CONFIDENTIAL

G.C.E. Advanced Level Examination - August 1992

Scheme of Assesment for Physics II

PART A - Structured Essay

1. A spiral spring of mass m_0 is hung vertically from the top end and a light scale pan is fastened to the lower end of the spring. A mass M is placed in the scale pan and the system is allowed to oscillate vertically by stretching the spring and then releasing it. The periodic time T for small vertical oscillations is given by the expression

$$T = 2\pi\sqrt{\frac{\left(M + \frac{m_0}{3}\right)}{k}}$$

where k is a constant.

In order to verify the above expression a student has measured the time for five oscillations for different values of M. The table shows the readings taken by the student.

M (kg)	Time for 5 oscillations (s)	Hence the Period T (s)
0.100	5.4	1.10
0.200	3.5	1.10
0.300	6.5	1.30
0.400	7.4	1.50
0.500	8.3	1.65

(a) Is the above number of oscillations sufficient ? Give reasons for your answer.

No , As the measured time is too small the error introduced in T measurement is large.
OR
Time (or period) is too small and cannot be measured accurately..... 01

(b) (i) Rearrange the above expression to draw a suitable graph in order to verify it ?

$$T^2 = \frac{4\Pi^2}{K}\left(M + \frac{m_0}{3}\right)$$

$$T^2 = \frac{4\Pi^2}{K}M + \frac{4\Pi^2 m_0}{3K}$$ 01

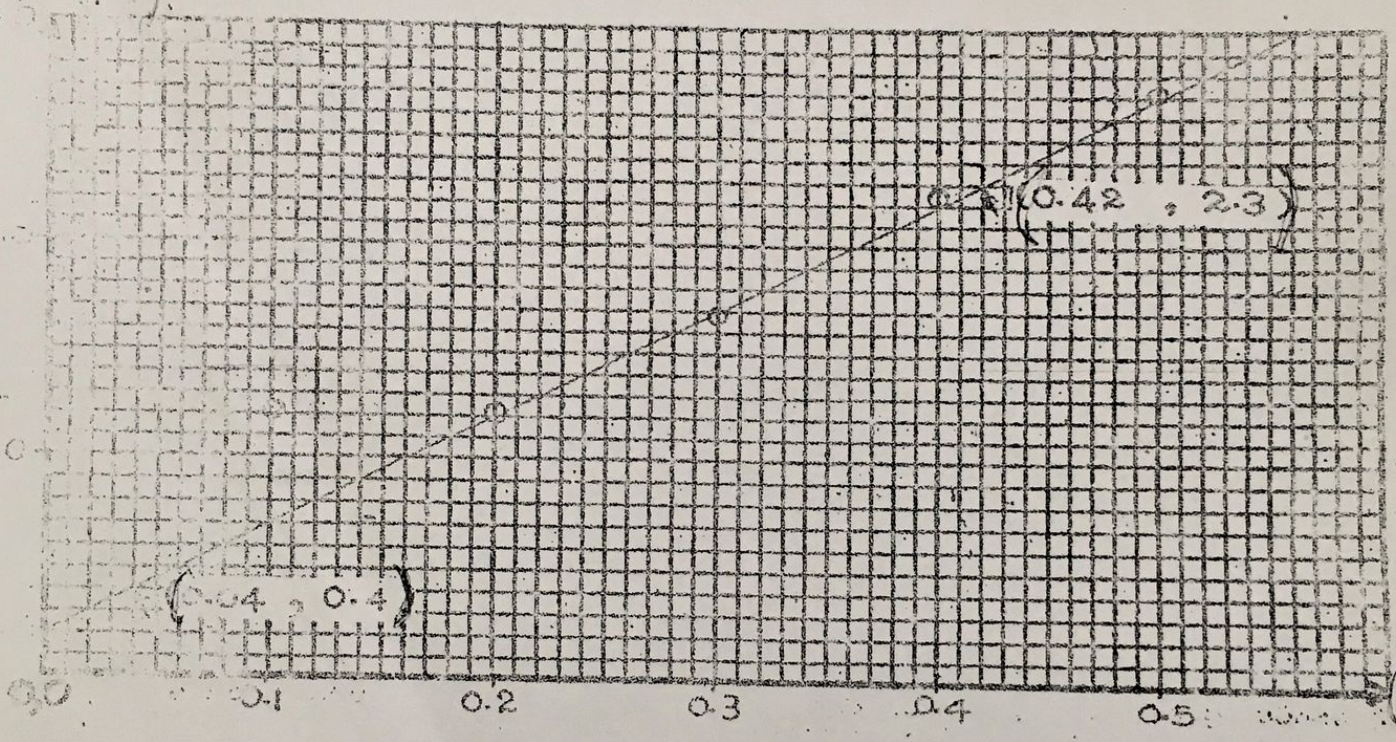
(ii) To draw a suitable graph tabulate the above readings.

X - axis [M(kg)]	Y - axis [$T^2(s^2)$]
0.100	1.21
0.200	1.21
0.300	1.69
0.400	2.25
0.500	2.72

X - axis for mass and Y - axis for $(\text{period})^2$. ..... (01)

(Award this mark even if some of the tabulated values for T^2 are wrong)

(iii) Draw a suitable graph on the grid provided below.



Award marks for the graph as follows.

No marks for interchanging x & y

For marking the axes with suitable scales ..... (01)

(Scales must be such that the student uses the entire graph paper and each small division in both axes is easily readable)

For drawing a straight line to go through experimental points ..... (01)

(Do not award this mark unless the first experimental point is excluded when drawing the graph)

(iv) Mark on the graph with arrows the two points which you would use in order to find the gradient of the graph, and write down the corresponding co-ordinates on the graph.

For selecting two suitable points and (marking co-ordinates) ..... (01)

The two points should not be too close to each other (at least about 7

OR

(Students should select two points at which the straight lines passes through the intersection of any two vertical and horizontal printed lines of the graph.)

(ii) What is the gradient of the graph ?

Gradient = 5 s^2kg^{-1} 01
(Accept answers within ±0.5 of this value as correct)

(iii) Hence calculate the constant K (you may take $\pi^2=10$)

$\frac{4\pi^2}{K} = 5$; $K = 8\ Nm^{-1}$ 01
(Accept answers within ± 1 of the above value as correct)

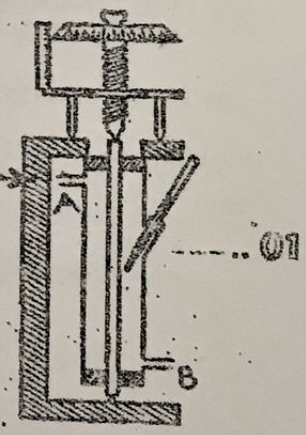
(d) (i) What is the intercept of the graph ?

Intercept = 0.2 s^2 essentially from the graph 01
(Accept answers within ± 0.1 of the above value as correct)

(ii) Hence find the mass m_0 of the spring.

m_0 = 0.12 kg 01
accept ± 0.06 kg (i.e. 120 ± 60 g)

2. The figure shows an experimental set up for determination of the linear expansivity of a metal in the form of a rod.



(a) Why do you use a long rod in this experiment ?

To obtain an appriciable increase in length due to expansion..... 01

(b) (i) In this experiment cold water is passed through the jacket before taking the initial reading. Give reasons for this.

To ensure a constant uniform temperature throughout the rod.
OR
To measure the initial temperature of the rod accurately..... 01

(ii) What inlet in the jacket would you use for this purpose (A or B) ?

B 01

(c) (i) After taking the initial reading of the spherometer what experimental step would you take next in connection with the spherometer before passing steam ?

Turn the spherometer screw until the lower end of the screw is sufficiently above the rod, (in order to make room for expansion of the rod)..... 01

OR Remove the

(ii) The rod will be heated by passing steam through the jacket. Mark the steam inlet on the above diagram.

Marking on the diagram or stating inlet A 01

(iii) Why do you use steam instead of hot water at boiling point to heat the rod ?

Temperature throughout the rod will not be ~~constant~~ the same if hot water is used

OR

Hot water is not convenient as large quantity is needed compared with steam.

OR

Steam circulates uniformly within the jacket and thereby ensures a uniform temperature 01

(d) How and when do you take the final reading of the spherometer ?

Adjust the screw of the spherometer until it touches the rod and take the reading.

