Marking Scheme (Physics - New Syllabus)

இலங்கைப் பரீட்சைத் திணைக்களம் / Department of Examinations, Sri Lanka

இலங்கைப் பொது சாதாரண தர (உயர் தர) பரீட்சை, 1997 ஓகஸ்ற் (புதிய பாடத்திட்டம்)
General Certificate of Education (Adv. Level) Examination, August 1997 (New Syllabus)

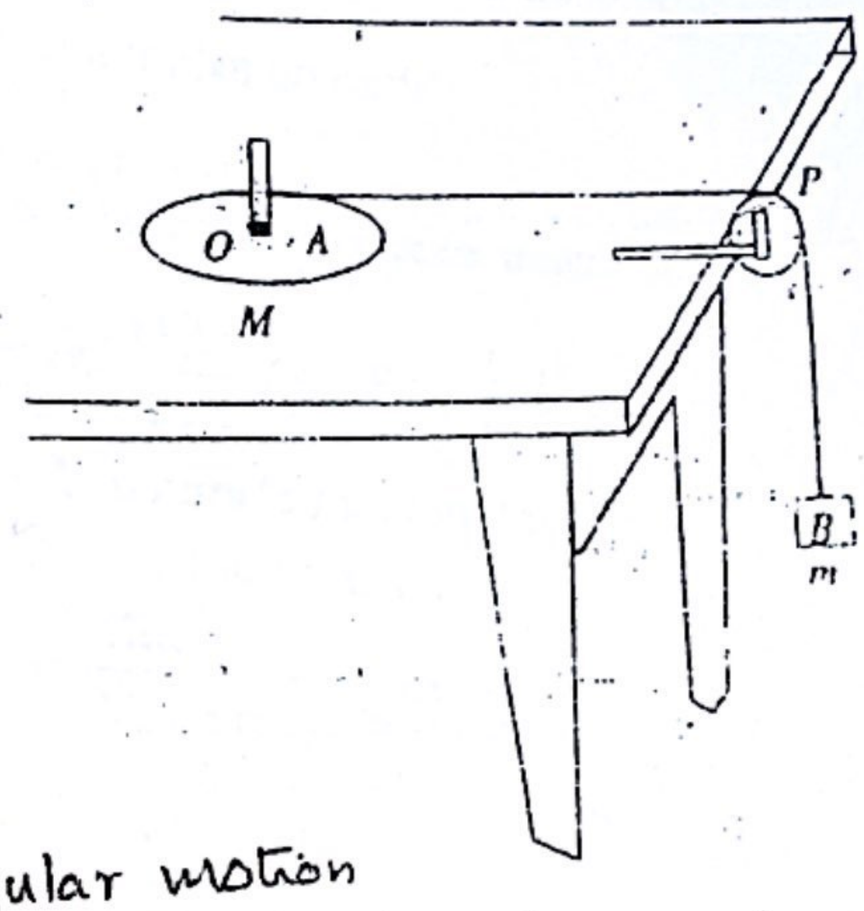
கணிதம் பௌதிகவியல் II
Physics II

01
S | II

மூன்று மணி / Three hours

Part A – Structured Essay
Answer all four questions.
($g = 10\ N\ kg^{-1}$)

A uniform circular disc A of mass M and radius R is mounted horizontally on a smooth table so that it is free to rotate about a frictionless vertical axle passing through its centre O. A light string which is tightly wrapped few times around the circumference of the disc passes over a light pulley P and carries a weight B of mass m at the free end as shown in the figure. The moment of inertia of the disc about the axis of rotation, $I = \frac{1}{2} MR^2$. The system is held at rest with the string taut and released at time $t = 0$.



(a) What type of motions will A and B have?

A: Rotational motion OR angular motion
(Circular motion is not acceptable)
B: Linear Motion OR Translational motion
OR Motion through a straight line; OR Vertical motion

both A and B correct.....01

(b) (i) If the angular acceleration of the disc A is α and the acceleration of the weight B is a, write down the relation between a and α.

$a = R\alpha$ 01

(ii) What is the relation between the torque (Γ) acting on the disc and α.

$\Gamma = I\alpha$ 01

(OR $\Gamma = \frac{1}{2} MR^2\alpha$)

(b) (i) and (ii) γ instead of R.

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(c) After a short time if the string breaks suddenly, what will happen to the motions of A and B

A: Will rotate with constant angular velocity. OR constant rotation (or constant angular motion) OR Uniform rotation (or uniform angular motion)

B: Will move with acceleration g OR falls under gravity
OR falls freely.

Both A and B correct.....01

(d) After the string has broken as mentioned in (c), a second disc of the same radius but of mass M/2 which is at rest is dropped symmetrically on the disc A. The two discs were found to stick together and rotate.

(i) What principle would you use to determine the new angular velocity of the discs ?

Conservation of angular momentum.....01
OR Angular momentum is constant.
OR $I\omega$ = Const. with I and ω clearly defined.

(ii) Under what condition is the above principle valid.

When no external torques act (about the axle).....01

(iii) If the angular velocity of disc A prior to dropping the second disc is ω_0, find the new angular velocity of the discs in terms of ω_0

$I_1 = \frac{1}{2}MR^2$, $I_2 = \frac{1}{2}\left(\frac{M}{2}\right)R^2$

Total moment of inertia $I = I_1 + I_2$ 01
(for addition)

$I_1\omega_0 = I\omega \Rightarrow \frac{MR^2}{2}\omega_0 = \frac{3}{4}MR^2\omega$

$\omega = \frac{2}{3}\omega_0$ 01

Do not award the mark for $(M+\frac{M}{2})\omega = H\omega_0$ instead of $\frac{MR^2}{2}\omega_0 = \frac{3}{4}MR^2\omega$.
But, the assigned mark for the final answer can be awarded if the answer is correct.

(e) Instead of the string breaking as mentioned in (c), suppose the axle breaks and the disc becomes free to move.

(i) What type of motion will A have?

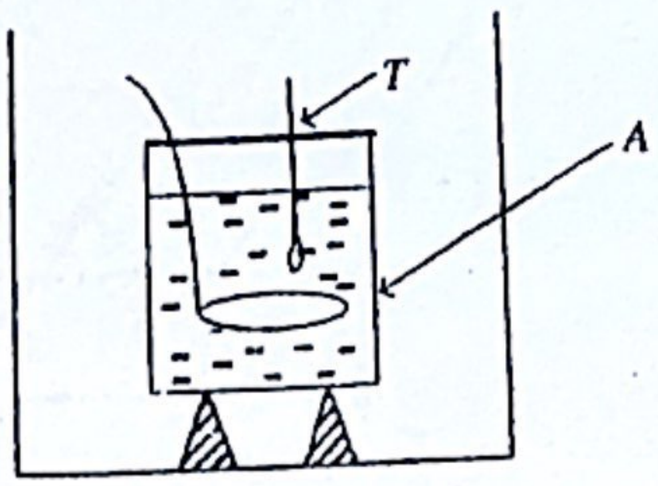
A will rotate and move (linearly) 01
OR Perform both rotational and translational (or linear) motions.
OR Diagram indicating both motions.

(ii) Will the angular acceleration of A remain same as in (b) (i)? Explain your answer.

No
Tension changes and therefore α is bound to change.
OR Because the energy lost by the weight B is now used to produce both rotational and translational motions 01

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Figure shows an experimental arrangement that can be used to determine the specific heat capacity of a liquid using the method of cooling.



(a) Identify the vessel A

Calorimeter ..... .01
[OR Metallic (Cu, Al etc.) vessel]

(b) What are the additional essential measuring instruments required for this experiment?

(i) Stop clock, (OR stop watch)
(ii) Balance

Both correct 01

(c) What are the physical factors of the vessel A, which determine the rate of loss of heat to the surrounding ?

(i) Temperature (OR Temperature difference)
(ii) Surface area
(iii) Nature of the surface (OR emissivity)

All correct 02
Any two 01

(d) In this experiment separate cooling curves are obtained for water and the liquid.
(i) What amount of liquid have to be used with respect to that of water?

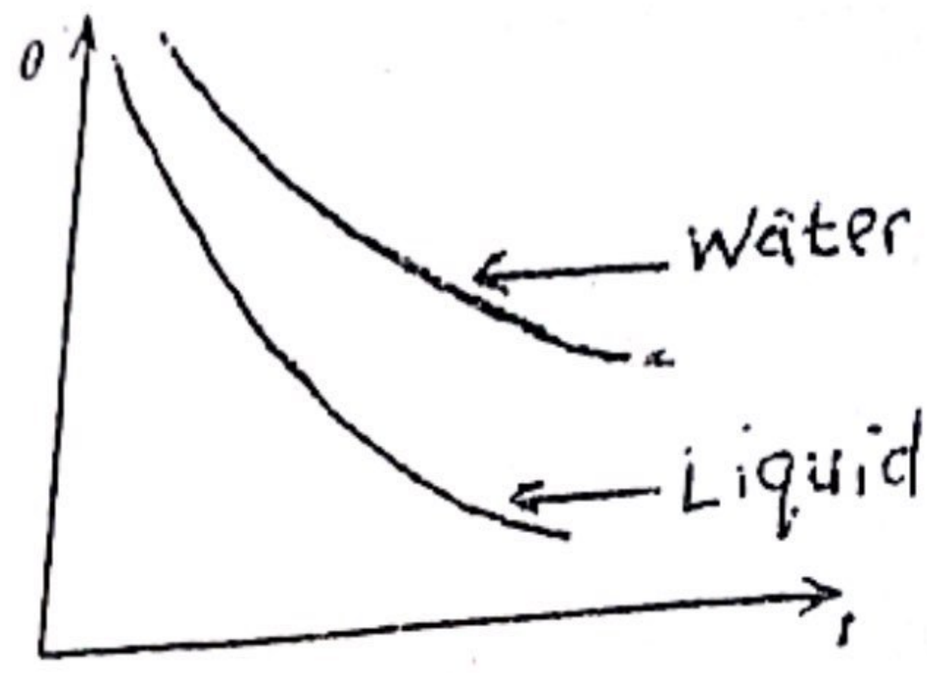
Equal Volumes..... 01
(No marks for ~~answers such as equal amounts, equal quantities~~, equal masses) OR equal amounts, OR equal quantities
Same height or level can be considered as correct answers.

(ii) Give the reason for your answer to d (i).

To keep the cooling conditions same OR to keep the exposed area same 01
OR to achieve identical rate of loss of heat.

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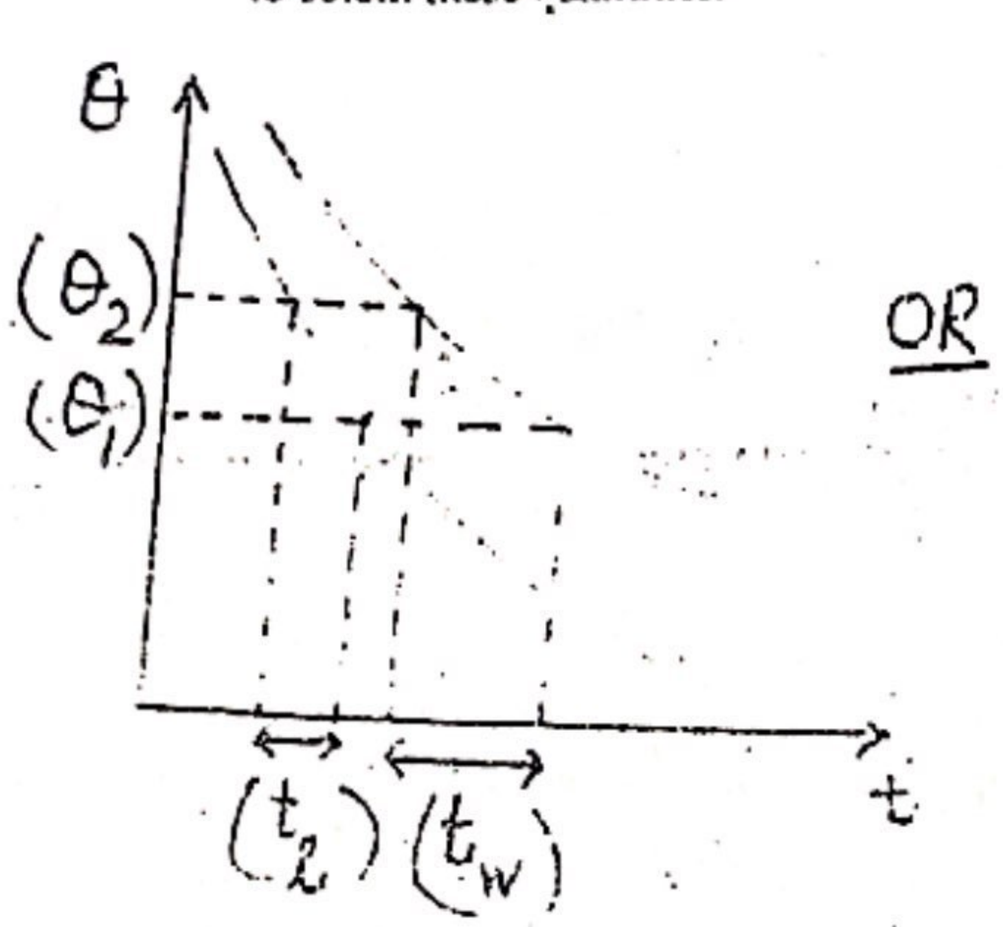
(e) Draw sketches of the two cooling curves you may obtain in this experiment assuming that the heat capacity of water is greater than that of the liquid used. Clearly label the curves



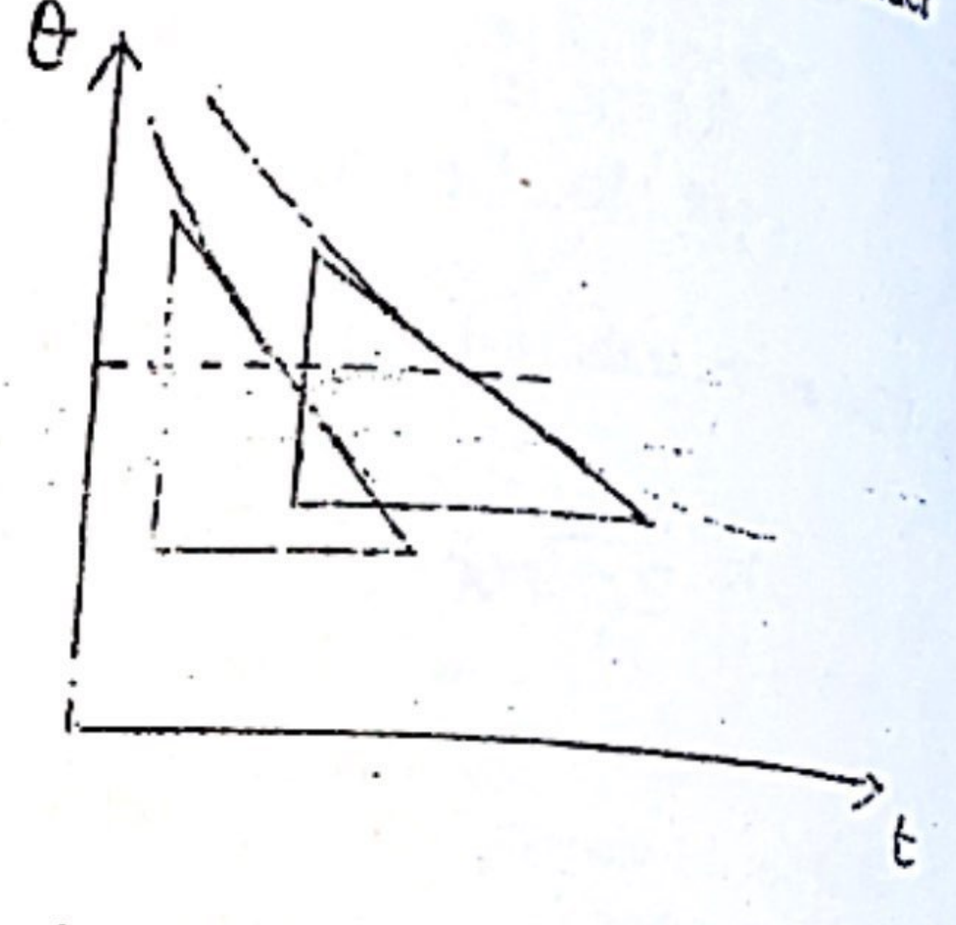
..... 01

(Curves should not be parallel to each other)

(f) Two quantities have to be extracted from the curves in order to determine the specific heat capacity of the liquid. Show the necessary constructions on the diagram given in (e) in order to obtain these quantities.



