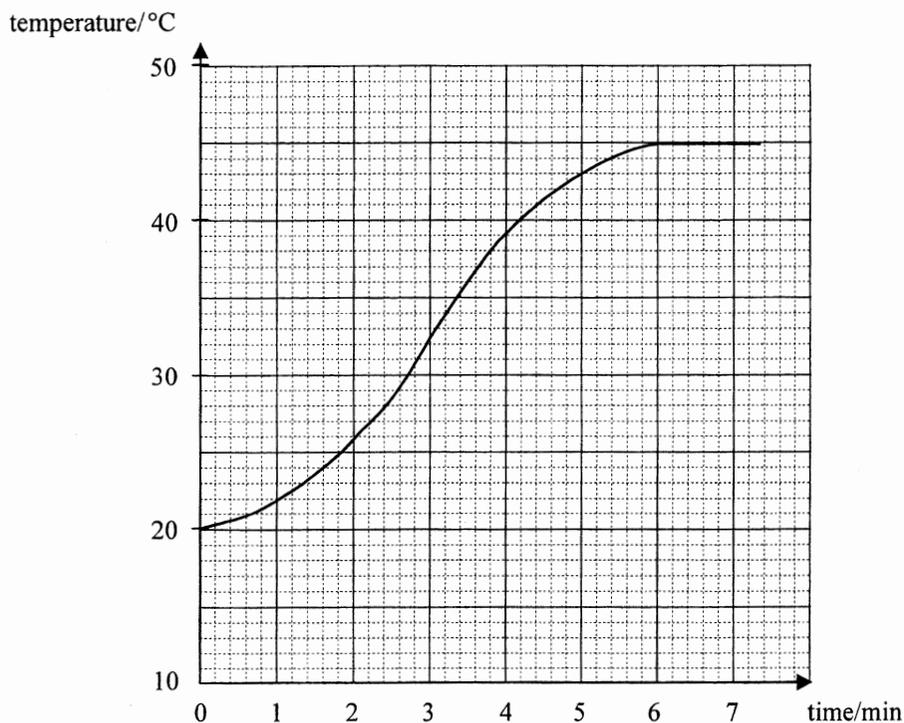


Figure 1.1 shows an experimental set-up to find the specific heat capacity of a metal. The metal block is wrapped by insulating material. A heater is connected to a power supply. It is switched on when the temperature of the metal block is 20°C and then switched off when the temperature reaches 43°C . The graph below shows the variation of the temperature of the metal block with time.



(a) Use the graph to find the duration that the heater is switched on. (1 mark)

(b) After the heater is switched off, the temperature of the metal block continues to rise for a while. Explain why. (1 mark)

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(c) Given: mass of the metal block = 0.80 kg
heater voltage = 12 V
heater current = 4.0 A

(i) By considering the maximum temperature rise of the metal block, calculate the specific heat capacity of the metal as found from the experiment. (2 marks)

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(ii) Would your result be the same, higher, or lower than the actual value of the specific heat capacity of the metal? Explain. (2 marks)

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(d) This method is not suitable for measuring the specific heat capacity of a glass block. Explain. (1 mark)

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- (b) Use kinetic theory of an ideal gas to explain the increase of pressure inside the basketball when air is pumped into it. (2 marks)