..... 01

This reading is taken when the thermometer reading ~~has~~ attained a steady value

..... 01

(e) Following is a set of readings obtained by a student from such an experiment.

Initial length of the rod = 0.50 m
Initial reading of the spherometer = 2.62 mm
Final reading of the spherometer = 1.22mm
Initial reading of the thermometer = 28 °C
Final reading of the thermometer = 98 °C

Calculate the linear expansivity of the metal.

$$\text{Linear expansivity } \alpha = \frac{(2.62 - 1.22)10^{-3}}{0.50 \times 70}$$

$= 4.0 \times 10^{-5}\ K^{-1}(^{o}C^{-1})$ 01

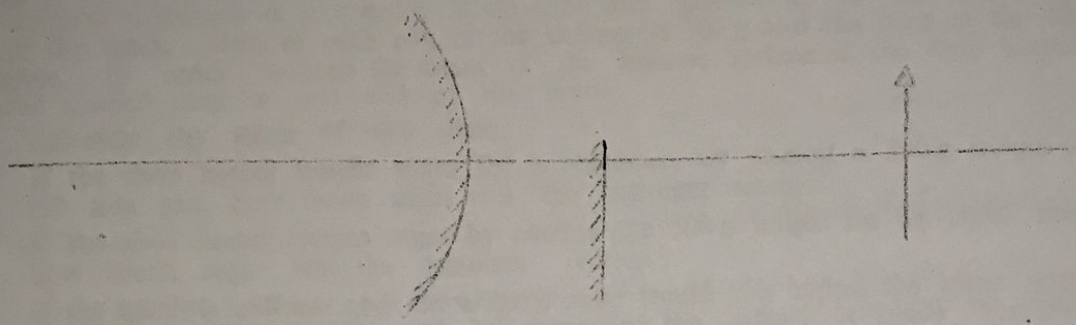
(f) Why must the increase in length of the rod be measured so accurately while the initial length of the rod itself can be determined with a metre ruler ?

Expansion is very small compared with the initial length.(Therefore the percentage error in this measurement will be large unless it is measured very accurately).

..... 01

(3) You are provided with a convex mirror, a plane mirror, a pin and a metre ruler.

(a) In the space provided below draw a sketch of the set up that can be used to find the image distance of the pin due to the convex mirror.



Position of the plane mirror, one end being placed on the axis 01
Position of the pin, one end being placed off the axis 01

(b) Describe briefly how you would locate the image of the pin seen through the convex mirror.

Adjust the plane mirror until there is no parallax between the images formed due to the convex mirror and plane mirror.....02
(mirror adjustment ..... 01 mark ; no parallax method .....01 mark)

(c) (i) Once the image is correctly located, the distances of the pin and the plane mirror from the convex mirror are found to be u and x respectively. Write down an expression for the image distance v in terms of u and x.

$v = -(u - 2x)$ OR $v = (u - 2x)$ 01

(ii) Also writedown an expression for the the focal length f of the convex mirror in terms of u and x,

$$\frac{1}{f} = \frac{1}{u} - \frac{1}{(u - 2x)}$$ 01

(iii) If u = 20 cm. and x = 10 cm. find f of the mirror.

(Delete this part)

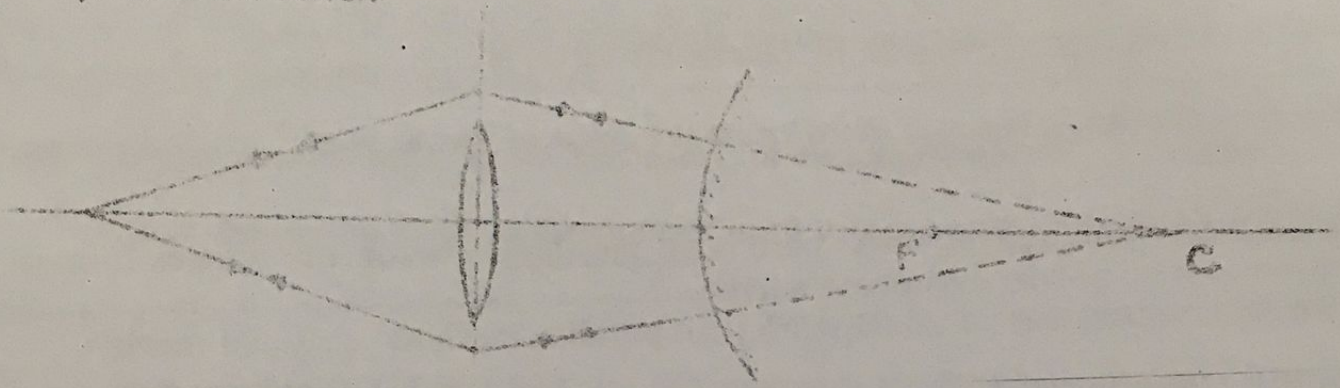
(d) If you are asked to verify the mirror formula for a convex mirror by plotting a suitable graph, it is desirable to use a mirror with a larger radius of curvature. What is the reason for this?

(In the case of the convex mirror the image distance is always less than half of the radius of curvature) Therefore if the radius of curvature is large several readings could easily be obtained for different image distances. 01
OR the range of the image distance is larger.
OR more points can be obtained for the graph.

(e) State the main advantage of using a convex mirror over a plane mirror as a side mirror in a vehicle.

It has a larger field of view..... 01

(f) The focal length f of the mirror can also be determined with the help of a convex lens. Draw such an arrangement with the corresponding ray diagram and locate the focal point of the mirror.

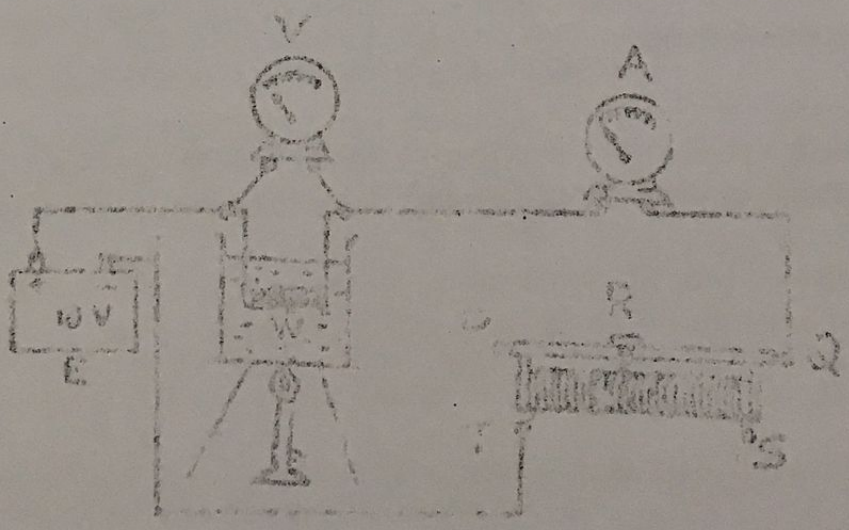


Correct ray diagram with an indication of principle of reversibility of light. (i.e. by reversible arrows or rays falling on the mirror ~~at right angles~~)

..... 01

Correct location of the focal point 01

4 Diagram below shows some of the apparatus which can be used in an experiment to investigate the variation of the resistance X_θ of a coil of wire with the increase in temperature θ. In this experiment the coil is heated to different temperatures and its resistance is measured using an electrical circuit. The value of X_θ at the room temperature is given as 100 Ω. The ammeter A provided has a full scale deflection of 50 mA. V is a voltmeter, R is a rheostat, E is a 10 V battery and W is a water bath in which the coil is immersed.



PART B - Essay

1. *Answer* either *part* (*a*) or *part* (*b*).

(*a*) Distinguish between the moment of a couple and the moment of a force.

The beam of a balance in a shop is 51 cm long and pivoted at 26 cm from the left end of the beam. Mass of each pan of the balance is 100 g and the mass of the beam is negligible. In order to keep the beam of the balance horizontal, the shop keeper has attached a small mass to one end of the beam.

(i) Calculate the value of this mass.

(ii) If the shop keeper weighs sugar for a customer, by placing a 500 g weight on the left side pan, how much sugar will the customer receive ?

(iii) If the shop keeper weighs sugar by placing the 500 g weight on the right side pan, how much sugar will the customer receive ?