OR



..... 01

(g) If the heat capacity of A with the stirrer is W, masses of water and the liquid are m_w and m_l and specific heat capacities of water and the liquid are s_w and s_l respectively, write down an expression relating these quantities with the quantities mentioned in (f)

$$\frac{(W + m_l s_l)(\theta_2 - \theta_1)}{t_l} = \frac{(W + m_w s_w)(\theta_2 - \theta_1)}{t_w}$$

OR

$$(W + m_l s_l)\left(\frac{d\theta}{dt}\right)_l = (W + m_w s_w)\left(\frac{d\theta}{dt}\right)_w$$

..... 01

(h) Can you perform this experiment properly by filling the space between A and the outer vessel with water? Explain your answer.

No; Surrounding temperature changes (with time)

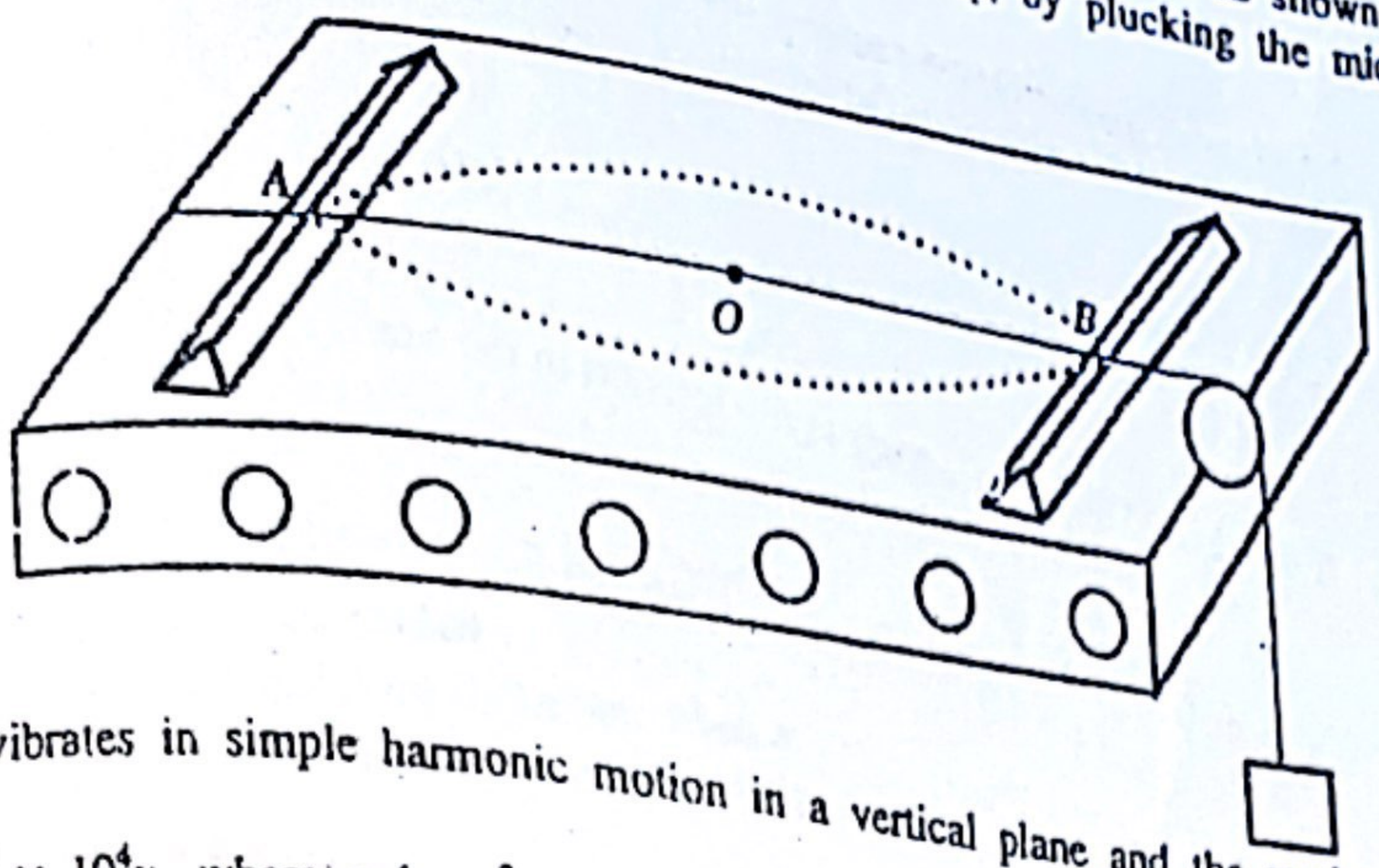
OR

Cooling conditions change with time .....

OR the constant environment conditions change. 01

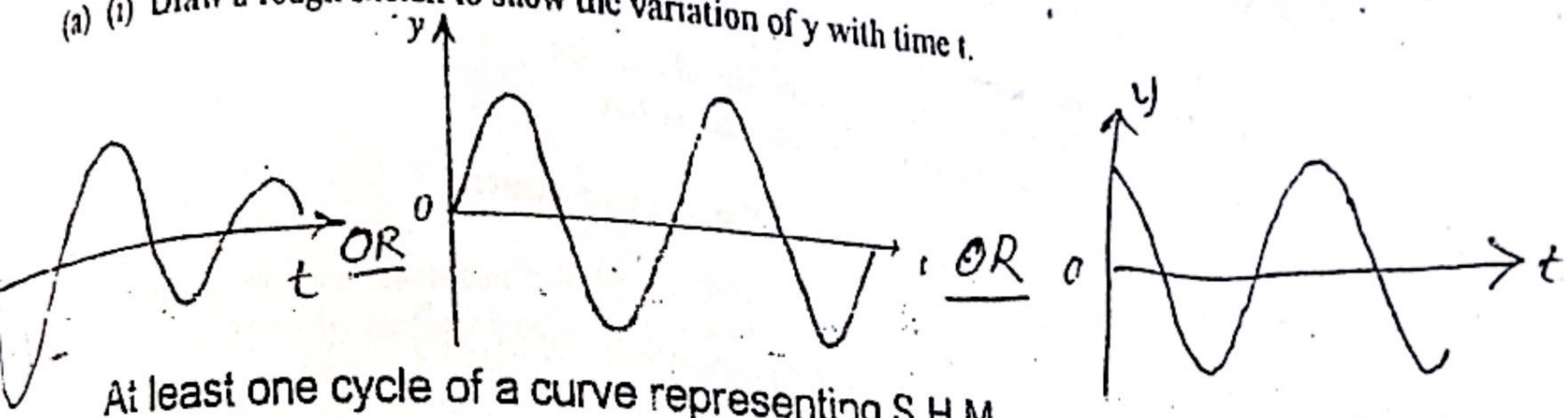
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3. A sonometer wire is stretched between two points A and B, 1·0 m apart as shown in the diagram. This wire is made to vibrate transversely with a single loop, by plucking the middle of the wire at O.



The wire vibrates in simple harmonic motion in a vertical plane and the motion is given by $a = -16\pi^2 \times 10^4 y$, where a (m s^{-2}) is the acceleration and y is the vertical displacement.

(a) (i) Draw a rough sketch to show the variation of y with time t.



At least one cycle of a curve representing S.H.M. C1
(sine or cosine)

(ii) Calculate the periodic time of the vibration of the wire.

$\omega^2 = 16\pi^2 \times 10^4 \quad \Rightarrow \quad \omega = 4\pi \times 10^2$

$T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{4\pi \times 10^2}$

$= \dfrac{1}{200}$ s (OR 5×10^{-3} s)..... 01

(iii) Find also the frequency of the vibration.

$f = \dfrac{1}{T} = 2 \times 10^2$ 01

= 200 Hz .....

(b) (i) What is the wavelength of the wave produced? 01

2 m .....

(ii) Hence calculate the velocity of the transverse wave in the wire. 01

$v = f\lambda = 200 \times 2 = 400\ ms^{-1}$

(Correct substitution)

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(c) (i) Write down an expression relating the transverse wave velocity (V), tension (T) and the mass per unit length (m) of the wire.

$V = \sqrt{\frac{T}{m}}$ 01

(ii) If $m = 1.0 \times 10^{-4}$ kg m^{-1}, what is the tension in the wire?

$V = 400 = \sqrt{\frac{T}{1 \times 10^{-4}}}$ 01

(Correct substitution)

$T = 16\ N$

(d) (i) When students were asked to resonate the sonometer wire using a vibrating tuning fork they used the following methods.

(1) Holding the tuning fork just above the middle of the wire.
(2) Keeping the tuning fork on the middle of the wire.
(3) Placing the tuning fork on the sonometer box.

Which one of the above method is correct? Explain your answer.

Answer: (3)
To transfer maximum amount of energy(efficiently) from the tuning fork..... 01
of the wire to the wire.

(ii) What should be the lowest frequency of the tuning fork which [illegible]

200 Hz 01
(or any value given in a(iii))

(e) If a paper rider is placed at the middle of the wire, at O, for what minimum displacement of the wire the rider will begin to fly off from the wire. (Hint: This will happen when the reaction on the paper rider by the wire becomes zero.)

$R - mg = ma$

Reaction $R = 0$

$\therefore a = -g$

But $a = -\omega^2 y_{max} = -g$

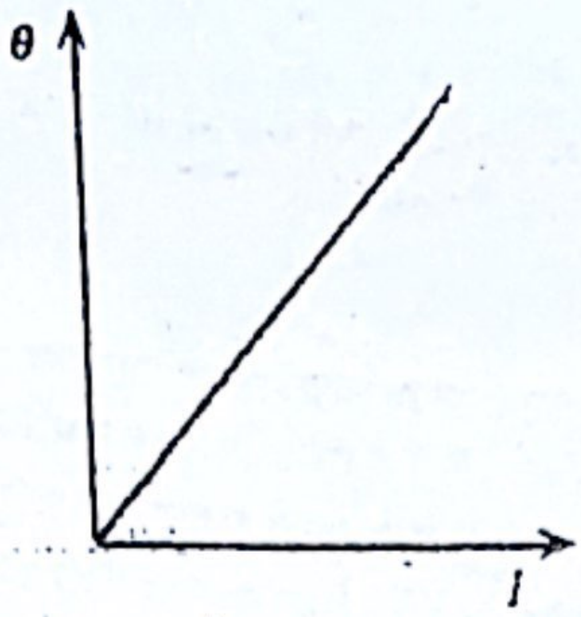
$y_{max} = \frac{g}{\omega^2} = \frac{10}{16\pi^2 \times 10^4}$ 01

$\left(= \frac{1}{160} mm = 6.25 \times 10^{-3} mm \right)$

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9.8 7

(a) A current I is passed through a moving coil galvanometer. Draw a rough sketch to show how the galvanometer deflection θ varies with the current I.



Straight line passing through the origin as shown. 01
(Labelling the origin is not necessary)

A moving coil galvanometer gives full scale deflection when a current of 1 mA is passed through it. Internal resistance of the galvanometer is 50 Ω.

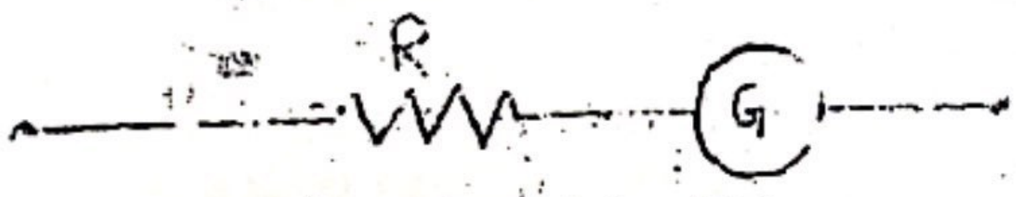
(b) If the galvanometer is calibrated as a voltmeter what will be the maximum potential difference that can be measured with this meter ?

$V = 1 \times 10^{-3} \times 50$

$= 50$ mV 01

$(5 \times 10^{-2}$ V)

(c) (i) If the above mentioned galvanometer is to be converted to a voltmeter with a full scale deflection of 1 V, show by means of a diagram how you would achieve this. (Clearly label the components with standard symbols.)



..... 01

The resistor need not be labelled. The galvanometer can be labelled by V or any A

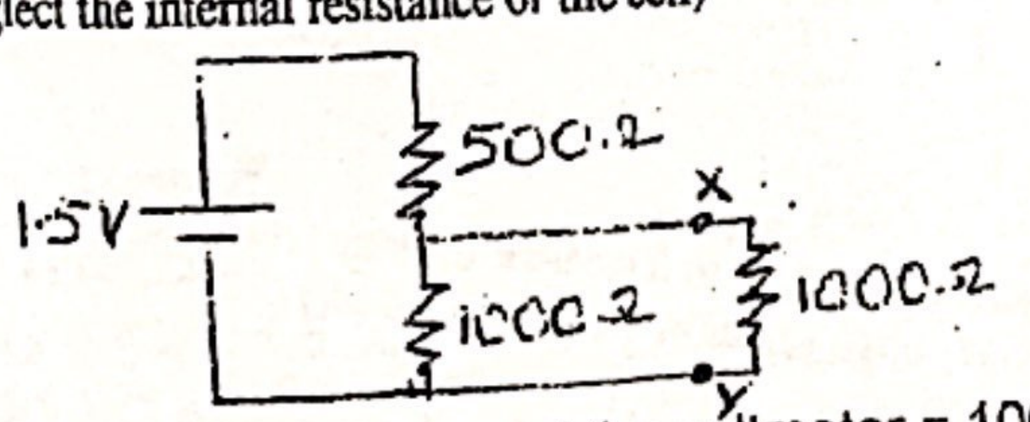
(ii) Calculate the value of the resistor needed.