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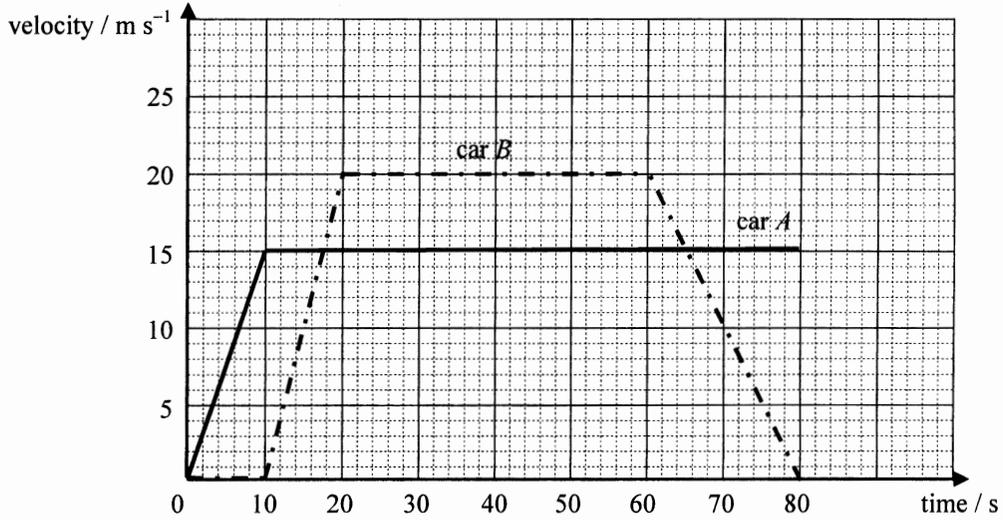
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3. Two cars *A* and *B* initially at the same position, start to travel along the same straight horizontal road. The graph below shows how their velocities vary with time.

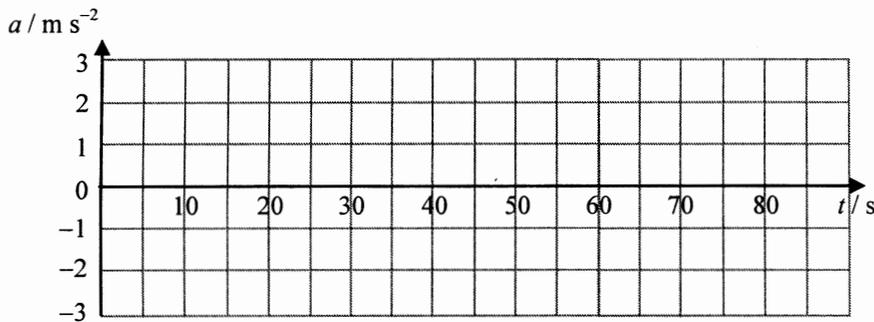


- (a) Describe the motion of car *A* along the whole journey from time $t = 0$ to $t = 80$ s. (2 marks)

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- (b) (i) Which car attained the greatest acceleration throughout the journey? Find this acceleration. (2 marks)

- (ii) Sketch the acceleration-time ($a-t$) graph of car *B* from $t = 0$ to $t = 80$ s. (2 marks)



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(c) (i) At $t = 20$ s, what is the separation between cars A and B ? (2 marks)

(ii) Deduce the time at which car B catches up with car A . (2 marks)

(d) Both cars are of similar size and shape. It is known that the total resistive force experienced by each car is proportional to the square of its velocity. Determine the ratio of power output of the engine of car A to that of car B within the period $t = 20$ s to $t = 60$ s. (2 marks)

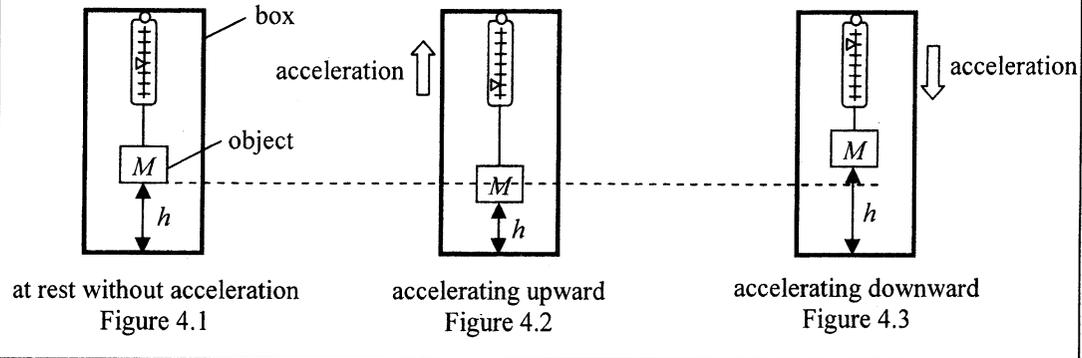
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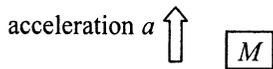
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4. Read the following description about **accelerometers** and answer the questions that follow.