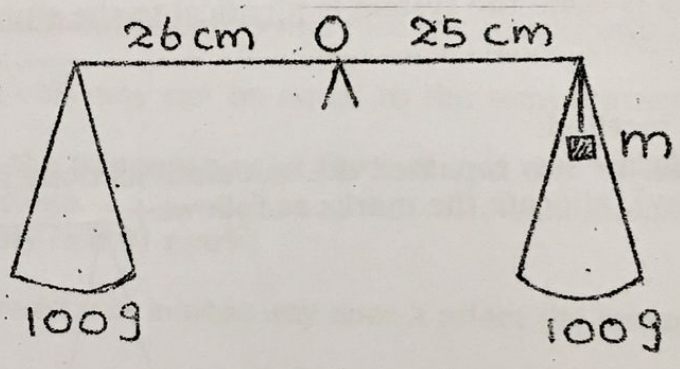
(iv) If the beam is uniform and has a finite mass would you expect the same results as obtained in (ii) and (iii), once the beam of the balance is made horizontal by attaching a suitable mass prior to the weighing ? Explain your answer.

OR it does not depend on the point around which it taken

Moment of a couple is a constant whereas the moment of a force depends on the distance of the point around which the moment is taken.....03

(If both facts are given award 03 marks ; deduct 01 mark if one fact is missing)

(i) Let the required mass be m



Taking moments about point O

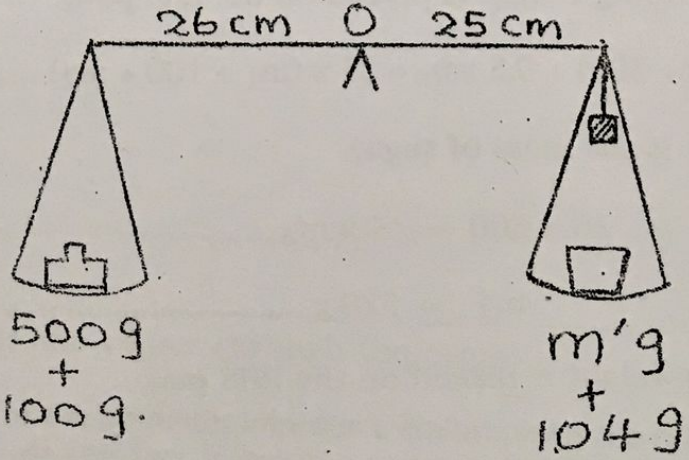
$26 \times 100 = 25 \times 100 + 25\,m$ 02

(or zero)

$m = 4\,g$ 01

(when taking moments candidates can select a point other than O as well)

(ii) Let m' be the mass of the sugar that the customer will receive when 500 g weight is placed on the LHS pan



By taking moments about O

OR $26 \times 500 = 25\,m'$

$26 \times 600 = 25 \times (m' + 104)$ 01

$m' = 520$ g.....01

(iii) Let m" be the corresponding mass of sugar when a 500 g weight is placed on the RHS pan

OR $26\,m'' = 25 \times 500$

$26 \times (100 + m'') = 25 \times (4 + 600)$ 01

$m'' = 480.8$ g (481 g) 01

(iv) YES

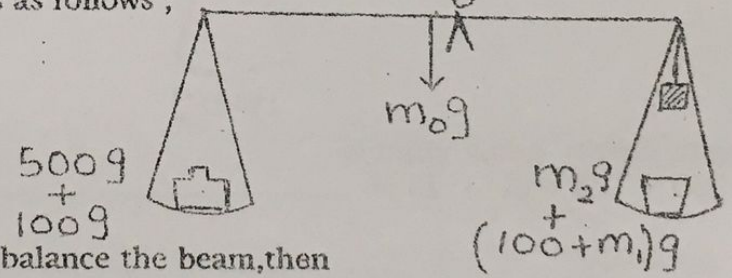
Weight of the beam acts through its centre of gravity which is 0.5 cm away from the point at which the beam is pivoted 01

Objective behind the balancing of the beam by hanging a suitable mass in this case is to shift the centre of gravity of the system to coincide with the point at which the beam is pivoted 02

Once this is done the system is identical to the situation considered under (ii) and (iii).....02

[Alternative method:

If a candidate has repeated the calculations done in (i), (ii), and (iii) with the beam of mass m_0 (say), allocate the marks as follows ;



Let m_1 be the mass needed to balance the beam,then

$26 \times 100 + m_0 \times 0.5 = (m_1 + 100) \times 25$ .....(A).....01

When the 500 g weight is placed on the LHS pan,

$26 \times (100 + 500) + 0.5 \times m_0 = 25 \times (m_1 + 100 + m_2)$ .....(B).....01

where m_2 is the mass of sugar.

(B) - (A) $26 \times 500 = 25 \times m_2$

$m_2 = 520$ g 01

If the 500 g weight is placed on the RHS pan,

(a) In the above figure join the items given to form a suitable electrical circuit,which enables you to measure the resistance of the coil at various temperatures.

Correct diagram as above 02
(Deduct one mark if the rheostat connection is wrong; Note that the connections PS,PTand QS are also possible)

(b) What measurements would you take from this circuit in order to find X_θ?

Voltmeter and the ammeter readings..... V and I ✓ 01

OR

Voltage across the coil and the current through the ammeter.

(c) What other items would you require to perform this experiment ?

Thermometer and stirrer 01

(d) In this experiment the coil can be heated by using the current provided by the 10 V battery instead of using a burner. Give reasons as to why this method is not practicable.

100Ω, 10V = 1W

(i) The heat generated is not sufficient to increase the temperature of the water bath.

(ii) Temperature inside the coil may not be equal to the temperature at its surface.

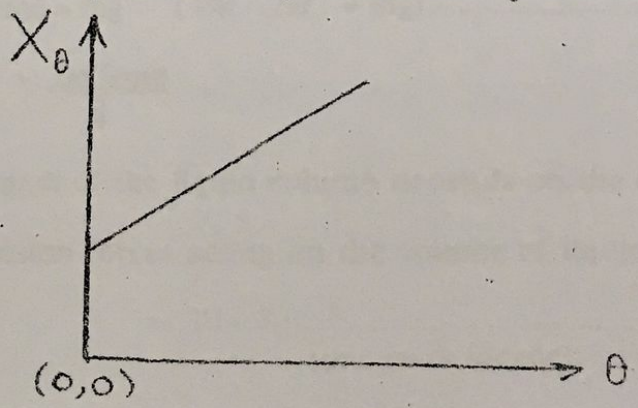
(iii) Under this condition the temperature of the coil and that of the water bath may not be the same. 02

(Any two 02 marks ; any one 01 mark)

(e) If the voltmeter has a finite resistance in what way does it affect the measurement X_θ?

The measured value of X_θ is less than its actual value 01

(f) Draw a rough sketch of X_θ versus θ which you would expect from this experiment.



Straight line as shown 01
(No mark if the straight line passes through the orgin)

(g) 50 mA full scale deflection of the ammeter imposes a limitation to the current through the circuit. How would you use this fact to select a voltmeter with a suitable full scale deflection ?

(The maximum current in the circuit = 50 mA).
Therefore the maximum possible voltage which can be applied across the coil (b)

= $100 \times 50 \times 10^{-3}$ V

= 5 V 01

A voltmeter with 5 V full scale deflection is therefore suitable for the experiment 01

(Full scale deflections between 5 V and 10 V can also be considerd as correct with the above calculation)

Calculation is essential

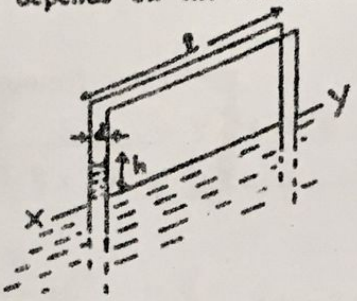
$26 \times (100 + m_3) + 0.5 \times m_o = 25 \times (m_1 + 100 + 500)$ 01

where m_3 is the mass of sugar.

$m_3 = 480.8$ g .....01]

(b) Define surface tension.

A capillary tube of internal radius r is partially dipped in a large vessel containing a liquid of surface tension T and density ρ. Show that the mass of the liquid column above the liquid surface of the vessel depends on the internal radius of the tube.



Two thin glass plates each of length l is placed distance d apart in the same liquid as shown in the figure. Derive an expression for the height h of the liquid column above the liquid surface XY if the angle of contact of the liquid and the glass is zero and $d << l$.

