CONFIDENTIAL

G.C.E. Advanced Level Examination - August 1990

Scheme of Assessment for PHYSICS II

PART A - Structured Essay

1. You are to find the density of wax given in the form of a cube. The actual mass of the cube is not known, but found to be of the order of 50g. The following apparatuses are available for the experiment.

(1) A metre ruler (2) 50 gram weight (3) Knife edge

(a) Write down an expression for the density of a solid in terms of its volume and mass.

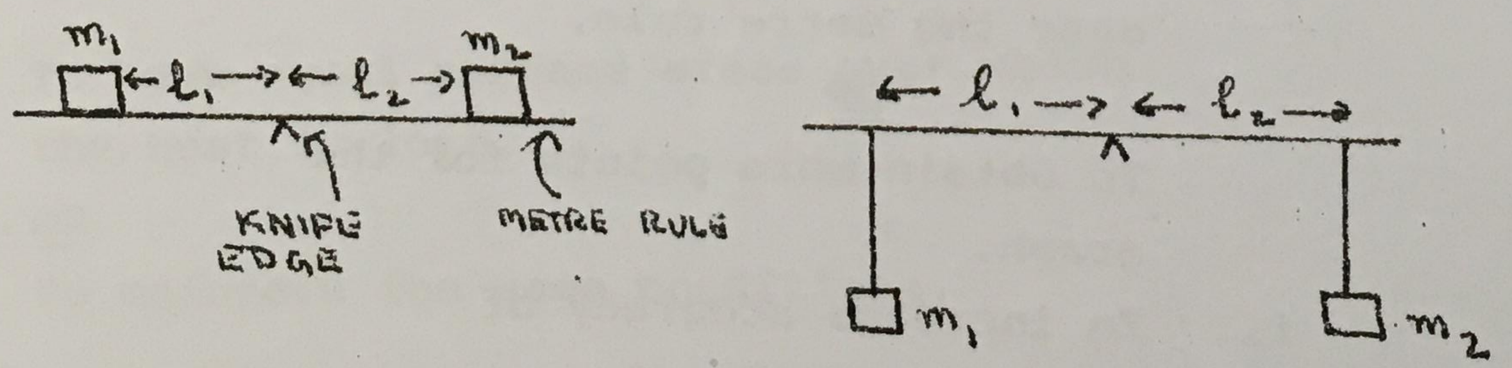
$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad (\text{OR } D = \frac{M}{V}) \qquad \ldots\ldots 01$$

(b) **Volume measurement :** How would you obtain the volume of the cube using the given apparatus?

Measure side/sides of the cube using metre rule and obtain the volume by appropriate multiplication. 01

(c) **Mass measurement :** The mass measurement is done by using the principle of moments. Draw an experimental setup that you use to find the mass of the cube without taking the mass of the metre ruler into account, and label its components.

Any one of the following diagrams 01



(Award this mark even if the knife edge is drawn away from the centre)

can draw light scale pans, with $m_1 < m_2$.
m_1 m_2, l_1, l_2 a/r.
do not give marks for a string instead of a knife edge!

The two labels knife edge and metre rule 01

(d) On the diagram for (c) label the masses and appropriate distances with symbols m_1, m_2 and l_1, l_2 respectively, and write down an expression relating these symbols.

$m_1 l_1 = m_2 l_2$ with or without g can give marks 01

(e) What precautions would you take in order to measure l_1 and l_2 as precisely as possible?

i Length measurement from knife edge to the centre of the weight and the centre of cube of wax/or to the vertical line through the centres of masses.

ii The metre rule must be perpendicular to the knife edge.

(Any one) 01

(f) If you wish to obtain the mass of wax by means of a graph, describe briefly how you would obtain sufficient data.

Vary l_1 (or l_2) and obtain the corresponding values for l_2 (or l_1) 02

(g) State two reasons as to why it is suitable to select a piece of wax whose mass is approximately equal to that of 50 gram weight as chosen in this experiment.

i. To obtain a proper spread of values for l_1 and l_2 over the metre rule,

OR

To obtain more points for the graph.

ii. To increase accuracy of length measurement 01

OR

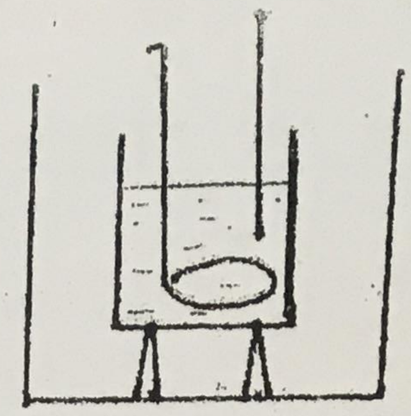
To obtain large values for l_1 and l_2.