$1 \times 10^{-3} \times (R + 50) = 1$

$R + 50 = 10^3$

$R = 950\ \Omega$ 01

(i) (i) If the voltmeter mentioned in (c) is connected across XY of the circuit shown what will be the reading on the meter. (Neglect the internal resistance of the cell)



The internal resistance of the voltmeter = 1000 Ω 01
(OR shown in the diagram above)

∴ Reading of the voltmeter = 0.75 V 01

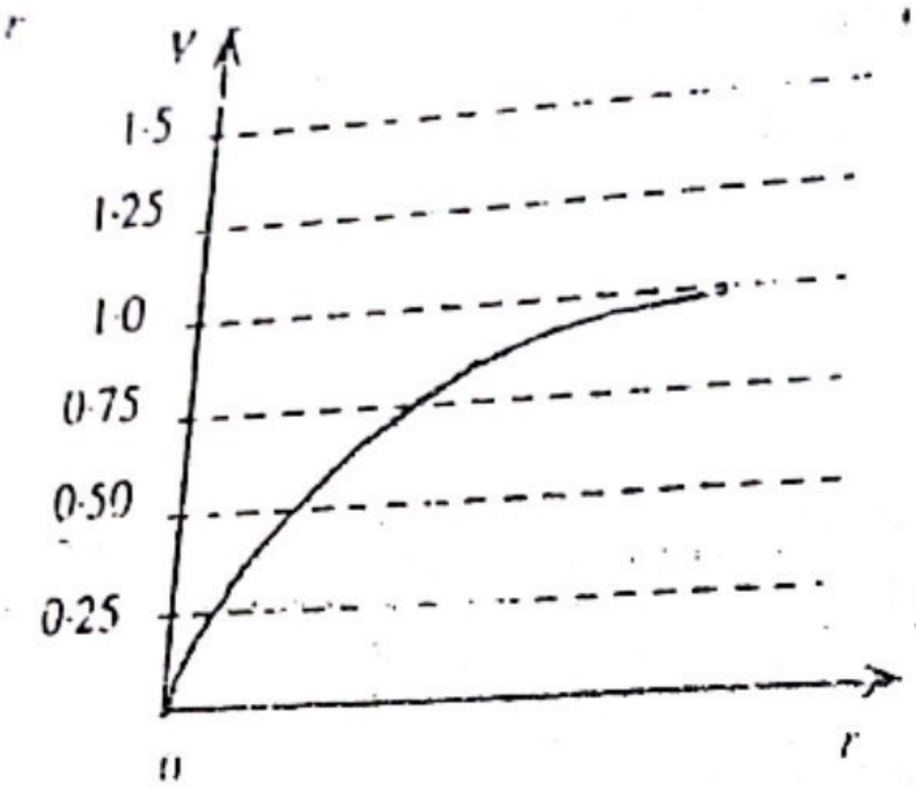
If the student has taken the internal resistance of the voltmeter as 950Ω instead of 1000Ω, then he will lose the mark awarded for the 1000Ω, but

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(ii) Does the voltmeter read the actual value of the potential difference across 1000 Ω ?
Explain your answer.

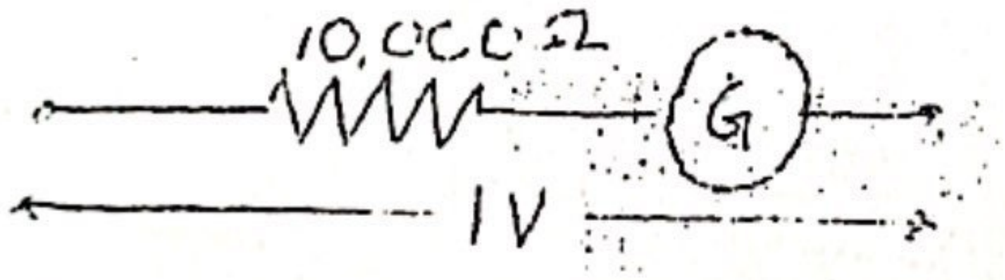
No
Because the resistance of the voltmeter will appear in parallel with 1000 Ω. OR Effective resistance of the 1000 Ω resistor becomes 500 Ω OR Internal resistance of the voltmeter is not large compared to 1000 Ω OR Because the voltmeter is not ideal OR the resistance of the circuit will change when the voltmeter is connected across XY. OR a part of the current flows through the voltmeter. 01

(c) Suppose you are provided with several other voltmeters having different internal resistances r to measure the voltage V across XY. Draw a rough sketch of a curve that you would expect if V is plotted against r



Non linear curve as shown 01
(The curve should not go beyond 1.0 V.)

(f) Suppose you want to construct a voltmeter having a full scale deflection of 1 V and an internal resistance of 10,000 Ω. What is the full scale deflection current of a moving coil galvanometer required for this purpose ?



Full scale deflection current

$I = \frac{1}{10,000} (A)$

$= 10^{-4} (A)$ 01

(OR 0.1 mA or 100 μA)

(g) Give one reason as to why it is practically difficult to increase the internal resistance of the voltmeter mentioned in (f) to extremely large values of the order of 10 MΩ.

Deflection will be too small to read OR the coil will not rotate OR the current through the coil will be too small OR the galvanometer needs a suspension wire with an extremely small torsion constant..... 01

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E	II

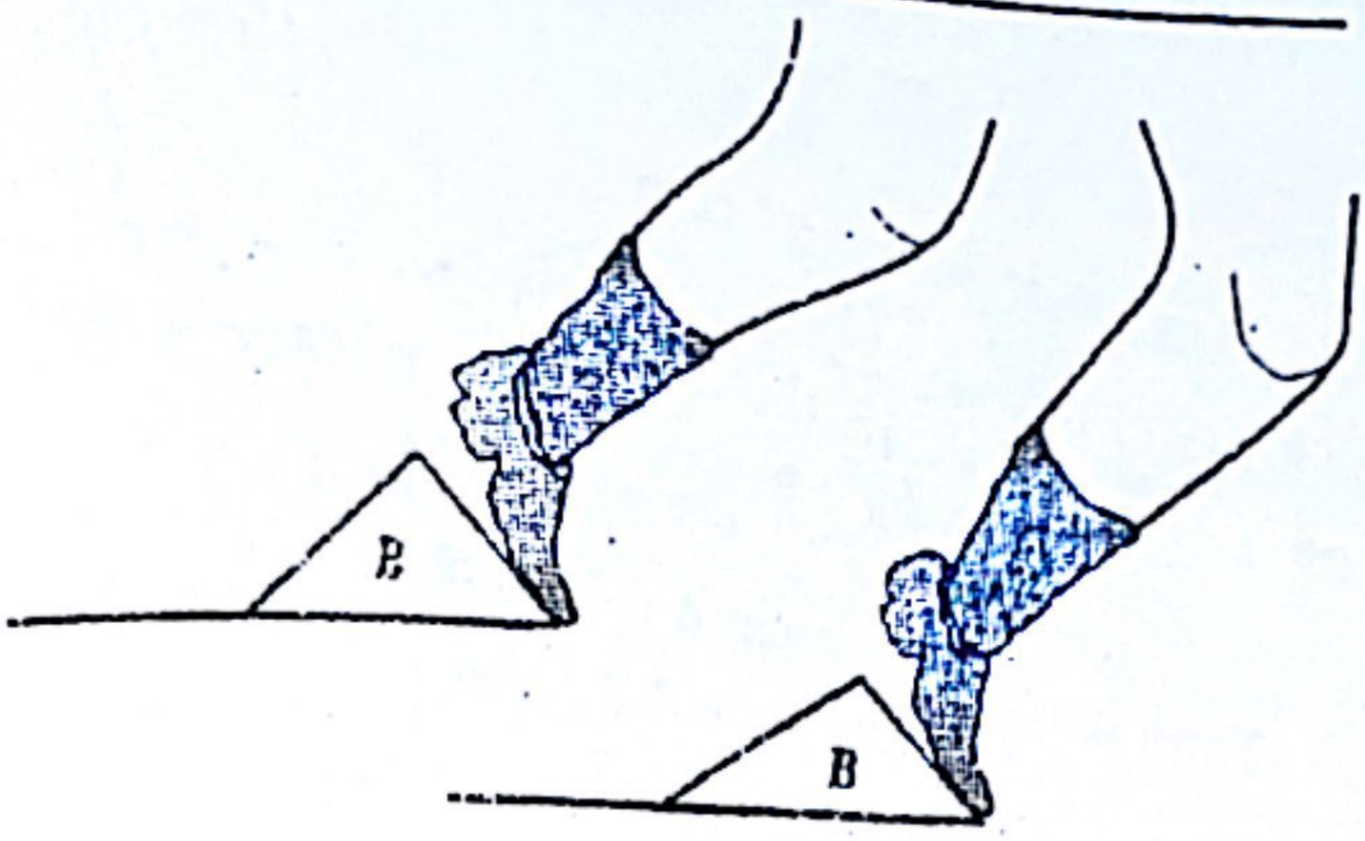
Physics II

Part B – Essay

Answer four questions only

($g = 10\,N\,kg^{-1}$)

a sprinter running a race of 100 m
e by starting blocks (*B*) for 0·2 s
ower them with a speed of
then accelerate for a further
that his speed becomes 12 $m\,s^{-1}$
continues with that speed until the



the reaction force exerted by
the starting blocks on the sprinter.

Calculate the distance covered by
the sprinter by the time he attains the
maximum velocity of 12 $m\,s^{-1}$

What is the mechanical work done by the sprinter during the accelerating period of 5 s?

the time taken by the sprinter to complete the race.

Let us consider another sprinter who took a better start by achieving an initial velocity of 5·4 $m\,s^{-1}$ in the
beginning of the race, however, spent 5·4 s to reach his maximum speed of 12 $m\,s^{-1}$. Calculate
the time at which the former sprinter overtakes the latter.
(Hint: overtaking takes place during the accelerating period of the former sprinter).

(i) Reaction Force $= \frac{70 \times 5}{0.2}$ 01

$= 1750$ N 01

(ii) Distance covered by the sprinter $= \frac{(v+u)}{2} t$ .....(for v-t graph)..... 01

$= \frac{(12+5)}{2} \times 5$ 01

$= 42.5$ m 01

[Alternate Method :

If the acceleration of the sprinter is a, then applying $v = u + at$ 01

$12 = 5 + a \times 5$ .....

$a = 7/5\ m\,s^{-2}$

If the distance covered by the sprinter is s, then applying $s = ut + (1/2)at^2$ 01

$s = 5 \times 5 + (1/2) \times (7/5) \times 25$ ..... 01]

$= 42.5$ m .....

(iii) Mechanical work done = Change in kinetic energy 01

$= \frac{1}{2} \times 70\,(12^2 - 5^2)$ 01

$= 4165$ J .....

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[Alternate Method :

Force (F) acting on the sprinter

$F = 70 \times (7/5)$ ..... 0_1

Work done $= F \times 42.5$

$= 4165\ J$ ..... 0_1]

(iv) Distance covered by the sprinter with $12\ ms^{-1}$

$= 100 - 42.5$ (for subtraction) ..... 0_1

$= 57.5\ m$

Time taken to run 57.5 m

$= \frac{57.5}{12}$ (for the division) ..... 0_1

$= 4.79\ s$

Time taken to complete the race

$= 0.2 + 5 + 4.79$ (for the addition) ..... 0_1

$= 9.99\ s\ (10\ s)$ ..... 0_1

(v) If the acceleration of the second sprinter is a'

$12 = 5.4 + a' \times 5.4$ ..... 0_1

$a' = 11/9\ m\ s^{-2}$

If t is the time taken to overtake the second sprinter, then

$5t + \frac{1}{2} \times \frac{7}{5} \times t^2 = 5.4t + \frac{1}{2} \times \frac{11}{9} \times t^2$ ..... 0_2

(01 mark for the R.H.S. ; 01 mark for equating)

$0.4t - \frac{1}{2} \times \frac{8}{45} \times t^2 = 0$

$t = 4.5\ s\ (4.0\ s - 4.7\ s)$ 01

2. Answer either part (a) or part (b) only.

(a) An empty boat floats in water with 10% of its volume submerged, and when it is loaded with 1200 kg, the volume submerged will increase to 70% of the total volume.

(i) Calculate the mass of the empty boat.

(ii) If a leak develops and water starts to enter the boat which is loaded with 1200 kg at a constant (average) rate of 100 kg per minute, for how long the boat can float before sinking?

(iii) What is the minimum force required to lift the sunk boat (without the load) up to the surface of water. Average density of the material of the boat is 2500 kg m^{-3} and the density of water is 1000 kg m^{-3}.

(iv) The moded boat with another load of 1200 kg on board, while sailing, suddenly enters a region where water is uniformly mixed with tiny air bubbles. If the average volume of an air bubble is $1\ mm^3$ and the air bubble concentration is $3.5 \times 10^8\ m^{-3}$, find the effective density of water. Neglect the mass of air. Hence show that the boat will sink.

(v) Use the effect described in (iv) to explain the danger in the following act.

"There is a deep pool at the foot of a tall water fall. A person starts to swim closer to the fall of the fall".

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(i) Let M be the mass of the empty boat and V be the volume of the boat

$Mg = \frac{10}{100} V\rho_w g$ .....(A) 01

$(M+1200)g = \frac{70}{100} V\rho_w g$ .....(B) 01

(A)÷(B) $\frac{M}{M+1200} = \frac{1}{7}$

$6M = 1200$

$M = 200$ kg 01

(ii) Mass required to sink the boat by 10% = 200 kg

∴ mass required to sink the boat completely = $200 \times \frac{100}{10}$ = 2000 kg

∴ additional mass needed to sink the boat = 2000 - 1400

= 600 kg 01

∴ time elapsed before sinking = 600/100

= 6 min. 01

(iii) Force required to pull the boat up = $200 \times 10 - \frac{200}{2500} \times 1000 \times 10$ 02

(01 mark for upthrust term ; 01 mark for subtraction)

= 1200 N 01

(iv) Consider 1 m^3 of water mixed with bubbles.

Total bubble (air) volume = $3.5 \times 10^8 \times 1 \times 10^{-9}$

= 0.35 m^3 01

∴ volume of water in 1m^3 = 1 - 0.35

= 0.65 m^3 01

∴ effective density of water = 0.65 x 1000

= 650 kg m^{-3} 01

Volume of the boat = $\frac{M}{(10/100)\rho_w}$

$= 200 \times \frac{100}{10} \times \frac{1}{1000}$

= 2 m^3 01

Maximum upthrust imparted by water = 2 x 650 x 10 N = 13000 N..... 01

Weight of the loaded boat = 14000 N

Since upthrust < weight of the boat, ... 01

the boat will sink.

(v) As the effective density of water is low due to the presence of air bubbles at the foot of the water fall the upthrust acting on the swimmer is low.... 01

Therefore he might drown.

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(b) Explain what is meant by the Doppler effect. How would you demostrate this effect using a ripple tank. Give an application of the Doppler effect.

A boat is travelling at 18 km per hour towards a small cliff, sounding its horn at 335 Hz. The speed of sound in air is 340 ms^{-1}.

(i) Find the frequency of the horn as heard by a boy on the cliff.

(ii) An echo of the horn is produced by the cliff. Find the frequency of the echo as heard by a man in the boat.

(iii) If the man hears the sound emitted by the horn and the echo together, find the number of beats per second heard by him.