If one plate is now removed leaving the other, draw the shape of the liquid surface near the plate and deduce the mass of the liquid above the liquid surface XY.

SURFACE TENSION: The force per unit length acting along the surface at right angles to one side of a line drawn on the surface.....03 or Zero

Upward force acting on the water column = $2\pi r T\cos\theta$

where θ is the angle of contact.

If m is the mass of the water column above the surface, then

$2\pi r T\cos\theta = mg$ (OR $2\pi r T = mg$).....02

$$m = \frac{2\pi r T\cos\theta}{g}$$

therefore the mass of the liquid column depends on the internal radius r.....01

The surface tension forces acting on the volume of liquid between glass plates

$= Tl + Tl$ 02
(one mark for each Tl term)

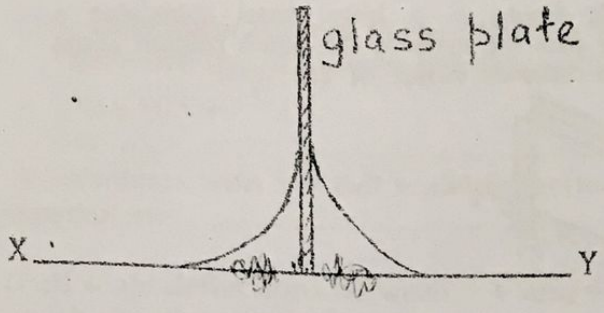
If m is the mass of the liquid column, then

$Tl + Tl = mg$ 01

but $mg = h\,d\,l\,\rho\,g$ 01

Therefore $2Tl = h\,d\,l\,\rho\,g$

$$h = \frac{2T}{d\rho g}$$ .....01.



.....02

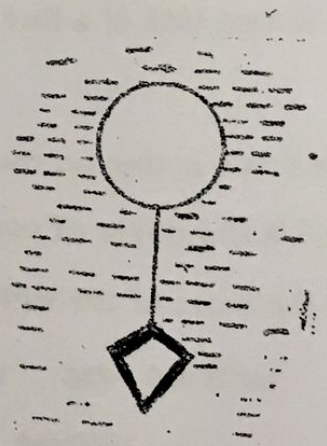
(one mark for each correct shape)

Mass (m') of the liquid above the liquid surface in this case is identical to that of the liquid between the two glass plates mentioned above. 01

Therefore $m'g = 2Tl$

$$m' = \frac{2Tl}{g}$$ 01

2. A metal object of mass 8 kg with an internal cavity is attached to an inflated spherical rubber baloon with an inextensible light string as shown in the figure. When the radius of the baloon is 10 cm the system just floats in a deep lake. Density of the metal is 8000 kg m^{-3} and the density of water is 1000 kg m^{-3}.



(i) Neglecting the mass of the baloon, find the volume of the cavity in the metal object.
(ii) Calculate the tension in the string.
(iii) If the baloon is given a small push downwards, explain clearly the subsequent motion of the system without deriving any mathematical expressions.

(i) Let the volume of the cavity be V (m^3).

Then the total volume of the metal object = $\frac{8}{8000} + V$ m^3 .....01+01

01

Upthrust on the metal object $= \left(\frac{8}{8000} + V\right) 10^3 g$ .....01+02 or zero

Upthrust on the baloon $= \frac{4\pi}{3}(10 \times 10^{-2})^3 \times 10^3 g$ 01

As the system just floats under above conditions,

.Total Upthrust = Weight of the system 01

$$\frac{4\pi}{3} \times 10^{-3} \times 10^3 g + \left[\frac{8}{8 \times 10^3} + V\right] \times 10^3 g = 8g$$ .....01+01 (for adding the two terms)

$$\frac{4\pi}{3} + 1 + V \times 10^3 = 8$$

$V = 2.81 \times 10^{-3}\ m^3$ 02

(ii) Tension (T) in the string = upthrust on the baloon 01

(OR T = weight of the metal object - upthrust on the metal object)

$$T = \frac{4\pi}{3} \times 10^{-3} \times 10^3 g$$

$T = 41.9\ N\ (42\ N)$ 02

(deduct 01 mark if the unit is wrong)

(iii) When the baloon is given a small push it will get compressed due to the excess pressure excerted by the column of water above the baloon 01

As a result the upthrust on the baloon will decrease 01

Therefore the effective downward force on the system will increase and it will start to sink 01

As it sinks the volume of the baloon will decrease further and therefore the system will move with an acceleration.....01

However, the system will reach its terminal velocity after some time when the upthrust due to the baloon becomes negligible and the motion of the system is governed by the weight of the metal object. 01

3. An aluminium rod 50 cm in length and of uniform cross-sectional area 2 cm^2 is inserted vertically into a thermally insulated vessel containing liquid helium at its boiling point of 4.2 K. The rod is initially at 300 K.

(i) If the whole rod is inserted carefully into liquid helium, how many litres of liquid helium will boil-off by the time when the rod cools down to 4.2 K ?

(ii) Now the upper half of the rod is lagged and its lower half is inserted into the liquid helium while maintaining the top of the rod at 300 K. What is the boil-off rate of liquid helium, once the rod has attained the steady state ?

(iii) Draw the variation of the temperature with the length of the rod starting from the top end, under the conditions mentioned in (ii) above.

Density of aluminium	= 2700 kg m^{-3}
Thermal conductivity of aluminium	= 210 W m^{-1} K^{-1}
Specific heat capacity of aluminium	= 910 J kg^{-1} K^{-1}
Latent heat of vaporization of helium	= 2.1 × 10^4 J kg^{-1}

1 kg of helium corresponds to 8 litres.

(i) Mass of the Aluminium rod = $2 \times 10^{-4} \times 50 \times 10^{-2} \times 2700$ kg 01

between and Liquid helium.

A Temperature difference across the rod = (300 - 4.2) K 01

The amount of heat given out by the rod = $2 \times 10^{-4} \times 50 \times 10^{-2} \times 2700 \times 910 \times 295.8$ 01

$= 27 \times 91 \times 295.8 \times 10^{-1}$ J

If m is the mass of liquid Helium boiled off when inserting the rod,

the amount of the heat absorbed by liquid Helium = $m \times 2.1 \times 10^4$ J 01

Therefore,

$m \times 2.1 \times 10^4 = 27 \times 91 \times 295.8 \times 10^{-1}$ 01

(for equating expressions)

$$m = \frac{27 \times 91 \times 295.8 \times 10^{-1}}{2.1 \times 10^4}$$

since 1 kg of liquid Helium = 8 litres

28

the amount of liquid Helium boiled off = $\frac{27 \times 91 \times 295.8 \times 10^{-1}}{2.1 \times 10^4} \times 8$ = 27.7 litres ...01

(ii) Temperature at the middle point of the rod at steady state = 4.2 K.....01

(this mark can be awarded at the next step provided that the candidate has used 25×10^{-2} m as the length of the rod)

Therefore, the rate of flow of heat through the rod = $\frac{210 \times 2 \times 10^{-4} \times (300 - 4.2)}{25 \times 10^{-2}}$

.....02

(OR zero)

If m' is the boil off rate of liquid Helium then

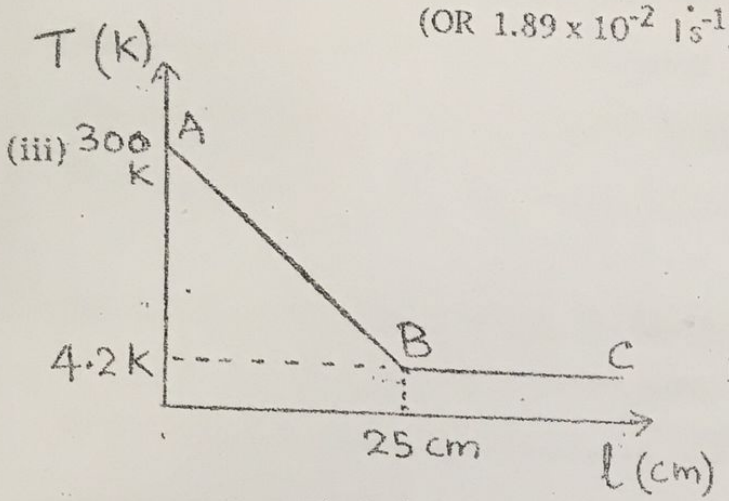
$$m' \times 2.1 \times 10^4 = \frac{210 \times 2 \times 10^{-4} \times (300 - 4.2)}{25 \times 10^{-2}}$$ 01

(for equating both terms)

m' = 23.6×10^{-4} kg s^{-1} 02

(OR 1.89×10^{-2} $l s^{-1}$)

[deduct one mark if the unit is wrong]



Linear region A-B.....01

Horizontal region BC 01

For indicating 300 K, 4.2 K, and 25 cm on the graph 01

4. The graph below shows the variations of the volume V of a mass of 10^3 kg of water with the temperature θ at one atomospheric pressure.