Total 01

..... 10

==

2. Figure shows an experimental arrangement used in the laboratory to determine the specific heat capacity of a liquid using the method of cooling. The liquid is in a small calorimeter which is kept on insulating supports inside a larger can.



(a) Write down three factors which determine the rate of the total heat loss of the liquid and the calorimeter.

(i) (Surface) area
(ii) Nature of the surface (Colour or emissivity)
(iii) Excess temperature (temp. difference)

} (All three) 02

(Any two - ~~01~~ 02) any one-01

(b) State Newton's law of cooling and the conditions under which it is valid.

Newton's law of cooling:

The rate of loss of heat is proportional to the excess temperature over the surroundings. 02

do not give marks for 'rate of cooling'.

Conditions:

(i) (true for all excess temperatures) under forced convection. ~~temp of the surrounding is const~~.
(ii) in still air only ~~for~~ upto excess temperature of about 30^0c. (OR for small temperature differences)

} Any one 01

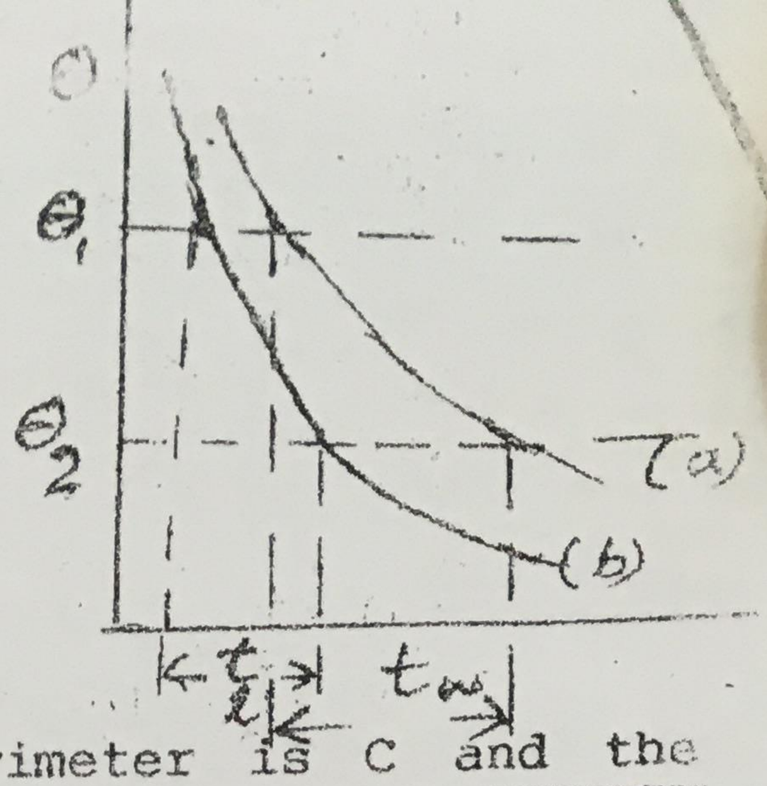
(c) Usually in this experiment equal volumes of the liquid and water are used. Explain briefly why equal volumes are used.

To have equal surface areas over which the heat is lost.

OR

To maintain the same conditions. 01

Figure shows the two cooling curves obtained for water (curve a) and the liquid (curve b) separately in this experiment.



(d) The heat capacity of the calorimeter is C and the specific heat capacity of the liquid and water are S_l and S_w respectively. The masses of the liquid and water used are m_l and m_w respectively.

(i) What is the average rate of heat loss of the liquid and the calorimeter during the cooling from θ_1 to θ_2?

$$(C + m_\ell S_\ell)\frac{(\theta_1 - \theta_2)}{t_\ell} \quad \ldots\ldots 01$$

(ii) What is the average rate of heat loss of water and the calorimeter during the cooling from θ_1 to θ_2?

$$(C + m_w S_w)\frac{(\theta_1 - \theta_2)}{t_w} \quad \ldots\ldots 01$$

(iii) Write down a relationship relating the expressions in (i) and (ii).

$$(C + m_\ell S_\ell)\frac{(\theta_1 - \theta_2)}{t_1} = (C + m_w S_w)\frac{(\theta_1 - \theta_2)}{t_w} \quad \ldots\ldots 01$$

Give this mark even (i) & (ii) are wrong.