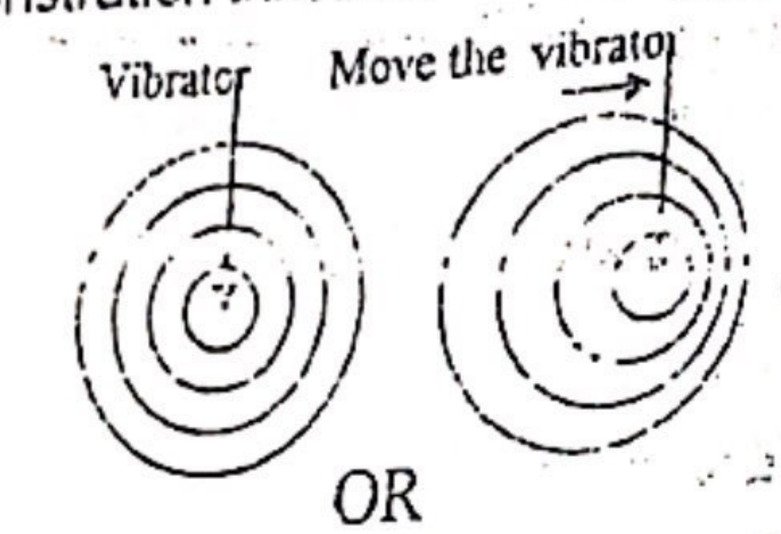
(iv) If the boat now turns back and moves away from the cliff with the same speed, what is the frequency of the echo as heard by the man?

Doppler Effect:

Change in observed frequency (and the wavelength) of a wave due to relative motion between the source and the observer 02

(02 or Zero)

Demonstration this effect using a ripple tank:



Wave fronts shrink (OR Decrease in wave length)

01 01 01

OR

(1) Create water waves in a ripple tank. 01

(2) Move the vibrating arm while it is in water. 01

(3) One can observe the ripples getting close together in the forward direction resulting a reduction in wavelength OR increase in frequency. 01

An application.

(1) Police radar to determine the speed of a moving vehicle.

(2) Determination of the speed of a blood cell.

(3) Determination of the heart beat of a fetus

(4) To find the speed of an air plane (OR ships)

(5) To find speeds (translational or rotational) of astronomical objects obtaining colours.

..... 01

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(i) The speed of the boat (V_s) = $\frac{18 \times 10^3}{3600}$

= 5 m s^{-1} 01

The frequency (f') heard by the boy 01

$$f' = \frac{V}{V - V_s} f$$

$$= \frac{340}{340 - 5} \times 335 \text{ .....}$$

= 340 Hz 01

(ii) The frequency (f'') of the echo heard by the man 01

$$f'' = \frac{V + 5}{V} f'$$

$$= \frac{340 + 5}{340} \times 340 \text{ .....}$$

= 345 Hz.. 01

Number of beats heard by the man = 345 - 335 01

= 10 beats per sec

(iv) The frequency (f''') of the sound reflected by the cliff.

$$f''' = \frac{V}{V + V_s} f$$

$$= \frac{340}{345} \times 335 \text{ .....} 01$$

The frequency (f^{iv}) of the echo heard by the man

$$f^{iv} = \frac{V - 5}{V} \times f''' \text{ .....} 01$$

$$= \frac{340 - 5}{340} \times \frac{340}{345} \times 335$$

= 325.3 Hz 01

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3. State the necessary conditions that has to be satisfied in order for a ray of light to undergo total internal reflection.

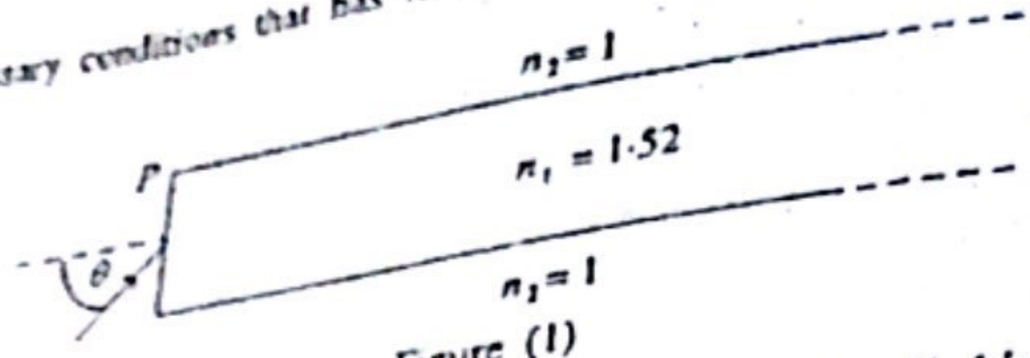


Figure (1)

(i) A ray of monochromatic light traveling in air enters a long solid cylindrical fibre made of plastic material of refractive index $n_1 = 1.52$ as shown in the figure (1). Calculate the critical angle for plastic-air interface. Hence show that the ray undergoes total internal reflection at the surface PQ for any angle of incidence θ. Disregard $\theta = 0$ situation.

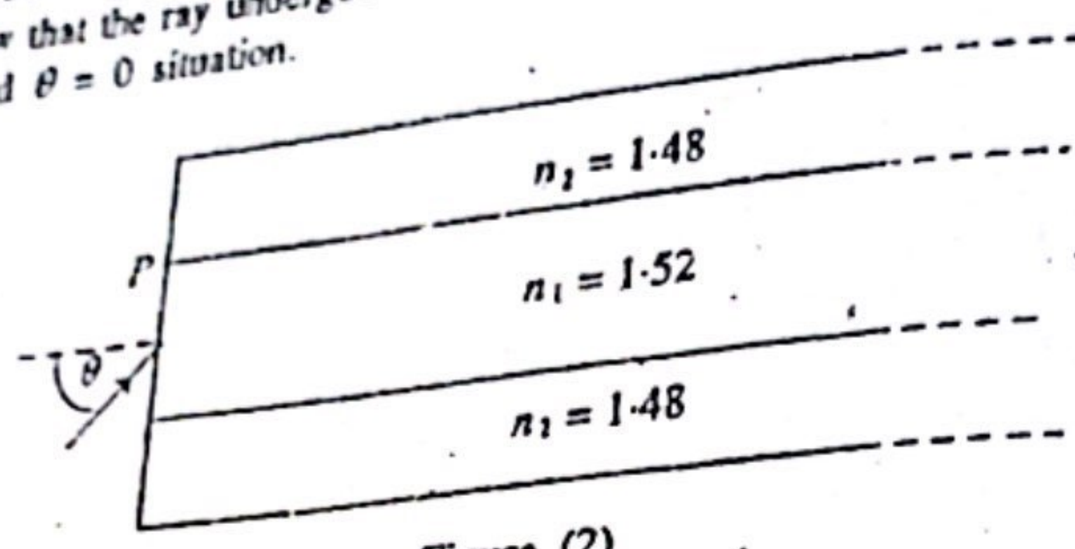


Figure (2)

(ii) Now the above fibre is completely surrounded with a different plastic material of refractive index $n_2 = 1.48$, as shown in figure (2). Determine the maximum value of angle θ for a ray which will undergo total internal reflection at the interface PQ.

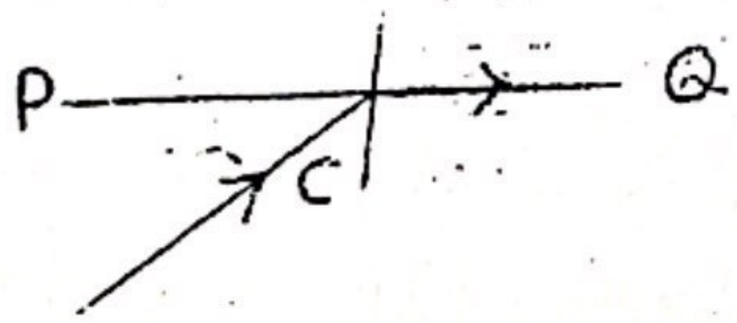
(iii) Show that a ray incident with $\theta = 80°$ will not emerge into the air.

Necessary conditions:

(1) Incident ray should be in a denser medium 01

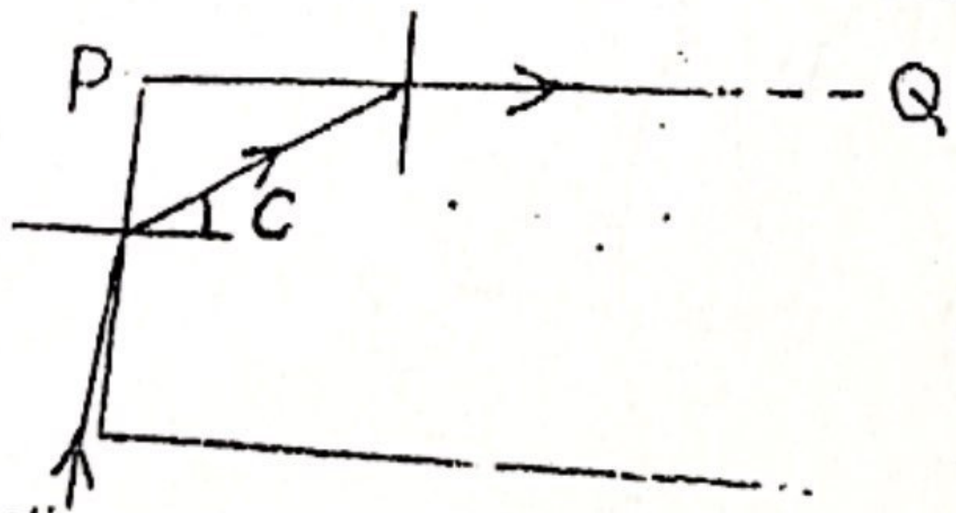
(2) The angle of incidence should be greater than the critical angle..... 01

(i)



$1.52 \sin C = 1$ 01

$C = 41^0\ 6'\ (\pm 3')$ 01



The maximum refracting angle that a ray can achieve at the flat surface is C.

In this situation the angle of incidence at the surface PQ 01

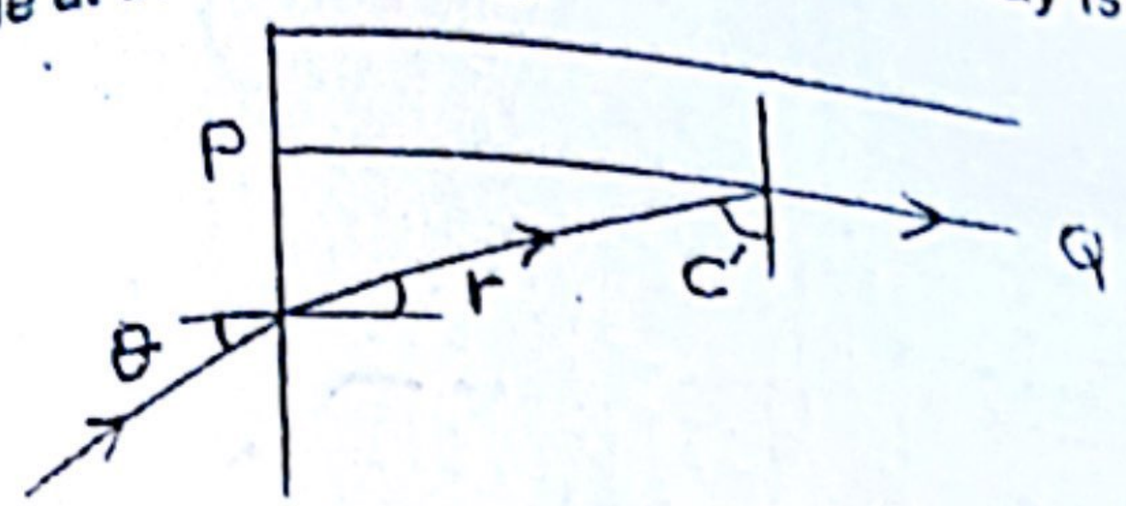
$= 90 - 41^0\ 6'$

$= 48^0\ 54'\ (\pm 3')$ 01

This value is greater than C, therefore the ray undergoes total internal reflection. 01

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(ii) Consider the critical situation where the ray is incident with the critical angle at the surface PQ. 13



$1.52 \sin C' = 1.48$ .....

$C' = 76^0\ 48'$

$r = 90 - 76^0\ 48'$ (for the subtraction) 01

$= 13^0\ 12'$ 01

For the flat surface

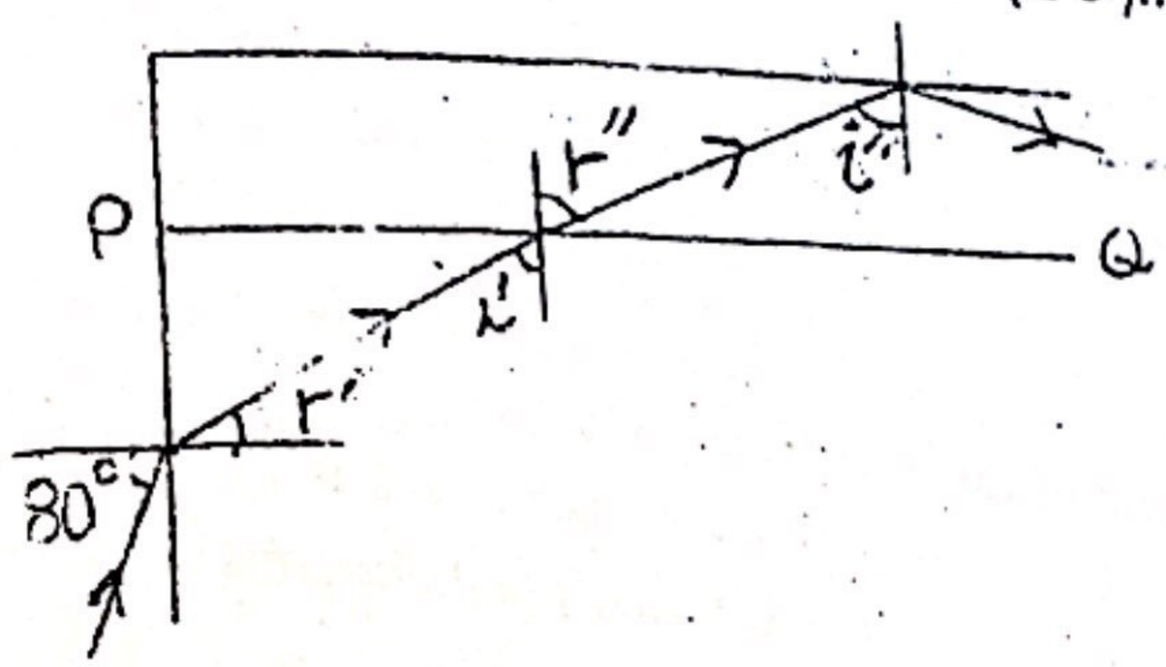
$\sin \theta = 1.52 \sin r$ .....

$\theta = 20^0\ 18'$ 01

When $\theta > 20^0\ 18'$ the angle of incidence of the ray at PQ will be less than C'.

$\therefore$ the maximum value of the angle $\theta = 20^0\ 18' (\pm 3')$..... 01

(iii)



$\sin 80 = 1.52 \sin r'$ 01

$r' = 40^0\ 24'$

$i' = 90 - 40^0\ 24' = 49^0\ 36'$

$1.52 \sin 49^0\ 36' = 1.48 \sin r''$ 01

$r'' = 51^0\ 30'$.