(a) According to the graph,

(i) at 0°C there is a change in volume even without a change in temperature. What does this imply ?

(ii) between 0°C and 4°C does water behave like other liquids ? If not what is the difference ?

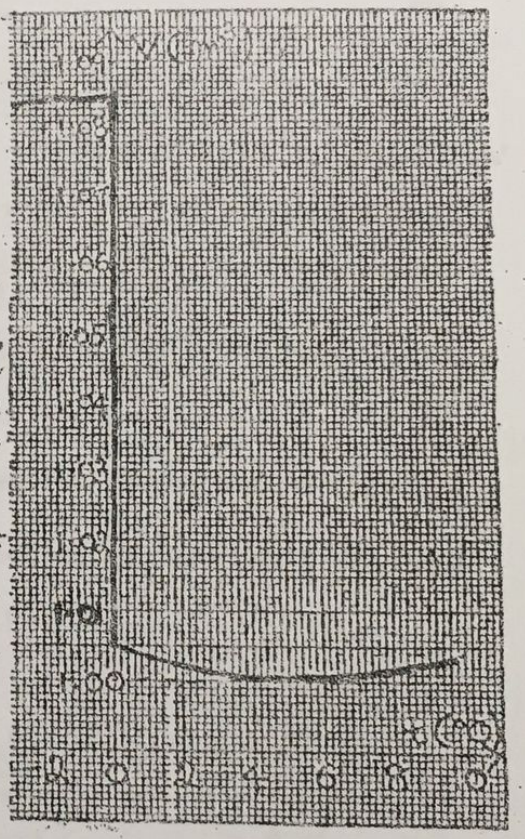
(b) With reference to the above graph briefly explain the following statements.

(i) A water filled glass bottle may crack when the water freezes inside.

(ii) When water freezes, the ice forms first at the top surface of water.

(iii) Water is an unsuitable liquid for use in liquid-in-glass thermometers for temperatures between 4°C and 10°C.

(c) Use the graph to calculate the densities of water and ice at 0°C. Draw a sketch showing the variation of the density of water from 0°C to 10°C.



(a) (i) This implies a change of state OR (a phase change) OR water changes to ice.

.....01

(ii) No, when the temperature increases from 0°C to 4°C water contracts ,(volume decreases) 01

whereas other liquids usually expands (volume increases) due to temperature increase 01

(b) (i) Water expands (volume increases) as it freezes 01

(ii) As the temperature falls below 4°C cold water masses at the surface remain there,(they will not move down to the bottom).....01

due to the continuous decrease in density. 01

(iii) Expansion is not linear 01

(c) Volume of 10^3 kg of water at 0°C = 1.005 m^3 01

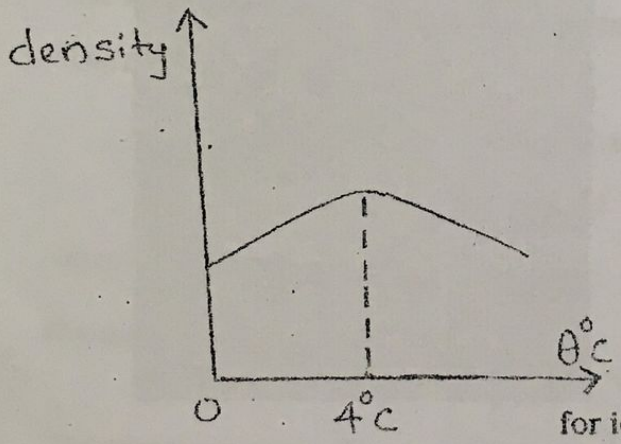
density of water at 0°C = $\frac{10^3}{1.005}$ 01

= 995 kg m^{-3} 01

Volume of 10^3 kg of ice at 0°C = 1.085 m^3 01

density of ice at 0°C = $\frac{10^3}{1.085}$

= 922 kg m^{-3} 01



only

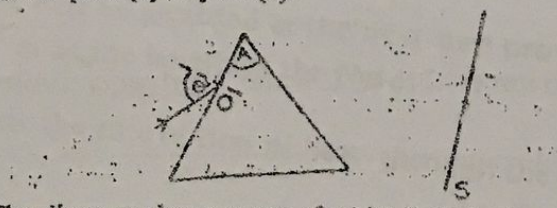
for the shape from 0°C to 4°C 01

for the shape from 4°C to 10°C 01

for identifying 4°C as the maximum density point.....01

5. *Answer* either *part* (*a*) or *part* (*b*).

(a)



The diagram shows a ray of white light incident on a glass prism of refracting angle A with an angle of incidence θ. Name the colours from bottom to top as seen on the screen S. If a beam of white light from a point source is incident instead of a ray what changes will occur in the spectrum seen above.

What additional apparatus are needed to produce a pure spectrum using the above arrangement ? Where should these apparatus be placed ?

In the set-up shown above the prism is now rotated in anti-clockwise direction around a vertical axis that passes through point O, and perpendicular to the plane of the paper. As θ decreases the colour spectrum on the screen will totally disappear when $\theta = 29° 30'$. What is the refracting angle A of the prism ?

(Refractive index of the prism material for red colour = 1.52.)

VIBGYOR ;

All seven colours marked on the screen in the right order OR written as above 01

Colour spectrum disappears except at the edges OR middle portion of the spectrum will be white, only the edges will have the colours. 02

Slit (aperture) 01

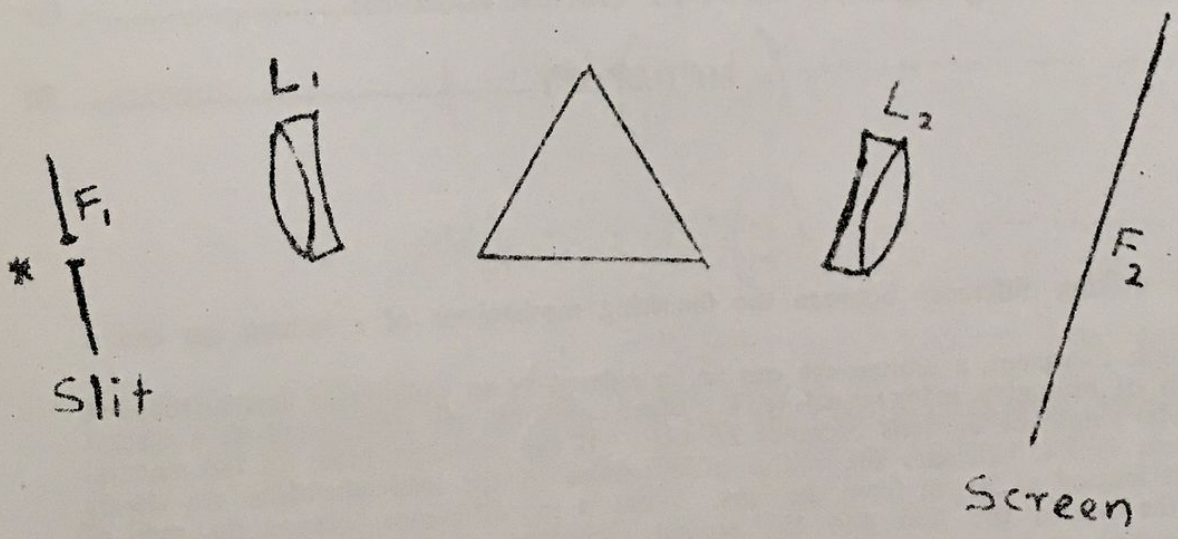
Two achromatic converging (convex) lenses 01