An accelerometer is a device for measuring acceleration. The following example illustrates the principle of a simple accelerometer. An object of mass M is suspended by a spring balance inside a box. If the box is at rest without acceleration, the object is h above the bottom of the box (Figure 4.1). When the box accelerates upward, h decreases (Figure 4.2). Likewise, when the box accelerates downward, h increases (Figure 4.3). Since it is known that the tension of the spring balance is directly proportional to its extension, we can therefore determine the magnitude and direction of the box's acceleration by measuring h .



- (a) Draw a labelled free-body diagram in the space provided below showing the forces acting on the object when the box accelerates upward with acceleration a . Explain why h decreases in this case. (4 marks)



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- (b) The scale of the spring balance is calibrated such that the pointer moves 1 cm for a change of 2 N of force. The weight of the object is 5 N. If h decreases by 0.5 cm compared to the situation in Figure 4.1, what is the reading of the balance? Hence find the magnitude of the corresponding acceleration of the box. (acceleration due to gravity $g = 9.81 \text{ m s}^{-2}$) (3 marks)

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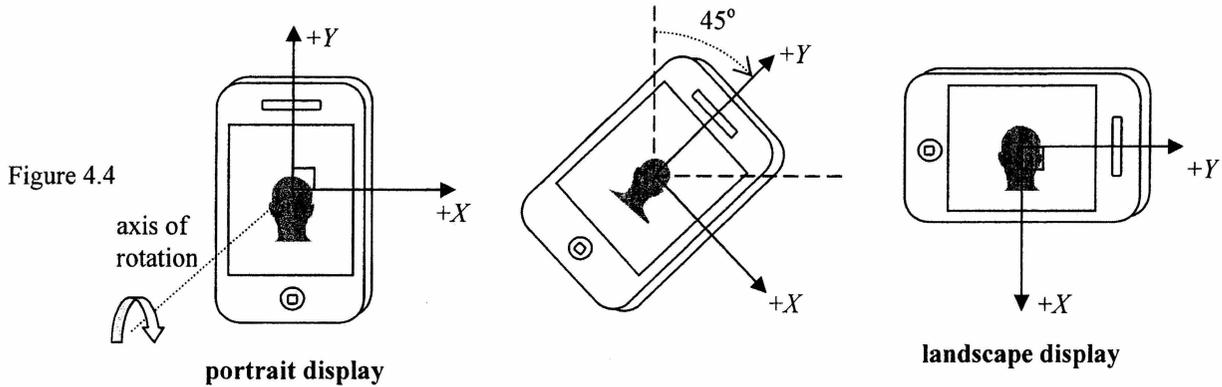
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Electronic accelerometers employing similar principles are widely used in smart phones. The phone's orientation is detected by a set of built-in accelerometers each detecting the acceleration due to gravity along mutually perpendicular axes of the phone. A phone in vertical orientation is shown on the left of Figure 4.4, its accelerometer along the Y axis would be sensing the acceleration due to gravity, denoted by $a_Y = -g$. When the phone is rotated about a horizontal axis perpendicular to both X and Y axes by more than 45° , 'portrait display' would change to 'landscape display' as shown on the right of Figure 4.4.



- (c) What would the kind of display be if the phone is rotated clockwise until the acceleration a_Y sensed by the accelerometer along the rotated Y axis is $-0.5 g$? Explain. (2 marks)

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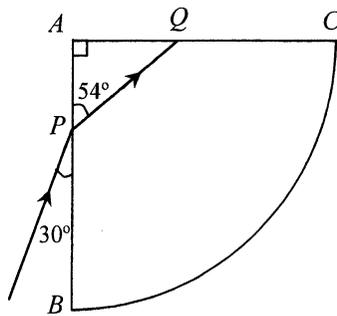


Figure 5.1

Figure 5.1 shows the cross-section of a glass block ABC . ABC is a quarter circle with its centre at A . A ray of red light is incident at P on face AB and the refracted ray strikes the face AC at Q as shown.