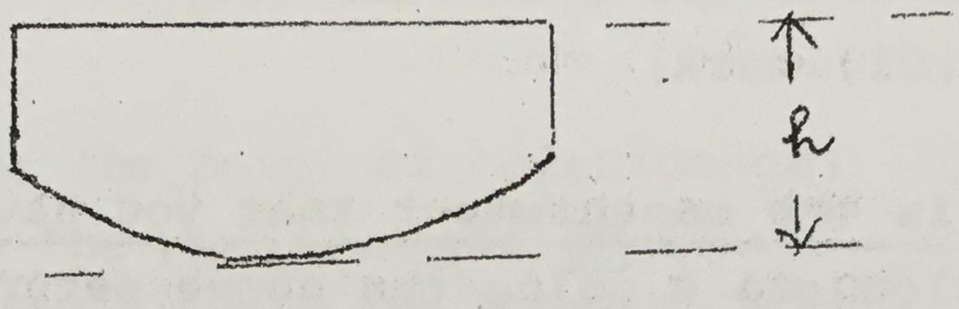
(e) Instead of the calorimeter a beaker is not suitable for this experiment. Explain why.

The temperature of the surface of the beaker is not uniform everywhere because the material is an insulator. Therefore the rate of heat loss is not uniform over the surface.
(for any correct part)

Temp of the inner surface of the beaker is not the temp of the outer surface. 01

Total 10

3. You are asked to determine the radius of curvature (R) of the curved surface of a cylindrical paper weight of glass of height h by an optical method. The vertical cross section of the paper weight is given in the diagram below.



A pin, a retort stand, a metre ruler and a trough of mercury are given to you.

(a) If the value for the refractive index of glass is given, draw and label on the diagram given above the relavant experimental setup that you would use to obtain R, given that h is an appreciable height but less than R.