$\therefore \quad i'' = 51^0\ 30' (\pm 3')$.....01

Critical angle(C'') for the plastic ($n_2 = 1.48$) - air interface is giving by,

$1.48 \sin C'' = 1$

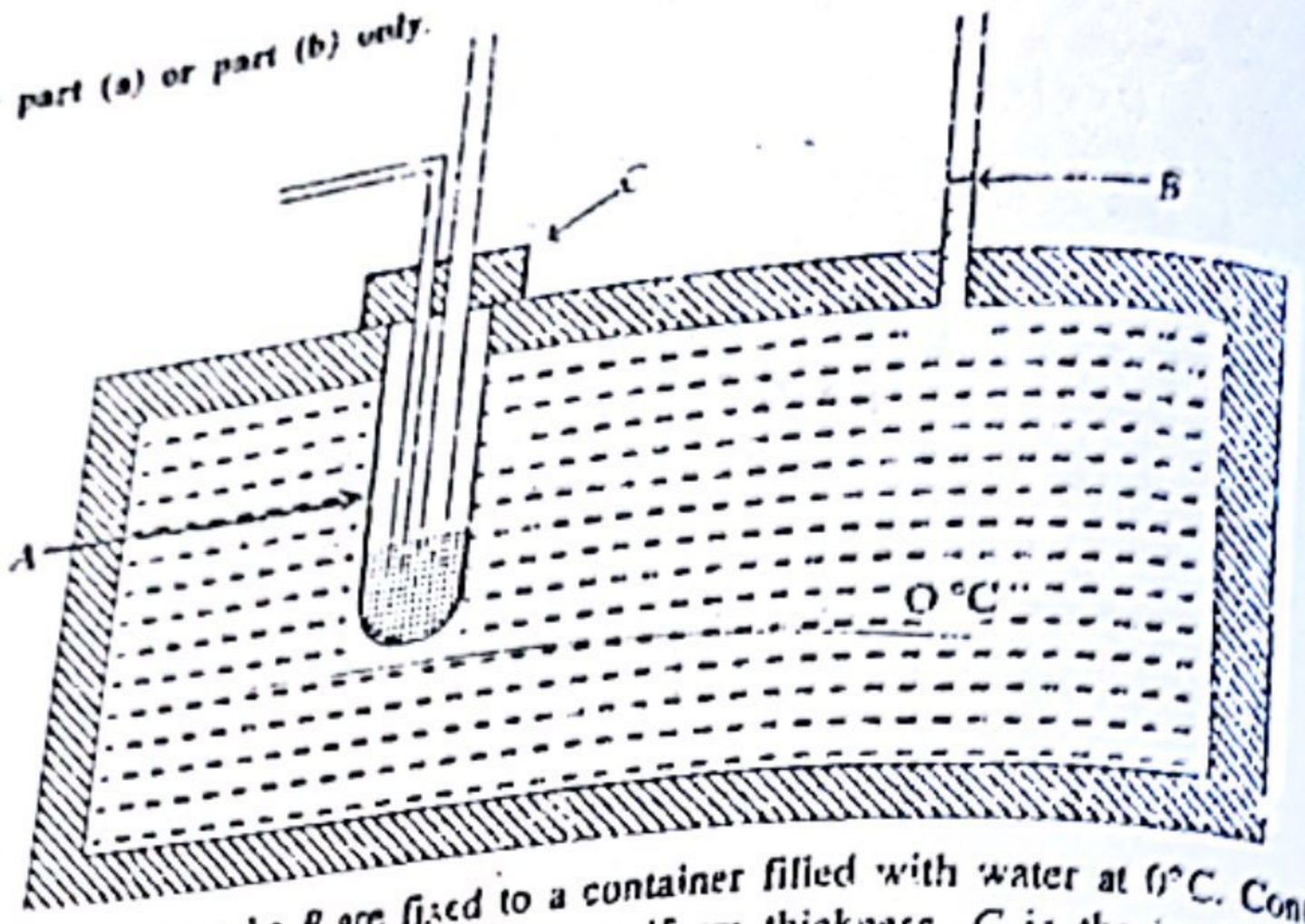
$C'' = 42^0\ 30'$

Since $i'' > C''$ $(42^0\ 30')$, the ray will not emerge into the air. 01

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4. Answer either part (a) or part (b) only.

(a)



A test tube *A* and a narrow tube *B* are fixed to a container filled with water at 0°C. Container walls are made of a poor conducting material having a uniform thickness. *C* is the insulating lid of the test tube made of the same material. 10^{-2} kg of ether at 0°C is inserted to the test tube and made to evaporate quickly by blowing air through it.

(i) As ether evaporates what change can be observed on the outer surface of the test tube?

(ii) If the area of cross-section of the tube *B* is 10^{-5} m^2, calculate the change in height of the water level in *B* due to the evaporation of ether.

Density of water at 0°C $= 1000\ kg\ m^{-3}$

Density of ice at 0°C $= 920\ kg\ m^{-3}$

Specific latent heat of evaporation of ether at 0°C $= 3.84 \times 10^5\ J\ kg^{-1}$

Specific latent heat of fusion of ice at 0°C $= 3.36 \times 10^5\ J\ kg^{-1}$

(iii) Once the evaporation of ether is completed and the apparatus is left in a room of room temperature 30 °C, the height of the water level in *B* starts to change slowly at a rate of 1 mm per second. If the thickness of the walls of the container is 2×10^{-2} m and its effective total surface area is 0·4 m^2, calculate the thermal conductivity of the material of the wall. Assume that the temperature of water remains at 0°C.

(i) A layer of ice will be formed (on the outer surface of the test tube)

..... 01

(ii) Let *m* be the mass of the ice formed due to the evaporation of ether.

Heat absorbed by ether $= 10^{-2} \times 3.84 \times 10^5$ 01

$= 3.84 \times 10^3\ J$

Heat given out by water $= m \times 3.36 \times 10^5$ 01

$\therefore\ m \times 3.36 \times 10^5 = 3.84 \times 10^3$ 01

(for equating the two expressions)

$$m = \frac{3.84}{3.36} \times 10^{-2}\ kg$$

Volume occupied by a mass m of water $= \frac{m}{\rho_w}$

Volume occupied by a mass m of ice $= \frac{m}{\rho_{ice}}$

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∴ Change in volume of a mass m of water = $m\left(\frac{1}{\rho_{ice}} - \frac{1}{\rho_w}\right)$ 01

∴ Change in height of the water level in B = $\frac{m}{10^{-5}}\left(\frac{1}{\rho_{ice}} - \frac{1}{\rho_w}\right)$ 01

(for division by 10^{-5})

$= \frac{3.84}{3.36} \times 10^{-2} \times \frac{1}{10^{-5}}\left(\frac{1}{920} - \frac{1}{1000}\right)$ 01

(for correct substitution)

$= \frac{8}{7} \times 10^{3} \times 8.7 \times 10^{-5}$

$= 9.94 \times 10^{-2}$ m 01

(OR 9.94 cm)

(iii) Rate of change of the volume of water in B = $10^{-3} \times 10^{-5}$ 01

$= 10^{-8}\ m^3\ s^{-1}$

If m' is the mass of ice melt per sec., then the corresponding change in volume of ice $= m'\left(\frac{1}{\rho_{ice}} - \frac{1}{\rho_w}\right)$

$= m' \times 8.7 \times 10^{-5}$ 01

(for correct substitution)

∴ $10^{-8} = m' \times 8.7 \times 10^{-5}$ 01

(for equating expressions)

$m' = \frac{10^{-3}}{8.7}$ kg

∴ rate at which heat is absorbed by ice = m' L

$= \frac{10^{-3}}{8.7} \times 3.36 \times 10^{5}$ 01

(for correct substitution)

But $mL = kA\frac{\Delta\theta}{\Delta l}$ 01

(for equating mL term toR.H.S.)

Where k is the thermal conductivity of the material of the wall.

∴ $\frac{3.36}{8.7} \times 10^{2} = k \times 0.4 \times \frac{30}{2 \times 10^{-2}}$ 01

(for correct substitution to R.H.S.)

$= 6.4 \times 10^{-1}\ W\ m^{-1}\ K^{-1}$ 01

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(e) Briefly the symbols in the above expression and the ideal gas equation to show that the $\frac{3}{2}kT$

Use the above expression and the ideal gas equation to show that the mean kinetic energy of a molecule of an ideal gas at a temperature T can be written as $\frac{3}{2}kT$, where k is the universal gas constant and N_A is the Avogadro's Number.

(i) An automobile tyre is found to have a pressure of 250 kPa at 27 °C. Additional air at 27 °C and at a pressure of 500 kPa should be pumped into the tyre to increase the pressure to 300 kPa. Assume that the volume of the tyre remains constant at 0.05 m^3 and that of the air in the tyre is also 27 °C.

(ii) After the automobile has been driven at high speed the temperature of the air in the tyre increased to 57 °C. If the initial air pressure in the tyre was 400 kPa and its volume increased by 5%, find the new pressure of air in the tyre.

$R = 8.3\ J\ K^{-1}\ mol^{-1}$

(iii) Determine the root mean square speed of air molecules at 57 °C.

Average relative molecular mass of air = 27.

Do all the molecules of air in the tyre move with the speed calculated above?

$$PV = \frac{1}{3}nmc^{\overline{2}}$$

P - pressure (of the gas) V - volume (of the gas)
n - number of (gas) molecules (in the volume)
m - mass of a (gas) molecule
$\overline{c^2}$ - mean square velocity (of the gas) molecules) .....

(all correct - 02 marks ; four correct - 01 mark)

$$PV = \frac{1}{3}nmc^{\overline{2}}$$

Ideal gas equation $PV = n'RT$..... OR ..... $PV = nRT$ .....

(n' - number of moles)

$$\therefore \frac{1}{3}nmc^{\overline{2}} = n'RT$$

$$\therefore \frac{2}{3}n\left(\frac{1}{2}mc^{\overline{2}}\right) = n'RT$$

$$\frac{1}{2}mc^{\overline{2}} = \frac{3}{2}\frac{n'RT}{n} = \frac{3}{2}\left(\frac{n}{N_A}\right)\frac{R}{n}T$$

$$= \frac{3}{2}\frac{R}{N_A}T \quad \text{.....}$$

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

[Alternate method:

For 1 mole of gas

$PV = RT$ 01

$$PV = \frac{1}{3}N_A mc^{\overline{2}}$$

$$\therefore \frac{1}{3}N_A mc^{\overline{2}} = RT$$

$$\frac{1}{2}mc^{\overline{2}} = \frac{3}{2}\frac{R}{N_A}T \quad \text{..... 01}$$

$$\therefore \frac{3}{2}kT$$

]

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Number of moles (n_1) in the tyre at 250 kPa and 27 ^{0}C

$$n_1 = \frac{P_1 V}{RT}$$

$$= \frac{250 \times 10^3 \times 0.05}{8.3 \times 300} \quad \ldots\ldots 01$$

$$= 5.02 \text{ moles}$$

Number of moles (n_2) in the tyre at 300 kPa and 27 ^{0}C

$$n_2 = \frac{P_2 V}{RT} = \frac{P_2 n_1}{P_1}$$

$$= \frac{300}{250} \times 5.02 \quad \ldots\ldots 01$$

$$= 6.02$$

The number of moles (n') to be pumped = 6.02 - 5.02 (for the subtraction) 01

= 1 mole

The corresponding volume at 500 kPa and 27 ^{0}C

$$= \frac{n' RT}{P}$$

$$= \frac{1 \times 8.3 \times 300}{500 \times 10^3} \quad \ldots\ldots 01$$

$$= 4.98 \times 10^{-3} \text{ m}^3$$

OR 5×10^{-3} m^3 01

[Alternate methods:

(1) The number of moles (n') to be pumped

$$n' = \frac{P_2 V}{RT} - \frac{P_1 V}{RT} \quad \ldots\ldots 02$$

(01 mark for the terms; 01mark for subtraction)

Corresponding volume V_p to be pumped = $\frac{n' RT}{P} = \frac{(P_2 - P_1)}{P} V$ ...01

$$= \frac{(300 - 250)}{500} \times 0.05 \quad \ldots\ldots 01$$

$$= 5 \times 10^{-3} \text{ m}^3 \quad \ldots\ldots 01$$

(2) Equating the number of moles before and after pumping,

$$\frac{P_1 V_1}{RT_1} + \frac{P_2 V_2}{RT_2} = \frac{PV}{RT} \quad \ldots\ldots 02$$

(01 mark for the L.H.S. ; 01 mark for equating)

But $T_1 = T_2 = T$

$P_1 V_1 + P_2 V_2 = PV$ 01

$250 \times 0.05 + 500 \times V_2 = 300 \times 0.05$ 01

$V_2 = 5 \times 10^{-3}$ m^3 01

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(3) A certain amount of air of volume V at 500 kPa and 27 °C is made to g
an additional pressure of 50 kPa in the tyre at the same temperature.
..... 02

Applying Boyle's law to the amount of air..... 01

$500 \times V = 50 \times 0.05$ 01

$V = 5 \times 10^{-3}\ m^3$ ..... 01]

(ii) P_1 = 300 kPa ; V_1 = V(volume of the tyre); T_1 = 300 K; P_2 = ? ;

$V_2 = \frac{105}{100} V$ .....

T_2 = 330 K

Using $\frac{PV}{T} = const$

$\frac{300 \times V}{300} = \frac{P_2 \times \frac{105}{100} V}{330}$ 01

P_2 = 314.3 kPa 01

[OR 314 kPa]

(iii) $\frac{1}{2} m \overline{c^2} = \frac{3}{2} k T = \frac{3}{2} \frac{R}{N_A} T$ .....

$\therefore \overline{c^2} = 3 \frac{R}{N_A m} T = \frac{3RT}{M}$ 01

$\therefore \sqrt{\overline{c^2}} = \sqrt{\frac{3RT}{M}}$

$= \sqrt{\frac{3 \times 8.3 \times 330}{27 \times 10^{-3}}}$ 01

= 551.7 m s^{-1} .....