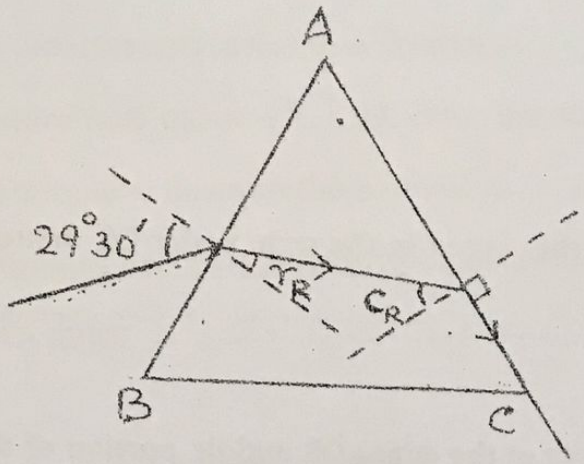
Slit in front the source 01

One lens is placed in between the slit and the prism so that the slit lies on the focal plane of the lens 01

Other lens is placed in between the prism and the screen so that the screen lies on the focal plane of the lens 01

(OR as shown in the diagram below ; Note : to award the two marks stated above, the candidate should mark the right positions of the lenses by indicating the focal planes of the lenses OR by an appropriate ray diagram)





When the red ray is incident on the face AC with an angle of incidence equal to the critical angle for the glass-air interface for the red colour, the spectrum on the screen will totally disappear, since

the red colour has the largest critical angle OR the smallest deviation 01

If the critical angle for the red ray is C_R, then

$$1.52 = \frac{1}{\sin C_R} \quad \text{.....01}$$

$C_R = 41^\circ\ (41^\circ 08')$.....01

If r_R is the angle of refraction of the red ray on the face AB, then

$$1.52 = \frac{\sin 29^\circ 30'}{\sin r_R} \quad \text{.....01}$$

$r_R = 19^\circ\ (18^\circ 54')$ 01

Therefore the refracting angle A = $41^\circ + 19^\circ$ (for the addition).....01

$= 60^\circ\ (60^\circ 02')$ 01

(b) What is the striking difference between the focussing mechanisms of a human eye and a camera ?

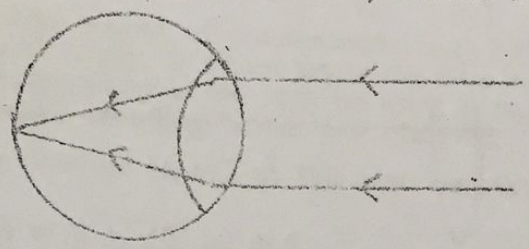
In a very simple treatment, a human eye can be considered as an equiconvex lens surrounded by a medium of refractive index equal to 1. When such an eye is focussed at a distant object, the focal length of the lens becomes 2.5 cm. If the refractive index of the material of the eye lens is 1.4, calculate the radius of curvature of the lens when the eye clearly sees an object located at 30 cm from the lens. What is the difference between the radii of curvature of the lens in the first and the second situations mentioned above ?

Now a convex lens of focal length 10 cm is placed 10 cm away from the eye lens. Can the eye still see a clear image of the object mentioned in the second situation ? Explain your answer.

In a human eye focussing of different objects on the retina is done by changing the shape of the eye lens. (OR changing the curvature of the lens.

In a camera focussing is accomplished by changing the distance between the lens and the photographic film.(OR by moving the lens.) 03

(If both facts are given award 03 marks ; deduct 02 marks if one is missing)



When the eye is focussed at a distant object the focal length is equal to the distance between the lens and the retina.

Therefore the distance from the lens to the retina = 2.5 cm 01

Let f' and r' be the focal length and the radius of curvature of the lens when the eye clearly sees an object located at 30 cm.

Applying, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ 01

$\frac{-1}{2.5} - \frac{1}{30} = \frac{1}{f'}$ 01

$\frac{1}{f'} = \frac{-32.5}{2.5 \times 30}$

applying, $\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ 01

$\frac{-32.5}{2.5 \times 30} = (1.4-1)\left(\frac{-2}{r'}\right)$ 01

$r' = 1.85$ cm 01

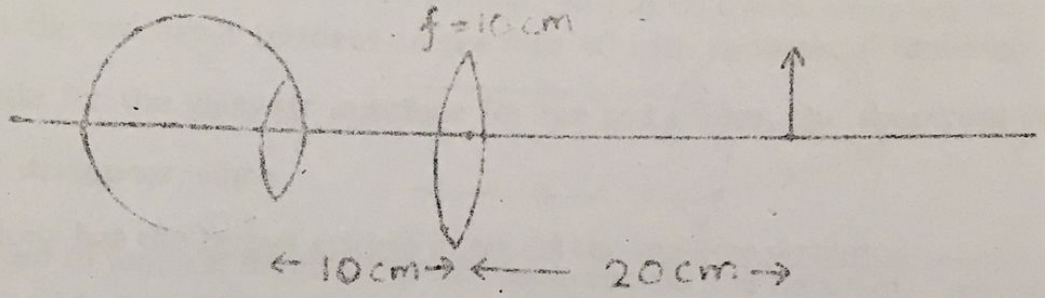
Let r be the radius of curvature of the lens in the first situation.

Applying again, $\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$$-\frac{1}{2.5} = (1.4 - 1)\left(\frac{-2}{r}\right)$$ 01

$r = 2$ cm 01

change in the radius $= (2 - 1.85)$ cm
$= 0.15$ cm 01



The image of the object due to the convex lens is formed behind the retina. 01

Therefore the eye cannot see a clear image of the object in this situation..... 02

(Do not award the two marks without the correct reason)

[OR the candidate may do a numerical calculation as follows :

If v' is the image distance of the object formed due to the convex lens, then

applying $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ for the convex lens

$$\frac{1}{v'} - \frac{1}{20} = -\frac{1}{10}$$

$v' = -20$ cm 01

The eye cannot see a clear image of the object in this situation. 02

Now this image act as a virtual object to the eye lens. Let f" be the focal length of the eye lens when it forms a real image of this virtual object on the retina.

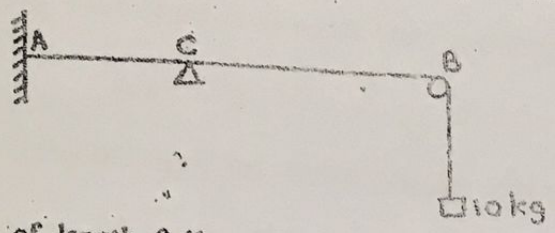
Then $v = -2.5$ cm ; $u = -10$ cm ; $f" = ?$

$$\frac{1}{2.5} + \frac{1}{10} = \frac{1}{f"}$$

$f" = -3.33$ cm

Since the largest value of the focal length that the eye lens can achieve is 2.5 cm, the image of the object cannot be focussed on the retina]

Explain the reason why it is practically difficult to produce nodes with exact zero displacement in a standing wave.



A metal wire AB of length 0.40 m and of cross-sectional area 1.0×10^{-6} m^2 is loaded with a block of mass 10 kg. A smooth bridge is placed under the wire at C, 0.15 m from A as shown in the figure. Transverse waves are set up in the wire by using a variable frequency source. Find the highest wavelength for which standing waves are observed.

What is the number of loops observed in AC, at this wave length? Calculate the corresponding frequency.

The density of the metal = 2×10^3 kg m^{-3}.

In practice the standing waves are produced by the superposition of an incident wave with its own reflection. Usually the amplitude of the reflected wave is slightly less than that of the incident wave and therefore it is not possible to obtain points with zero displacement by the superposition of the two waves.....01

Let λ be the highest wavelength for which standing waves are observed in the wire, and n_1 and n_2 be the corresponding numbers of loops observed in AC and CB respectively under above condition.