- (a) Calculate the refractive index of the glass for red light. (2 marks)

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- (b) Explain why the ray is totally reflected when it strikes the face AC at Q . (2 marks)

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- (c) In Figure 5.1, sketch the subsequent path of the ray until it finally emerges from the block to the air. (2 marks)

- (d) If the incident ray is a ray of white light, what can be observed when it finally emerges from the block? (1 mark)

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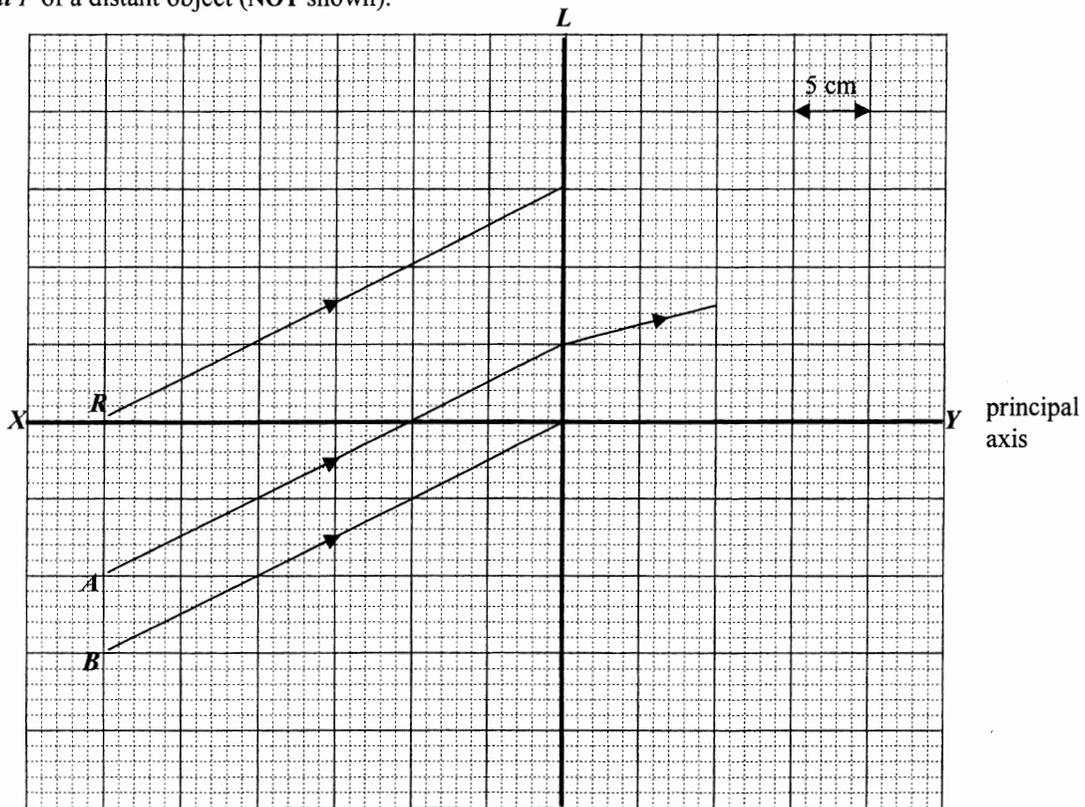
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6. In Figure 6.1, XY is the principal axis of a thin spherical lens L while A, B are two parallel rays coming from a point P of a distant object (NOT shown).

Figure 6.1



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

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- (b) (i) Locate the image of P (denoted it as point P'). (2 marks)

- (ii) Hence, determine the focal length of the lens. (1 mark)

Focal length =

- (c) R is a ray coming from the same point P ; complete its path after passing through the lens. (1 mark)

- (d) Based on the situation shown in the ray diagram above, describe a simple experimental method to determine the focal length of lens L . (2 marks)