[OR 552 m s^{-1}] 01

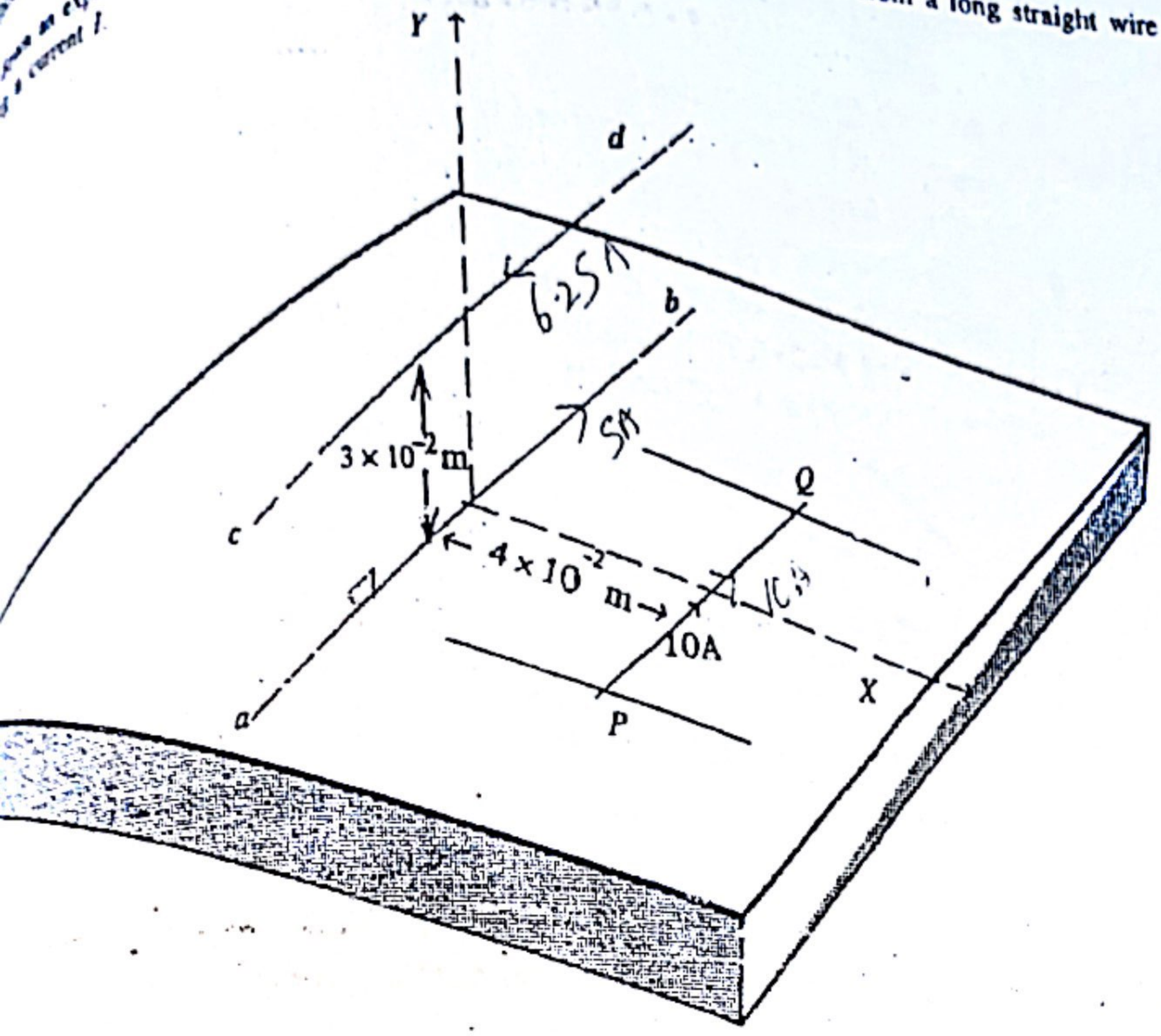
No.

The molecules move with various speeds. (The above value is the r.m.s.(mean) velocity of gas molecules.) 01

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...Savart law in the form of an expression and identify all the symbols used.

...from an expression for the magnetic flux density B at a point, a distance r from a long straight wire ...g a current I.



...s a long straight wire placed on a table, and cd is a similar wire kept 3×10^{-2} m vertically above ...and run parallel to it, as shown in the figure. PQ is a small current carrying conductor placed on ...table parallel to ab. The distance between ab and PQ is 4×10^{-2} m. PQ is free to move on two ...zontal conducting rails. Length of PQ is 10^{-1} m and a current of 10 A flows through it in the direction, ...o Q.

) If the write ab carries a current of 5 A in the direction a to b, find the magnitude and direction of the force acting on PQ due to this current $\left(\frac{\mu_0}{2\pi}=2\times10^{-7}\ \text{T m A}^{-1}\right)$.

) In addition to the current in ab, if cd also carries a current of 6·25 A in the direction d to c, find the magnitude of the force acting on PQ due to this current. Indicate the direction of the force on a diagram.

) If the mass of the conductor PQ is 10^{-4} kg find the direction of motion, and the magnitude of the initial acceleration of PQ.

) Find the magnitude and direction of the **minimum** current that should be setup in cd in order to lift PQ from rails.

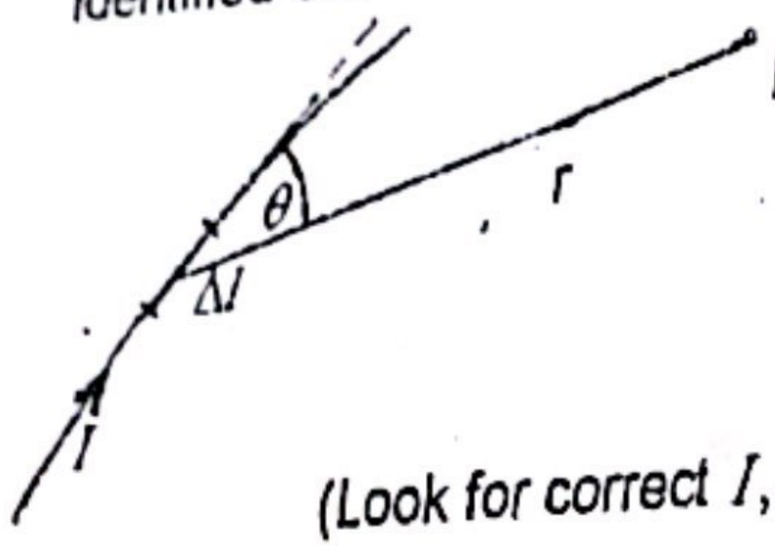
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$$\Delta B \propto \frac{I\,\Delta l \sin\theta}{r^2}$$ 01

OR

$$\Delta B = \frac{\mu_0}{4\pi}\frac{I\,\Delta l \sin\theta}{r^2}$$

I - current in the conductor.
Δl - length of the current element.
r - distance from the current element to the point concerned.
θ - angle between Δl and r.
ΔB - Magnetic flux density due to Δl
(To award the above mark all the symbols have to be correctly identified OR correctly shown in the following diagram)



(Do not look for the direction of ΔB in the diagrammatic representation of the Biot-Savart law.

(Look for correct I, θ and ΔB directions)

$B = \frac{\mu_0 I}{2\pi r}$ 01

(i) Magnetic flux density along PQ due to the current in ab

$$= \frac{2\times10^{-7}\times5}{\quad\times10^{-2}}$$ 01

$$= \frac{10^{-4}}{4}\ T$$

award full marks in using $\frac{\mu_0 I_1 I_2 L}{2\pi r}$ straight away calculate the force on PQ.

∴ Force on PQ due to the current in ab = BIL 01

$$= \frac{10^{-4}}{4}\times10\times10^{-1}$$

$$= 2.5\times10^{-5}\ N$$ 01

Direction of the force : towards ab OR in the –X direction ...OR... ← 01

(ii) Perpendicular distance between the wires PQ and cd

$$= \sqrt{\left(3\times10^{-2}\right)^2+\left(4\times10^{-2}\right)^2}$$

$$= 5\times10^{-2}\ m$$

Magnetic flux density along PQ due to the current in cd

$$= \frac{2\times10^{-7}\times6.25}{5\times10^{-2}}\ T$$

(Note: 01 mark can be awarded to the correct expression here ONLY IF it is not already awarded to a similar expression under (I))

∴ Magnitude of the force (F) on PQ due to the current in cd

= BIL

(see the note above)

$$= \frac{2\times10^{-7}\times6.25}{5\times10^{-2}}\times10\times10^{-1}$$

$$= 2.5\times10^{-5}\ N$$ 01

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Direction of the force :



21

..... 01

(iii) Magnitude of the component of F along X direction

$= F.\cos\theta$

$= 2.5 \times 10^{-5} \times \frac{4}{5}$ 01

$= 2 \times 10^{-5}$ N

∴ the magnitude of the resultant force acting on PQ along the –X direction

$= 2.5 \times 10^{-5} - 2 \times 10^{-5}$ 01

(for subtraction)

$= 0.5 \times 10^{-5}$ N

Direction of motion of the conductor PQ :

Towards ab OR in the – X direction ..... OR ← 01

Magnitude of the initial acceleration $= \frac{0.5 \times 10^{-5}}{10^{-4}}$

$= 5 \times 10^{-2}$ m s^{-2} 01

OR 0.05 m s^{-2}

(iv) Let I be the minimum current that should be set-up in cd to lift PQ

The magnetic force acting vertically upwards

$= \frac{\mu_0 I}{2\pi \times 5 \times 10^{-2}} \left(\frac{3}{5}\right) \times 10 \times 10^{-1}$

$= \frac{6 \times 10^{-5}}{25} I$

Then for lifting PQ

$10^{-4} \times 10 = \frac{6 \times 10^{-5}}{25} I$ 01

$I = 416.7$ A (OR 417 A) 01

Direction of the current in cd should be from c to d. 01

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6. A square coil PQRS of side [illegible] cm contains [illegible] 0 turns and is positioned perpendicular to a uniform m[illegible]etic field of f[illegible] x density B = 1·2 T as shown in the figure. It is then [illegible] lled at an unif[illegible] n velocity to the right to a region [illegible] ro magnetic field while keepin[illegible] the plane of the coil perpendicular [illegible] e magnetic field. It takes 0·2 s for [illegible] e whole coil to reach the field free region.

(i) Calculate the e.m.f. i[illegible]ced in the c[illegible]il during the 0·2 s time period.

(ii) Name the side/sides of the coil in which [illegible] e.m.f. is induced and indicate the direction of the induced curre[illegible]on a diagram.

(iii) If the resistance of the coil is 100 Ω calculate the energy dissipated in the [illegible] interval.

(iv) Hence, deduce the work needed to pull the coil out of the field. State the law used to arrive at the answer.

(v) If the magnetic field is reduced to zero uniformly during the same time in[illegible] pulling the coil, will you observe the same induced e.m.f. as in (i). Give [illegible]

Area of the coil = $(5 \times 10^{-2})^2$ .....

Change in flux = $200 \times (5 \times 10^{-2})^2 \times 1.2$ .....

Rate of change of flux = $\dfrac{200 \times (5 \times 10^{-2})^2 \times 1.2}{0.2}$ .....

Induced e.m.f. (E) = Rate of change of flux .....

(OR induced e.m.f.(E) = $\dfrac{\Delta\phi}{\Delta t}$)

= 3 V .. ..

[Alternate method:

Induced e.m.f. on one turn = BLv 01

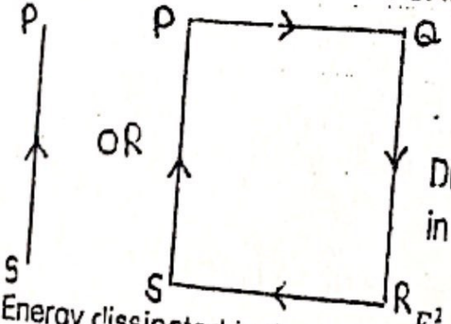
Induced e.m.f. on 200 turns = NBLv..... 01

But $v = \dfrac{5 \times 10^{-2}}{0.2}$ m s^{-1} 01

$\therefore$ Induced e.m.f. (E) = $200 \times 1.2 \times 5 \times 10^{-2} \times \dfrac{5 \times 10^{-2}}{0.2}$ ..01

= 3 V ..... 01]

(ii) e.m.f. will be induced in side PS. .....



Direction indicated on PS OR in the coil. .....

(iii) Energy dissipated in the coil = $\dfrac{E^2}{R} t$ .....

= $\dfrac{3^2}{100} \times 0.2$ .....

= 1.8×10^{-2} J .....

(Deduct 01 mark if the unit is wrong)

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[Alternative method:

Current (i) in coil = $\frac{3}{100}$ A 01

Energy dissipated = i^2Rt 01

= $(3 \times 10^{-2})^2 \times 100 \times 0.2$ 01

= 1.8×10^{-2} J 02

(Deduct 01 mark if the unit is wrong)]

(iv) Work needed to pull the coil = 1.8×10^{-2} J 01

OR the same as above.

Law of conservation of energy..... 01

(v) The induced e.m.f. will be the same. 01

Rate of change of magnetic flux linking the coil will be the same in both situations. 01

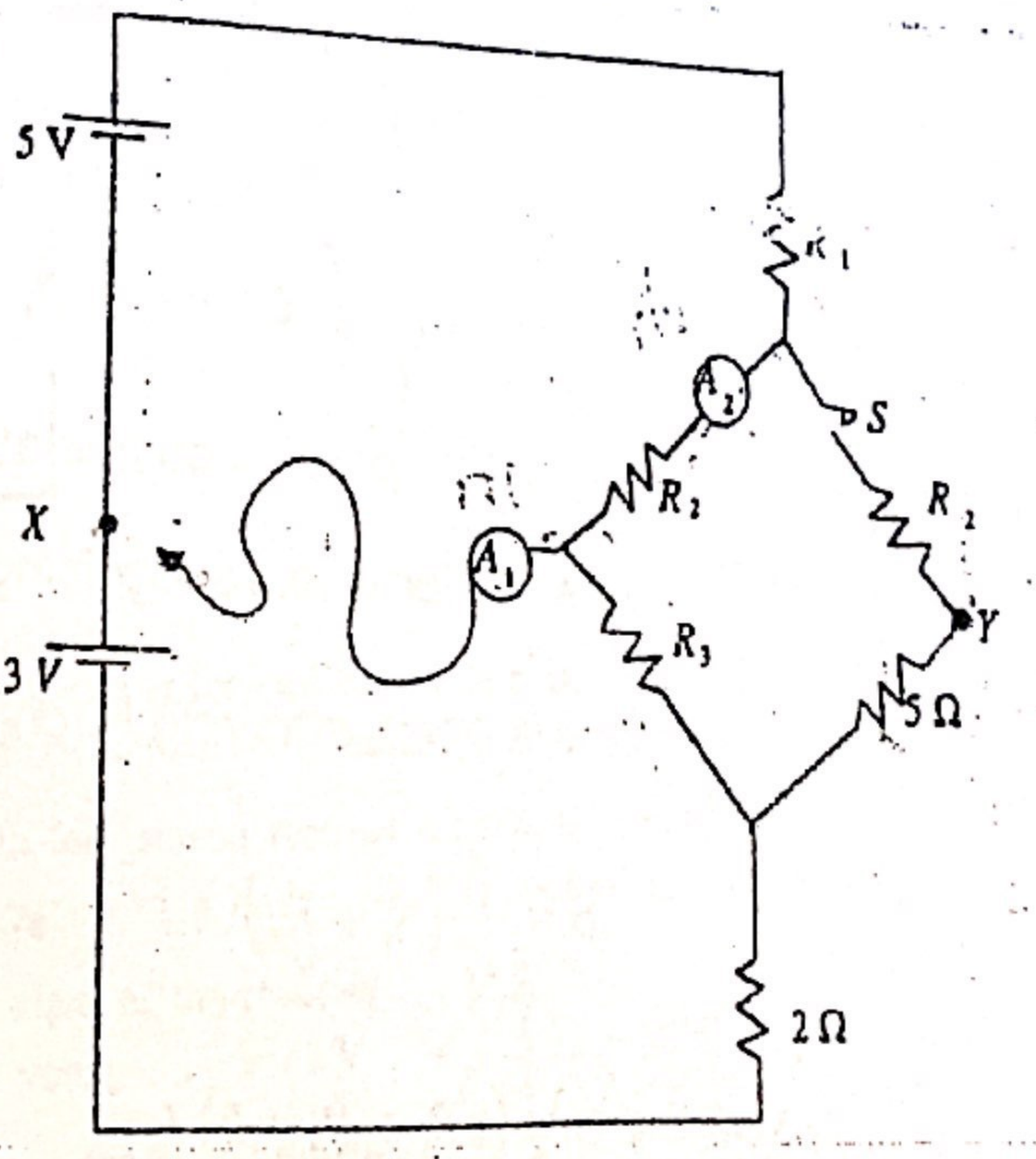
...r either part (a) or part (b) only.

...the circuit shown, cells and both ...meters A_1 and A_2 have negligible internal ...sistance. S is a switch. Once the switch ...is closed, the ammeter A_1 indicates a zero ...ading, when its free terminal is connected ...her to point X or Y. It is also found that ...en S is opened and A_1 is connected to ... the ammeter A_2 reads $\frac{5}{12}$ A.