Then $AC = \frac{n_1\lambda}{2} = 0.15$ 02

$CB = \frac{n_2\lambda}{2} = 0.25$ 01

$\therefore \frac{n_1}{n_2} = \frac{15}{25} = \frac{3}{5}$ 01

As the minimum values of n_1 and n_2 which satisfy the above ratio correspond to the highest wavelength λ,

$n_1 = 3$ 02

$\lambda = \frac{0.15 \times 4}{3}$ (OR $= \frac{0.25 \times 2}{5}$)

$= 0.1$ m. 01

(ii) Calculation of the frequency:

velocity of transverse waves in the wire $v = \sqrt{\frac{T}{m}}$ 01

Tension T in the wire $= 10 \times 10$ N 01

mass per unit length m in the wire $= 2 \times 10^{-3} \times 1 \times 10^{-6}$ 01

$$v = \sqrt{\frac{10 \times 10}{2 \times 10^{-3}}}$$

$$= 100/\sqrt{5} \text{ m s}^{-1}$$

But $v = f\lambda$ 01

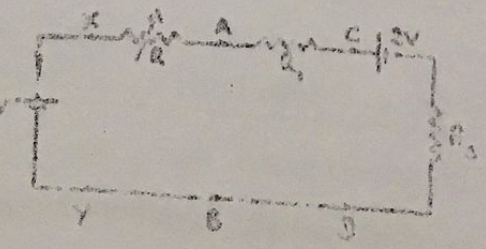
$\therefore$ the corresponding frequency $f = \frac{100/\sqrt{5}}{0.1}$ 01

$= 2236$ Hz 02

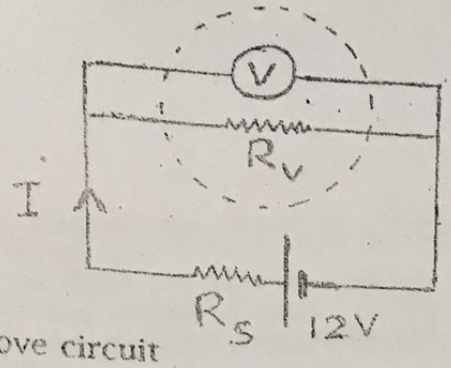
(deduct one mark if the unit is wrong)

7 Answer [illegible] or part (b)

(a) [illegible] connected across a battery of e. m. f. 12 V it reads 11.5 V. If [illegible] of the battery is 20 Ω, what is the internal resistance (R_V) of the [illegible] a circuit the way in which the battery, R_x and R_V are connected, and [illegible] the measured voltage of 11.5 V will appear.



(b) [illegible] shown R_1 [illegible] a slider r slider are both cells have negligible internal resistance. With [illegible] equal to 50 Ω a voltmeter connected across AB reads 5 V. If the 10 V cell [illegible] and the points X and Y are joined together while keeping A at 50 Ω a voltmeter connected across CD reads 1.5 V. Calculate R_1 and R_2.



Applying Kirchhoff's law to the above circuit

$12 = I R_S + I R_V$ 01

where I is the current through the circuit.

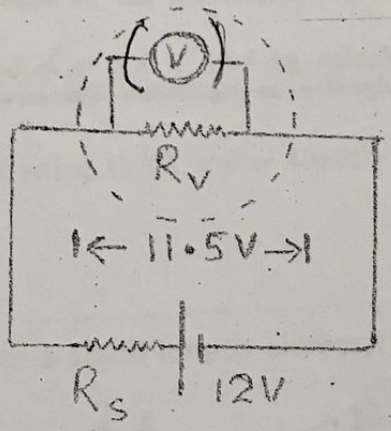
But $I R_V = 11.5$ 01

$\therefore \quad I R_S = 12 - 11.5 = 0.5\ V$

$I = \frac{0.5}{R_S} = \frac{0.5}{20}$ 01

$\therefore \quad R_V = 11.5 \times \frac{20}{0.5}\ \Omega$

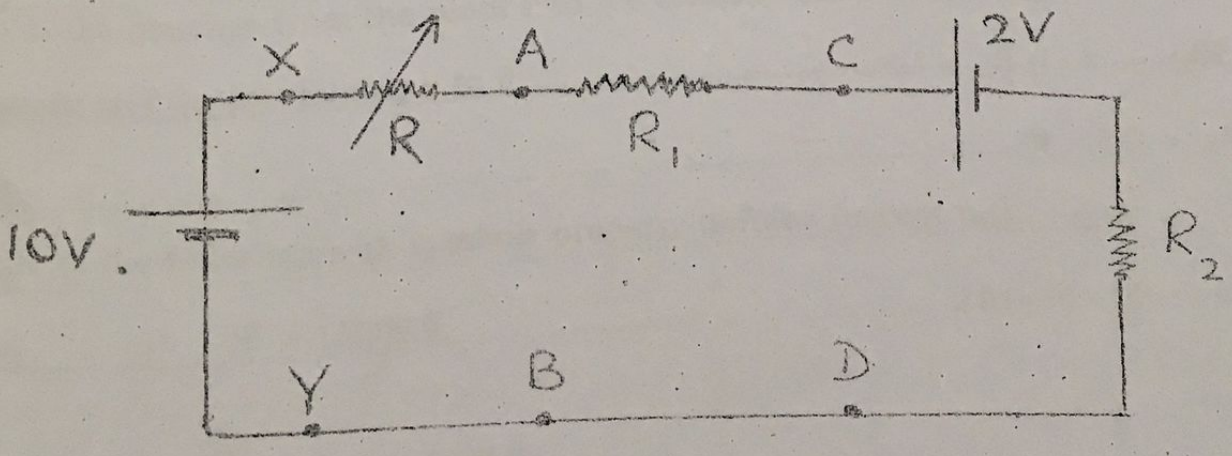
$= 460\ \Omega$ 01



$R_S, R_V, 12V$ — 01

11.5 — 01

Correct diagram as above ..... (01) + 01



When $V_{AB} = 5$ V, voltage across the 50 Ω resistor is equal to 5 V 01

$\therefore$ current through the circuit, $I = \frac{5}{50} = 0.1$ A 01

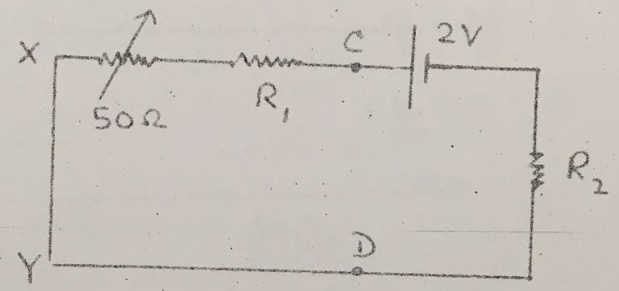
Applying Kirchhoff's law to the circuit

$10 - 2 = 50I + IR_1 + IR_2$ 01

But $50I = 5$

$\therefore \quad 8 = 5 + I(R_1 + R_2)$

$\therefore \quad R_1 + R_2 = 30\,\Omega$ 01



If I_1 is the current in the circuit when XY is joined together, then applying Kirchhoff's law

$2 = I_1(50 + R_1 + R_2)$ 01

But $R_1 + R_2 = 30$

$\therefore \quad 2 = I_1 \times 80$

$I_1 = \frac{1}{40}$ A 01

Now $V_{CD} = 2 - I_1 R_2 = 1.5$ 01

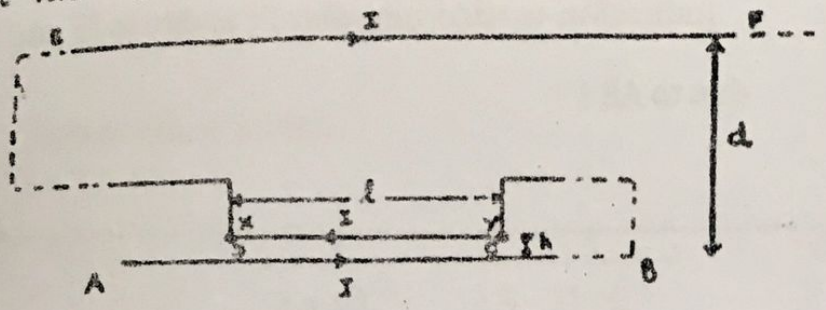
$\therefore \quad R_2 = 0.5 \times 40$ 01

$= 20\,\Omega$ .....

$R_1 = 30 - 20 = 10\,\Omega$ 01

..... 01

(b) State Biot-Savart Law.
Write down an expression for the magnitude of the magnetic flux density at a distance r from an infinitely long straight wire carrying a current I.
Two long wires ABC and DEF bent as shown in the figure are kept in a vertical plane so that the straight sections AB and EF are parallel and distance d apart. Another wire XY, vertically above AB and having a length l and mass m is free to slide up and down on the vertical parts of the above mentioned wires.



The two wires are connected through the sliding contacts and carry a current I. The wire XY is now brought down to its lowest position, a distance h above the wire AB and released from rest. Assuming that the magnetic forces on it are due to the currents in the wires AB and EF only

(i) indicate on a diagram the forces acting on the wire XY, when it is at its lowest position.