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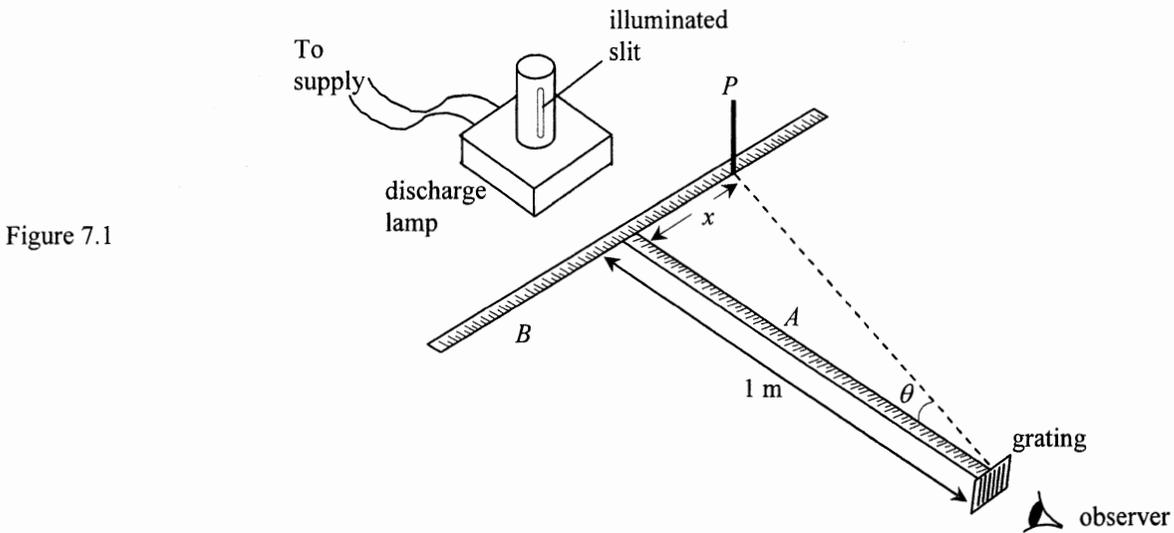
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7. Figure 7.1 shows an experimental set-up to determine the wavelength of monochromatic light emitted from the vertical narrow slit of a discharge lamp. A , B are two mutually perpendicular metre rules on the bench with rule A pointing towards the lamp. A diffraction grating with vertical lines is placed at one end of rule A . A vertically mounted pin P is moved along rule B until the pin is in line with the diffracted image of the second-order to the observer. The corresponding distance x is measured for finding the diffraction angle θ .



The grating has 300 lines per mm and x is found to be 0.38 m for the **second-order** image.

- (a) (i) Calculate the diffraction angle θ . (1 mark)

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- *(ii) Hence find the wavelength of the light from the lamp. (3 marks)

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- (a) (iii) Give **ONE** advantage of measuring the position of the second-order image instead of the first-order one. (1 mark)

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- (b) In the experiment, the illuminated slit may not be well aligned along metre rule *A*. Suggest one way to reduce this error. (2 marks)

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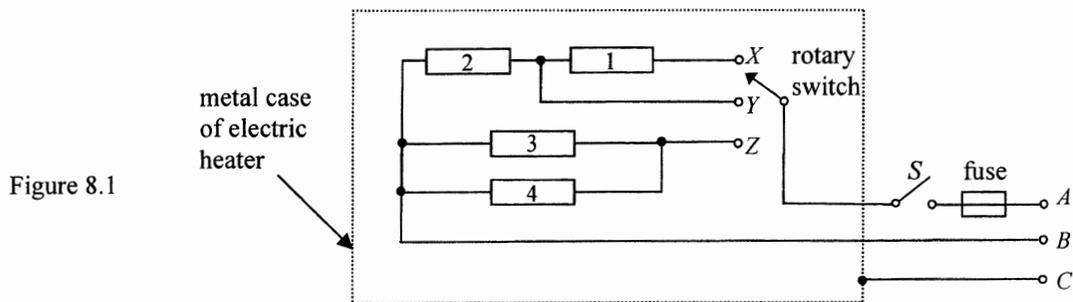
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8. Figure 8.1 shows the schematic diagram of an electric heater consisting of four identical heating elements, each having a rated value of '500 W 220 V'. A user can use the rotary switch to select one of the three modes of operation X, Y, Z. Wires A, B, C from the heater are connected to the 220 V a.c. mains via a 3-pin plug.