...) Determine the value of R_3. Clearly state your arguments in arriving at the answer. Also calculate the values of R_1 and R_2.

When S is open and A_1 is connected to X, will a part of the current that is flowing through R_2, pass through R_3 as well? Explain your answer.

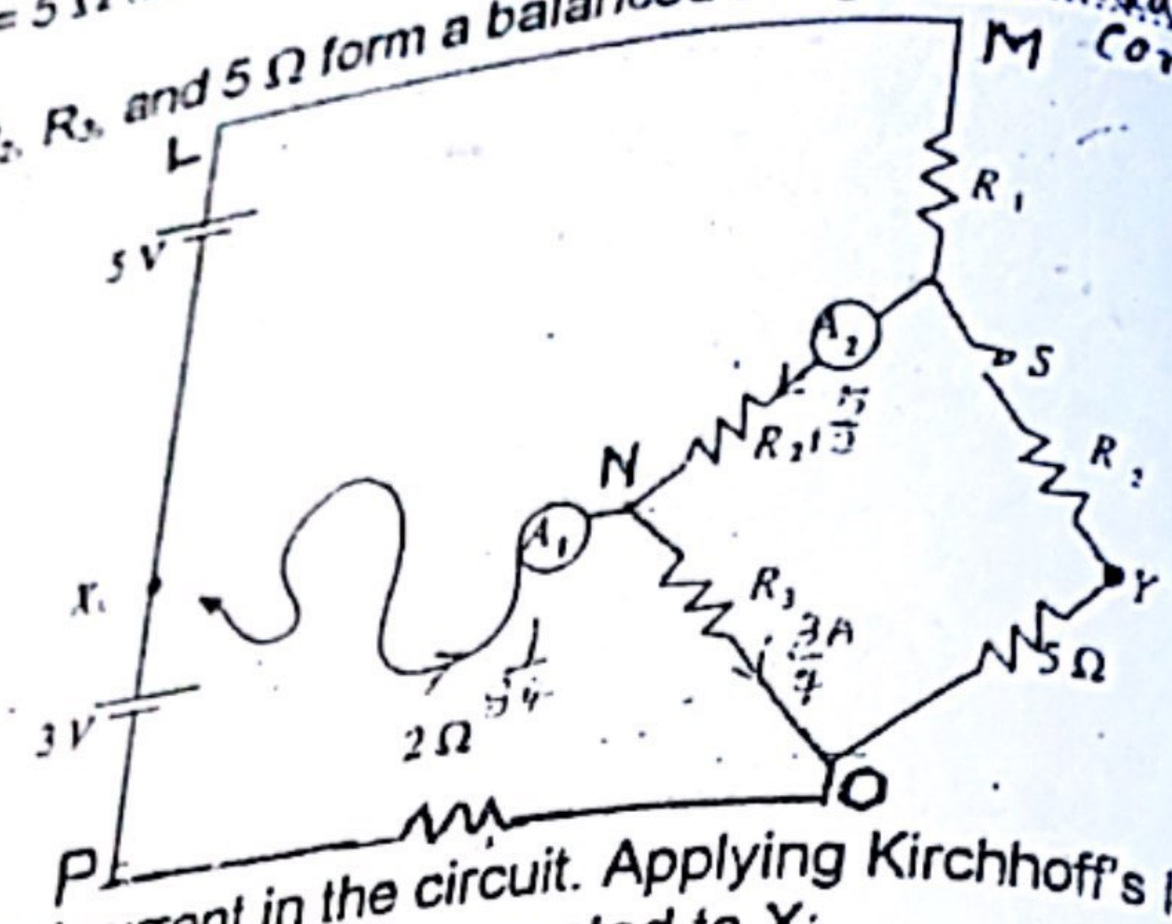
What will be the reading of the ammeter A_1 in (ii).



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(i) $R_3 = 5\ \Omega$

R_2, R_3, R_3 and $5\ \Omega$ form a balanced bridge.. OR Wheaston bridge



Let I be the total current in the circuit. Applying Kirchhoff's law to LMOP loop, when S is closed and A_1 connected to X:

$$8 = \left(R_1 + \frac{R_2}{2} + \frac{5}{2} + 2\right)I \quad \ldots\ldots (A)$$

OR considering XNOP loop

$$3 = \left(\frac{5}{2} + 2\right)I$$

Applying Kirchhoff's law to LMNX loop

$$5 = IR_1 + \frac{I}{2}R_2 \quad \ldots\ldots (B)$$

Identifying the parallel combination of resistors OR taking $\frac{I}{2}$ OR $\frac{R}{2}$ in above equations(i.e. recognising the symmetry) .....

When S is open, applying Kirchhoff's law to LMNX loop

$$5 = \frac{5}{12}(R_1 + R_2) \quad \ldots\ldots (C)$$

$$A \Rightarrow 16 = (2R_1 + R_2 + 9)I$$

$$B \Rightarrow 10 = (2R_1 + R_2)I$$

$$\frac{A}{B} \Rightarrow \frac{16}{10} = \frac{2R_1 + R_2 + 9}{2R_1 + R_2}$$

$$C \Rightarrow \begin{matrix} 2R_1 + R_2 = 15 \\ R_1 + R_2 = 12 \end{matrix}$$

Solving above equations

$$R_1 = 3\ \Omega$$

$$R_2 = 9\ \Omega$$

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(ii) No. 25 97(27

When the free terminal of A_1 is connected to X the upper half of the circuit (LMNX) becomes isolated from the lower half of the circuit. Therefore the current $\frac{5}{12}$ A is confined to that circuit. ....OR...the terminals...N.and. 02

(02 or zero) X get short cct.

(iii) Consider the XNOP loop. Current I in loop is given by

$3 = I(5 + 2)$ 01

$I = \frac{3}{7}$ A 01

$\therefore$ the reading of the ammeter $A_1 = \frac{3}{7} - \frac{5}{12}$ 02

(01 mark for taking $\frac{5}{12}$ A as the other current component;

01 mark for the correct expression)

$= \frac{1}{84}$ A

$= 0.012$ A 01

(b) In the circuits shown D is a silicon junction diode.

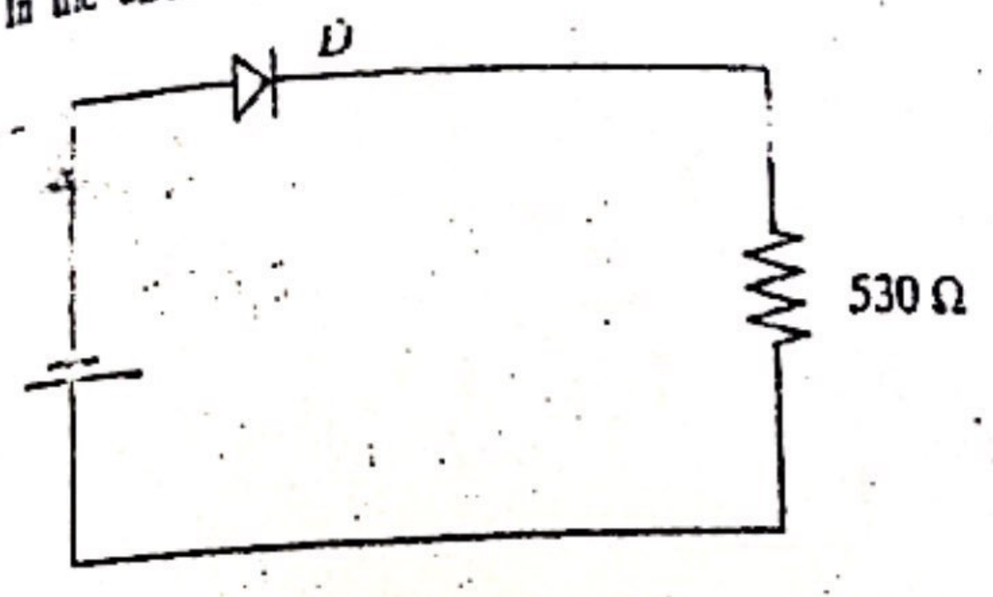


Figure (1)

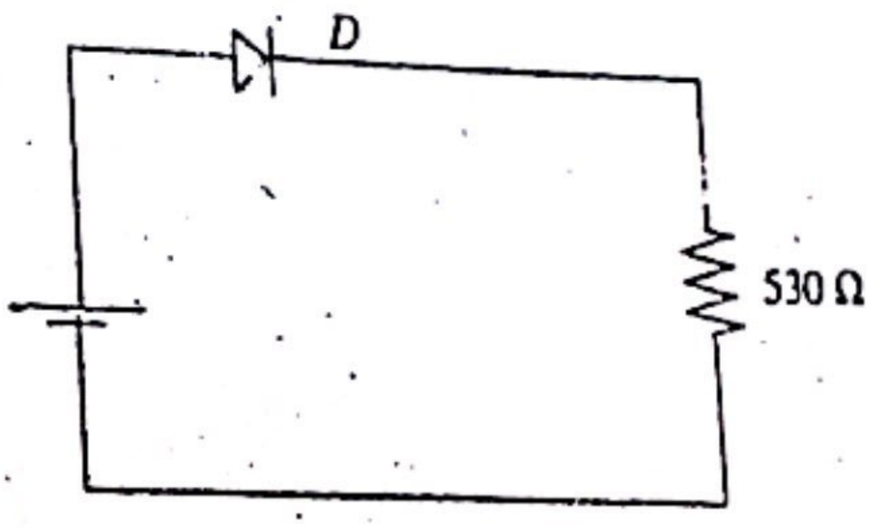


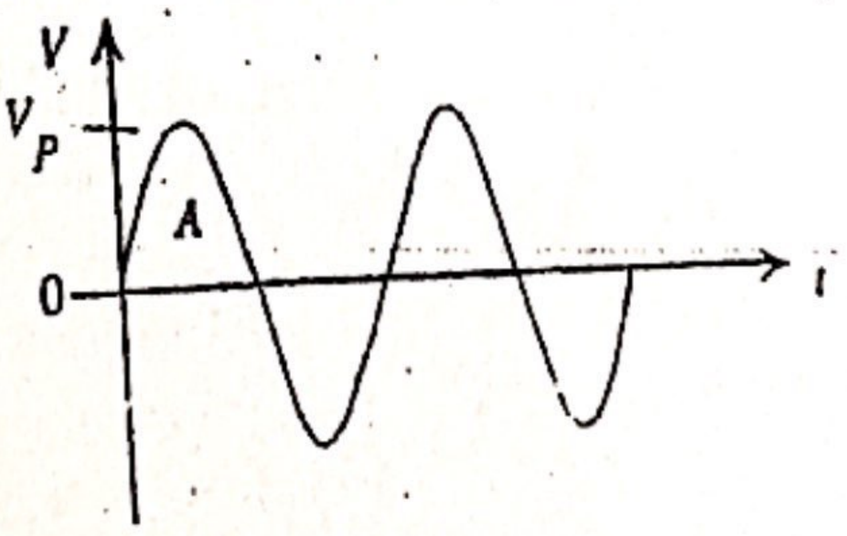
Figure (2)

(i) Identify the circuit in which the diode is forward biased. If a current of 10 mA flows in that circuit by considering the potential drops across components, estimate the voltage of the cell.

(ii) Suppose you are provided with four silicon rectifier diodes, a smoothing capacitor C and a load resistor R_L. Draw a circuit diagram of a bridge rectifier including the C and R_L.

(iii) The voltage V applied at the input of the rectifier is shown in the figure. Peak voltage, $V_p = 12$ V.

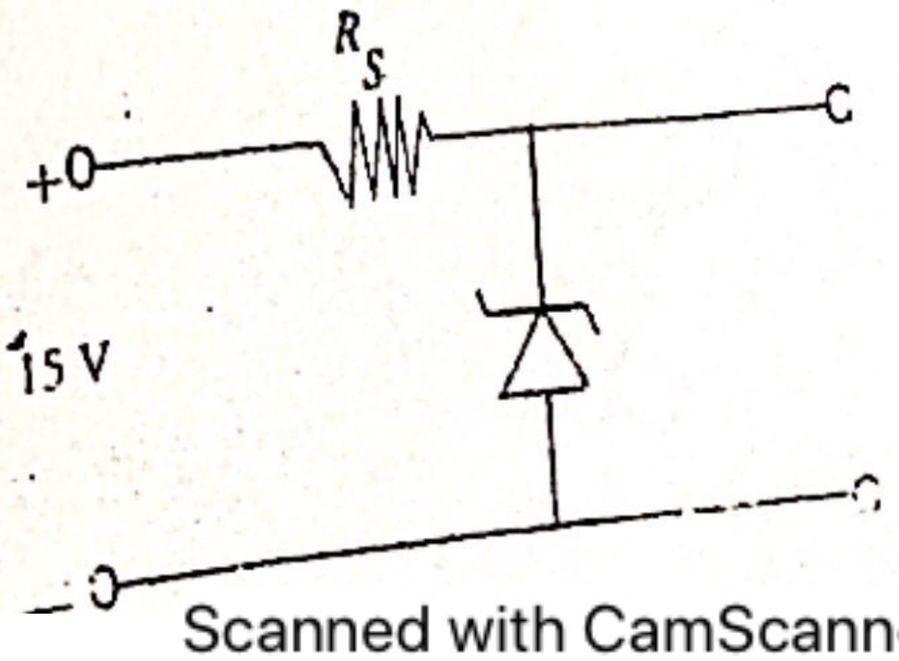
Indicate the path of the current in the circuit drawn in (ii) during the first half cycle A of the input using arrows.



(iv) Draw the output voltage waveform of the rectifier circuit including C and R_L, and estimate the peak value of the output voltage.

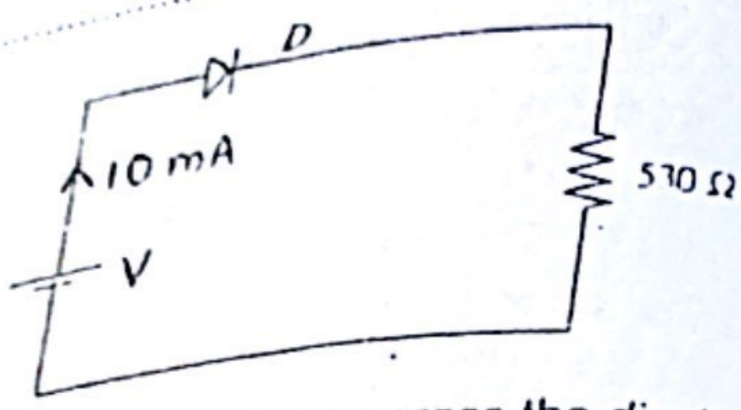
(v) The circuit shown is provided to obtain a 10 V regulated dc voltage from an unregulated voltage of 15 V.