(ii) explain how you would find the direction in which XY begins to move depending on the magnitude of the various forces that you have indicated in (i).

(iii) derive an expression for the magnitude of the acceleration with which XY begins to move.

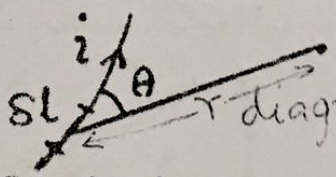
(iv) If $d = 5 \times 10^{-2}$ m, $l = 1$ m and $m = 7.5 \times 10^{-3}$ kg calculate the magnitude of the current necessary to keep the wire XY stationary at a height of 2 cm from AB.

$\left(\frac{\mu_0}{4\pi} = 10^{-7}\ T\ m\ A^{-1}\right)$

Biot - Savart Law :

The flux density δB at a point P due to a small length element δl of a conductor carrying a current i is given by

$$\delta B \propto \frac{i \delta l \sin\theta}{r^2}$$



r diagram without Definitions ✓

Where r is the distance from the piont P to the element and θ is the angle between the element and the line joining it to P. 02

OR

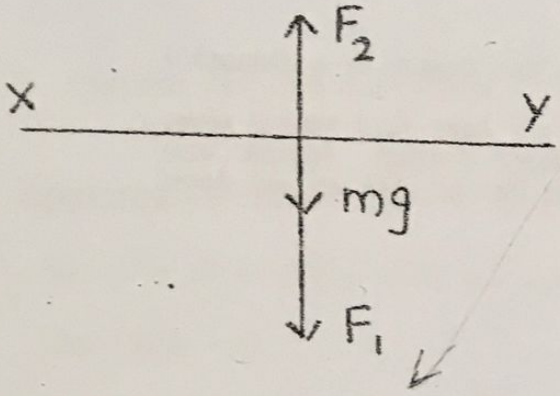
[any one of the following with symbols properly defined (except μ_0)

(i) $\delta B \propto \frac{i \delta l \sin\theta}{r^2}$

(ii) $\delta B = \frac{\mu_0}{4\pi} \frac{i \delta l \sin\theta}{r^2}$]

Magnetic flux density = $\frac{\mu_0 I}{2\pi r}$ 01

(i) $F = BIl$ ——— 01



.....01

(do not award this mark unless there is a clear indication to ascertain that F_1 is due to EF and F_2 is due to AB)

$F_1 = \frac{\mu_o}{2\pi} \frac{I^2 l}{(d - h)}$ 02 01

$F_2 = \frac{\mu_o}{2\pi} \frac{I^2 l}{h}$ 01

(ii) If $F_2 > F_1 + mg$ then XY begins to move up 01

If $F_2 < F_1 + mg$ then XY begins to move down 01

(OR in words as below :

If the force F_2 is greater than the sum of the forces mg and F_1, then XY will move up & vice versa)

(iii) If f is the acceleration with which XY begins to move then,

$F_2 - mg - F_1 = mf$ 01

(OR $F_1 + mg - F_2 = mf$)

$$\frac{\mu_o}{2\pi} \frac{I^2 l}{h} - mg - \frac{\mu_o}{2\pi} \frac{I^2 l}{(d - h)} = mf$$

$$\therefore \quad f = \left(\frac{\mu_o}{2\pi} \frac{I^2 l}{h} - mg - \frac{\mu_o}{2\pi} \frac{I^2 l}{(d - h)} \right) \Big/ m$$ 01

(iv) Let I be the magnitude of the current necessary to keep the wire XY at a height of 2 cm (say h_o) from AB.

Then at equilibrium,

$$\frac{\mu_o}{2\pi}\frac{I^2 l}{h_o} - mg - \frac{\mu_o}{2\pi}\frac{I^2 l}{(d - h_o)} = 0 \quad \text{.....01}$$

i.e. $$\frac{1}{h_o} - \frac{1}{d - h_o} = \frac{2\pi}{\mu_o I^2 l} mg$$

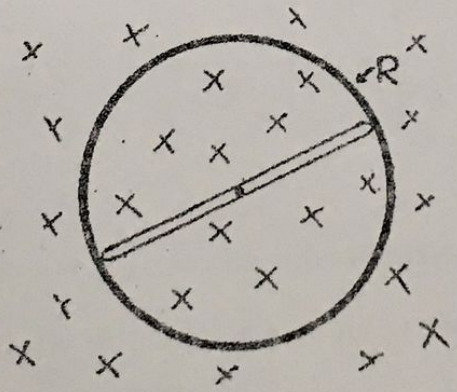
Substituting values

$$\frac{1}{2 \times 10^{-2}} - \frac{1}{(5 - 2)10^{-2}} = \frac{10^7}{2}\frac{x\,7.5 \times 10^{-3}\, x\,10}{I^2} \quad \text{.....01}$$

$$I^2 = \frac{10^3 \times 7.5}{12}$$

$\therefore$ I = ~~25 A~~ 15 A 02

8. State two methods by which the magnetic flux through a circuit can be changed.
A metal rod is pivoted at its mid point to the end of a vertical metal axle which is going into the plane of the paper so that the rod can rotate freely on the plane of the paper with its both ends touching a fixed metal ring (R) as shown in the figure.



The arrangement is placed in a uniform vertical magnetic field of flux density 0.1 T and directed into the paper.

(i) If the length of the rod is 28 cm and its resistance is 0.4 Ω, and all the other components have negligible resistance calculate the e. m. f. generated across the axle and the ring if the rod is rotated at a constant rate of 100 revolutions per second.

(ii) What is the rate at which the rod mentioned in (i) should be rotated in order to light a 1 W, 1 V electric bulb at its full brightness when connected across the ring and the axle

(iii) If large number of similar rods are fixed to the arrangement as mentioned above instead of a single rod, would you be able to obtain the same brightness as mentioned in (ii) by rotating all of them at a lower rate? Explain your answer.

(a) By moving the circuit across a magnetic field along a direction which is not parallel to the field.....01

(b) By changing the magnetic flux through the circuit with time.....01

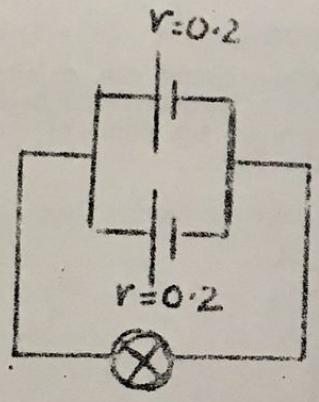
(i) Induced e. m. f. across the axle and the ring = $100 \times \pi \times (14 \times 10^{-2})^2 \times 0.1$ 02

(01 mark for the expresssion ; 01 mark for the correct substitution)

= 0.616 V (0.62 V).....01

(ii) The current I which flows through the bulb when it lights with its full brightness is given by $I = \frac{1}{1} = 1$ A.....01

Since each one half of the rod can generate an e. m. f. across the axle an the ring, both halves can be treated as two identical seats of e. m. f. connected in parallel and each having an "internal resistance" of 0.2 Ω as shown in the figure.....01



∴ the effective internal resistance

= 0.1 Ω

$1 \times 0.2 = 0.2$

The potential drop across the internal resistance = $1 \times 0.1 = 0.1$ V.....01

(Award this mark even if a wrong value is used for the effective resistance)

∴ e. m. f. that should be maintained across the axle and the ring in order to achieve the required potential difference of 1 V across the bulb = 1 + 0.1 = 1.1 V.....01

(award this mark for the addition)

If n is the rate at which the rod should be rotated in order to obtain 1.1 V, then

$n = \frac{1.0}{0.616} \times 1.1$.....01

= 1.78 (OR 1.79) revolutions per sec.....01

[OR

$1.1 = n \times \pi \times (14 \times 10^{-2})^2 \times 0.1$..... 01

n = 178 (OR 179) revolutions per sec .....01]

(iii) YES,

When a large number of similar rods are fixed to the arrangement, the effective "internal" resistance appearing across the axle and the ring is reduced.....01

As a consequence the potential drop due to "internal" resistance is also reduced.

OR it is equivalent to connecting several e. m. f. 's in parallel.....01

Hence a smaller e. m. f. is sufficient to maintain the required voltage of 1 V across the bulb.....01

Thus, the same brightness of the bulb can be obtained by rotating the rods at a lower rate.....01

****