- (a) Find the resistance R of a heating element. (1 mark)

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- (b) What is the total power dissipation when mode X is selected? Assume that the resistance of each heating element remains unchanged. (2 marks)

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- (c) Without the need of calculations, explain which mode of operation has the largest total power dissipation. (2 marks)

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- (d) (i) If fuses 3 A, 5 A and 13 A are available, determine which will be the most suitable to limit an excess current. Show your work. (3 marks)

- (ii) A student claims that since a.c. is used for the heater, the switch S can be installed in either wire A or wire B . Comment on this claim. (2 marks)

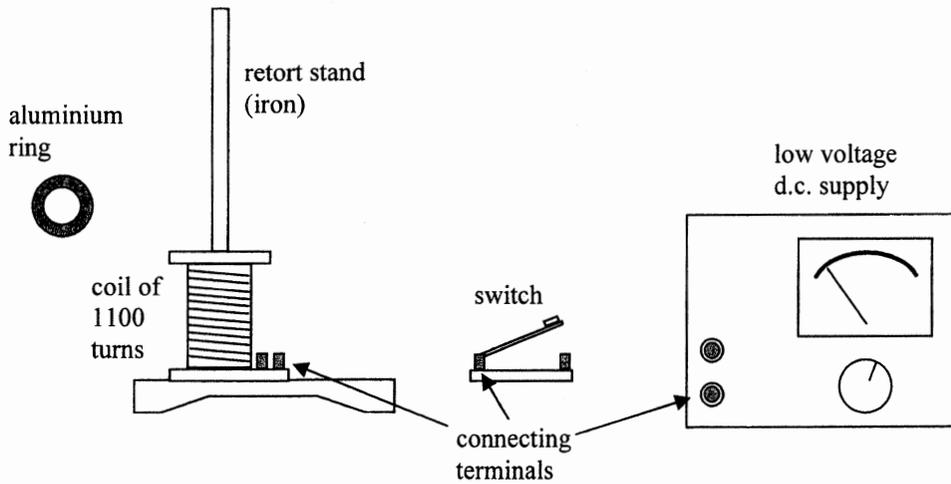
- (iii) If a fault resulted in the live wire having contact with the metal case of the heater, which wire, A , B or C , could prevent an electric shock of a person touched the case of the heater? Explain. (2 marks)

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9. (a) You are given a low voltage d.c. supply, an aluminium ring, a switch, a coil of 1100 turns and a retort stand arranged as shown. Use three connecting leads to complete the connections among the apparatus in the figure and describe how to demonstrate Lenz's law in electromagnetic induction. State and explain the observation. (6 marks)



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(b) Describe what would be observed if the experiment in part (a) is repeated with

(i) a low voltage a.c. supply;

(1 mark)

(ii) a low voltage a.c. supply and an aluminium ring with a slit cut through it as shown [].

(1 mark)

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10. *Voyager I* is a space probe designed by NASA to operate for over ten years in space. It was equipped with a radioisotope thermoelectric generator (RTG) which can convert the energy released from the decay of a radioactive source into electrical power. *Voyager I* operates with a plutonium-238 radioactive source that undergoes α -decay.

- (a) The plutonium-238 source is sealed inside a thin metallic casing of the RTG. The photo shows a NASA staff handling the RTG with his bare hands. Explain why it is fine for it to be handled by the staff in this way. (1 mark)



Figure 10.1

When *Voyager I* was launched, the number of plutonium-238 atoms in the source was 3.2×10^{25} .
Given: half-life of plutonium-238 = 87.74 years.
Take 1 year = 3.16×10^7 s.

- (b) *(i) Find the activity, in Bq, of the plutonium source at the time of launch. (3 marks)

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- (b) (ii) When a plutonium-238 atom decays, it releases 5.5 MeV of energy. Estimate the power, in kW, delivered by the source at the time of launch. (2 marks)

- *(iii) The RTG of *Voyager I* is still in operation as *Voyager I* just left the solar system in September 2013 after it was launched 36 years ago. Estimate the corresponding power delivered by the plutonium source, expressed in **percentage** of the power delivered at the time of launch. (2 marks)

END OF PAPER

Sources of materials used in this paper will be acknowledged in the *Examination Report and Question Papers* published by the Hong Kong Examinations and Assessment Authority at a later stage.

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