If the maximum current that can be sent through the zener diode is 200 mA, and the zener voltage



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(i) Figure (2)

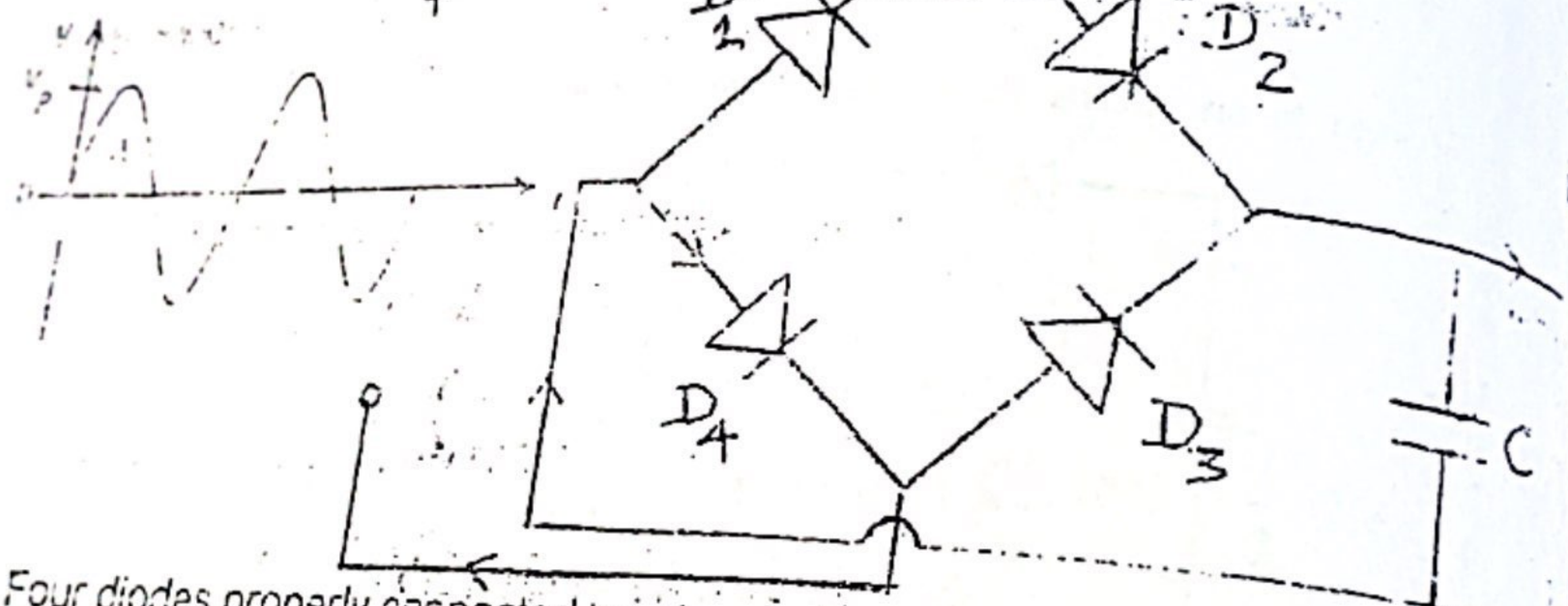


In forward biased situation, the voltage across the diode is of the order of 0.7 V (OR 0.6 V)

Voltage across 530 Ω :: $530 \times 10 \times 10^{-3}$
= 5.3 V

Voltage of the cell = 5.3 + 0.7(or 0.6)
OR
≅ 6 V (or 5.9 V)

(ii)



Four diodes properly connected as shown

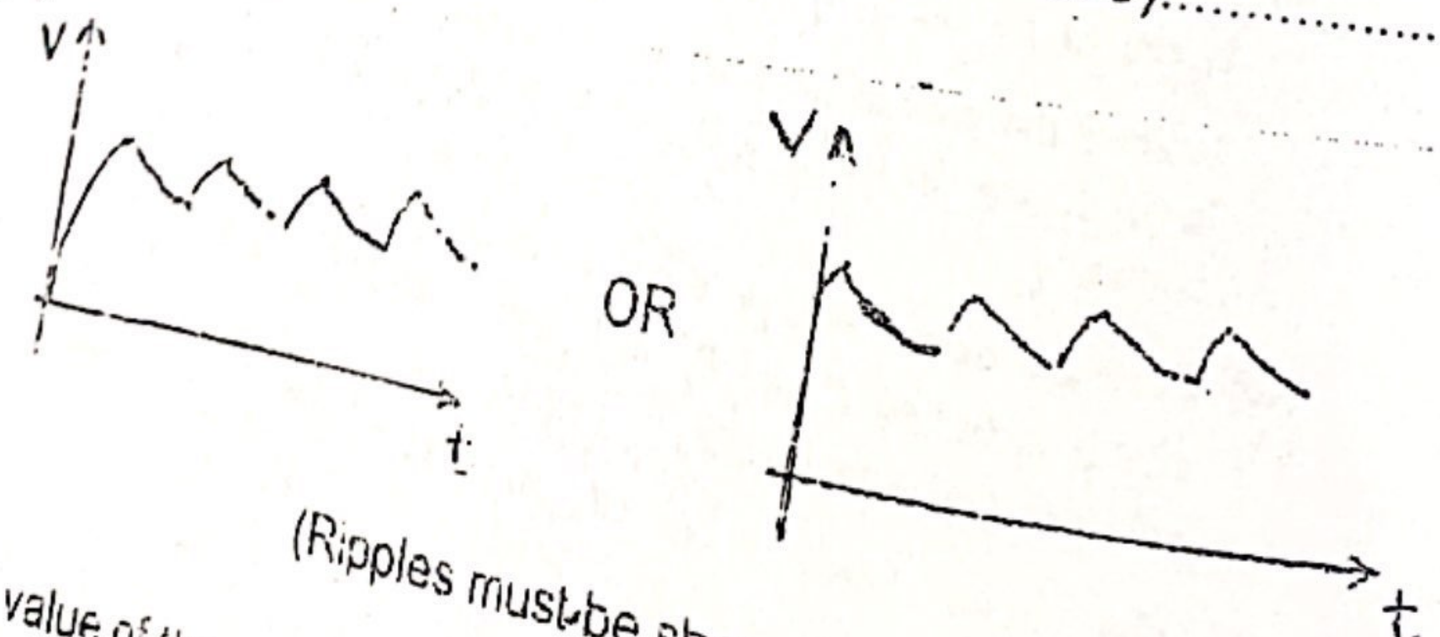
Connection of C

Connection of R_L

(iii) Indication of the current through D_2 (first diode)

Indication of the current through D_4 (second diode)

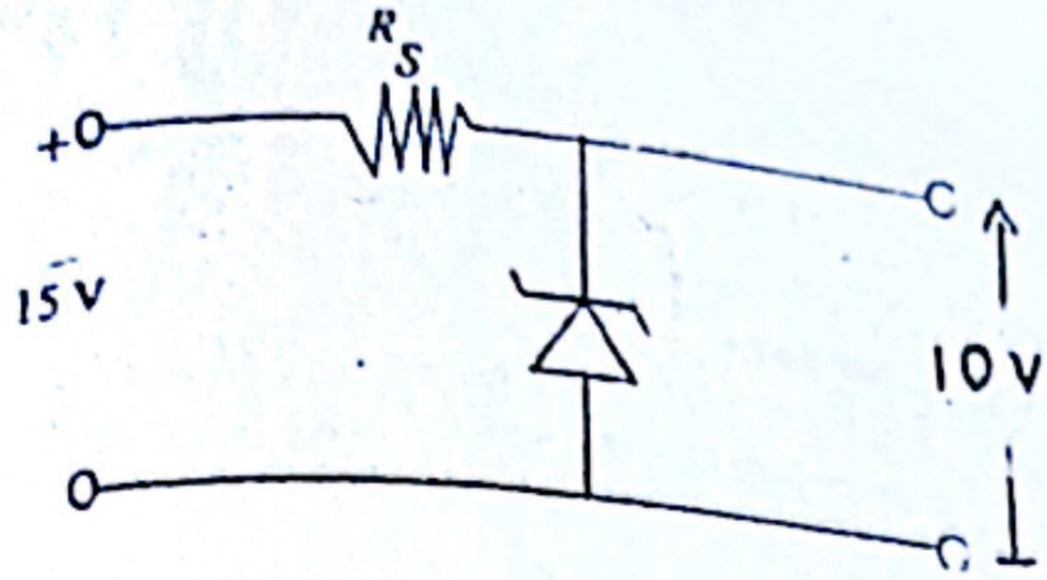
(iv)



(Ripples must be shown clearly)

Peak value of the output = 12 - 2 x 0.7 (or 12 - 2 x 0.6)
= 10.6 V (or 10.8 V)

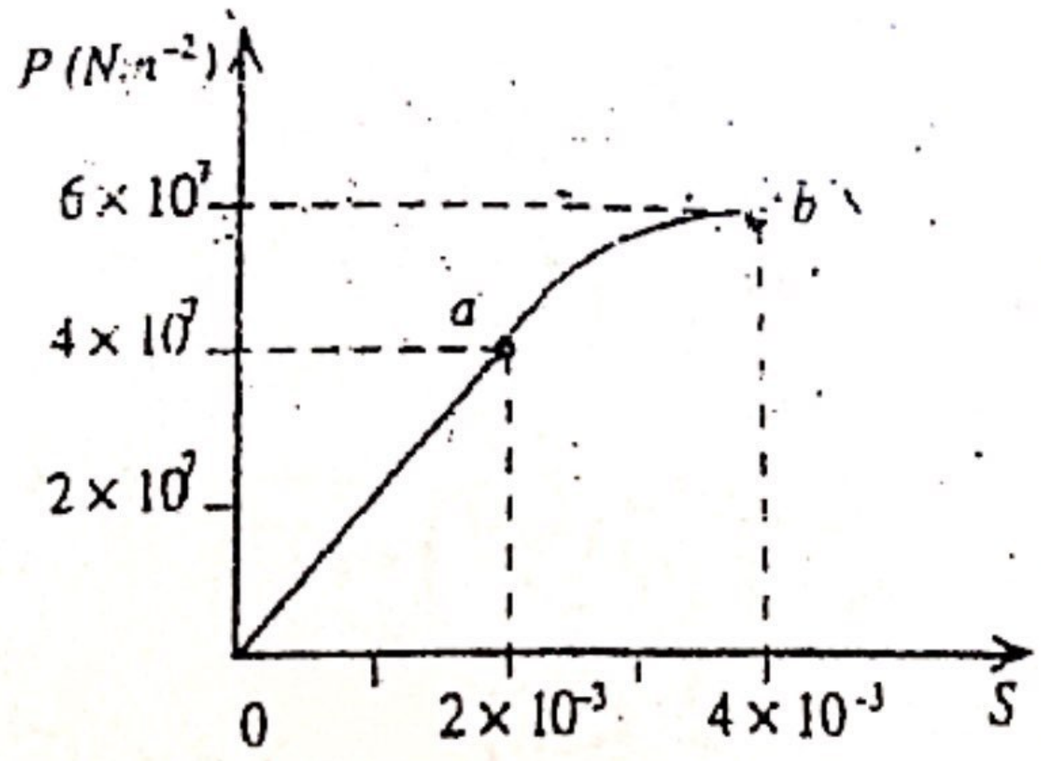
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Voltage appearing across R_S = 15 - 10
= 5 V

$\therefore$ $5 = 200 \times 10^{-3} \times R_S$ 01

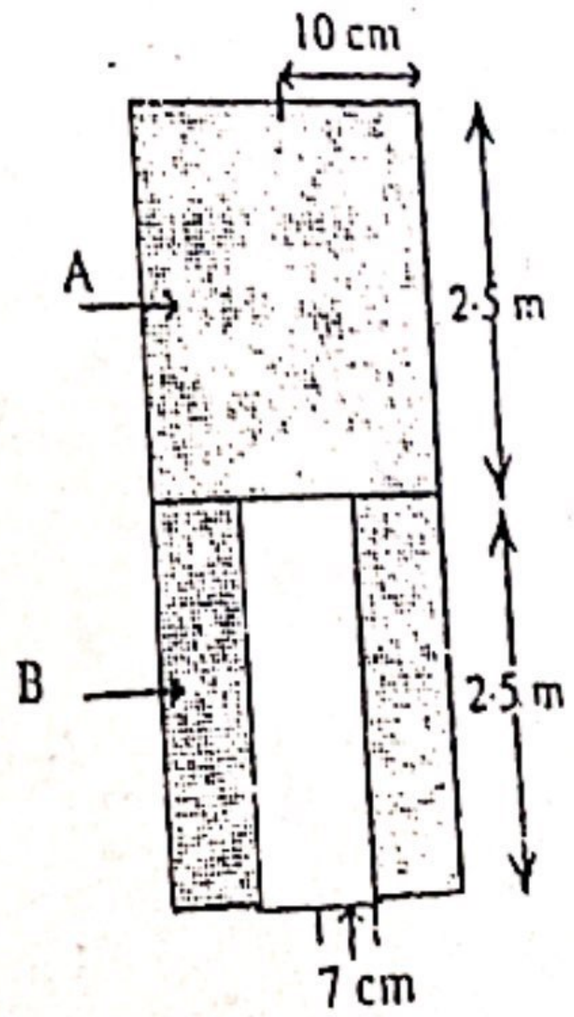
$R_S = 25\ \Omega$ 01 01



Identify the points a and b on the curve.

Calculate the Young's modulus of the material. What is the energy stored per unit volume when the strain in the material is 2×10^{-3} ?

A vertical cross-section of a cylindrical pillar consisting of a solid cylinder A and a hollow cylinder B each of height 2·5 m and made of the above mentioned material is shown in the figure. Radius of A is 10 cm and the external and internal radii of B are 10 cm and 7 cm respectively. (The diagram is not drawn to the scale).



(a) What is the compression of the pillar when a load of 1×10^5 N is supported by it?

(b) What is the maximum load that can be supported by the pillar without breaking it?

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(i) a - proportional limit .....
b - breaking point .....
(breaking stress)

(ii) Young's modulus $= \frac{Stress}{Strain}$ .....

$= \frac{4 \times 10^{7}}{2 \times 10^{-3}}$

$= 2 \times 10^{10}\ N\ m^{-2}$ .....

Energy stored per unit volume $= \frac{1}{2} \times stress \times strain$ .....

$= \frac{1}{2} \times (4 \times 10^{7}) \times (2 \times 10^{-3})$ .....

$= 4 \times 10^{4}\ J\ m^{-3}$ .....

(iii) (a) Using $\frac{F}{A} = E\frac{e}{L}$

For the solid cylinder A,

$\frac{1 \times 10^{5}}{\pi \times 10^{2} \times 10^{-4}} = 2 \times 10^{10} \times \frac{e_1}{2.5}$ .....

$e_1 = 4.0 \times 10^{-4}$ m

$(4.0 \pm 0.1) \times 10^{-4}$ m

For the hollow cylinder B,

$\frac{1 \times 10^{5}}{\pi \times (10^{2} - 7^{2}) \times 10^{-4}} = 2 \times 10^{10} \times \frac{e_2}{2.5}$ .....

$e_2 = 7.8 \times 10^{-4}$ m .....

$(7.8 \pm 0.2) \times 10^{-4}$ m

$\therefore$ the total compression of the pillar $= e_1 + e_2$ .....

$= 1.2 \times 10^{-3}$ m .....

$(1.2 \pm 0.05) \times 10^{-3}$ m

(b) Hollow cylinder B attains the breaking stress first.....

From the above curve, breaking stress $= 6 \times 10^{7}\ N\ m^{2}$

If F is the maximum load that can be supported by the pillar, then

$\frac{F}{\pi \times (10^{2} - 7^{2}) \times 10^{-4}} = 6 \times 10^{7}$ .....

$\therefore F = 9.6 \times 10^{5}$ N .....

$(9.6 \pm 0.2) \times 10^{5}$ N.

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