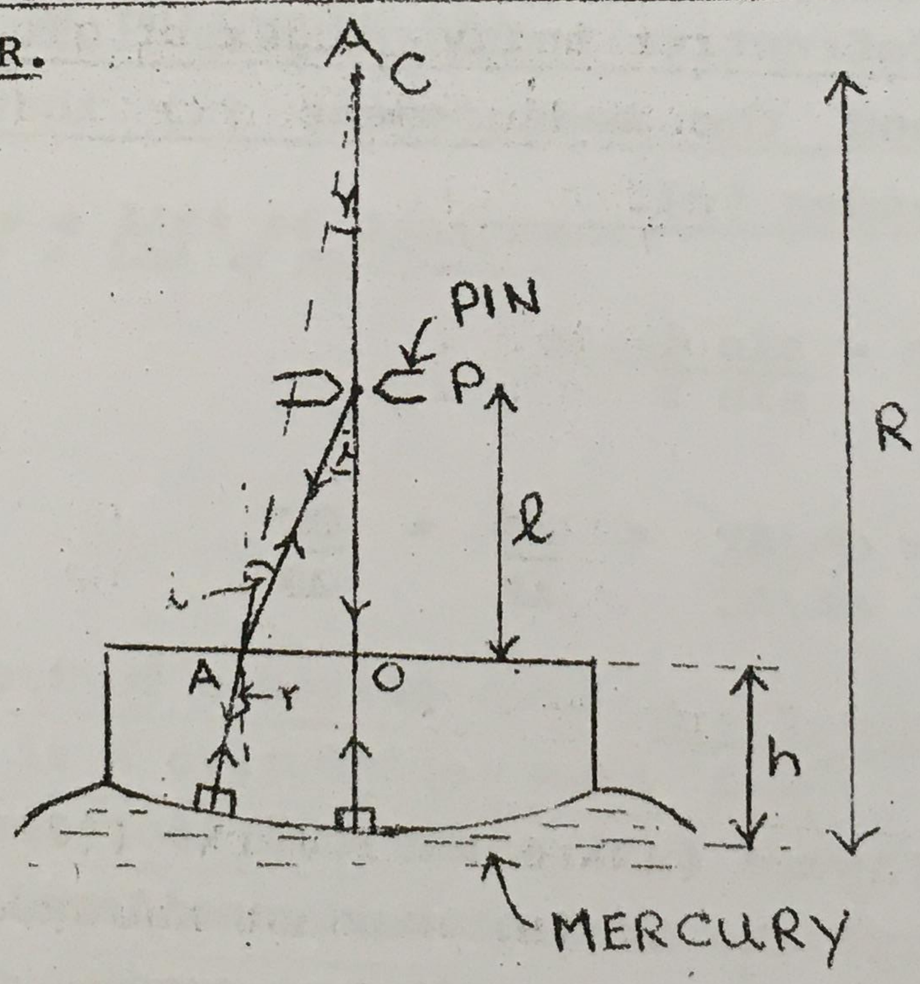


Diagram 01

(trough of mercury and pin on the axis)

Labelling 01

(labelling mercury is enough)

(b) Draw the paths of the rays of light in your diag. that would enable you to calculate R.

Any two rays indicating reversible property 02

(this can be shown using oppositely directed arrow heads OR perpendicular mark at the bottom OR drawing the image of the pin at P)

(One ray with any one of the properties above carries only one (01) mark)

(c) What is the measurement that you have to take in order to calculate R using the above setup.

The distance from the plane surface to the pin OR to the point P OR to the image OR to the point of coincidence. 01

(d) (i) Obtain an expression for R in terms of the refractive index of glass (n), the height (h) and the measurement (l) that you have taken under (c).

$$n = \frac{\sin i}{\sin r}$$

..... 01

$$= \frac{OA/AP}{OA/AC} = \frac{AC}{AP} = \frac{OC}{OP}$$

$$n = \frac{R - h}{l}$$

..... 01

(Award full marks (02) for the right expression if the student has considered refraction at the plane surface OR has used

$$\frac{1}{n} = \frac{\text{real depth}}{\text{apparent depth}}$$

(ii) What is the assumption that you have made in this derivation.

Paraxial rays OR rays are close
to the axis OR i is a small angle
OR sin i = tan i OR point
A is close to point O. 01

(e) Is it possible to obtain the measurement that you have mentioned (c) if h is greater than R? Explain your answer.

The image (or the point of coincidence)
forms inside the paper weight OR it
forms below the point O OR ℓ will take
a negative value. Therefore the
measurement cannot be taken. 01
(No mark for just writing cannot
be taken)

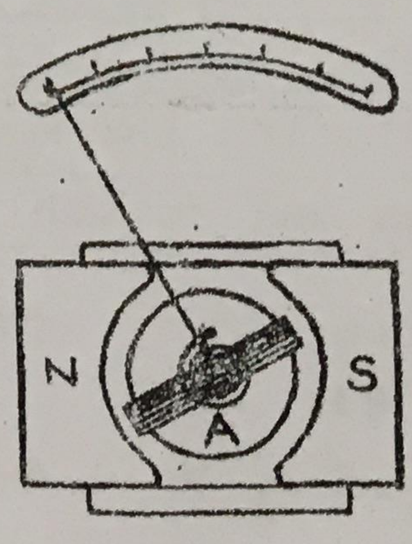
(f) Name another instrument that can be used to measure this radius of curvature (R).

Spherometer 01

(~~No mark for a list of equipment~~)
No mark for a list of equipment.

Total 10

4. Figure shows a part of a moving coil galvanometer. A is a cylindrical soft iron core, and a coil of wire is suitably wound round the cylinder to form n rectangular turns with length l and width b.



4. (a) What is the reason to have a cylindrical shape for t
iron core and the magnetic poles.

To obtain a radial magnetic field.

OR

To keep the direction of the force
due to current always perpendicular
to the plane of the coil.

OR

To achieve a linear relationship
between the current and the deflection
of the coil.

Any one of the above reasons 01

(b) The coil of wire used in the galvanometer is an insulated wire. Explain why?

Otherwise the turns will get
short circuited. 01

(c) If the magnetic flux density around the coil is B, write down an expression for the moment of the couple exerted on the coil by the magnetic field when a current I is passed through the coil.

BIbln

..... 02

(If the expression is given as BIAn
then A has to be defined;
ie. A = bl
BIAn without defining A..... 01 mark)

(d) This moment is compensated by the action of a spring whose torsional constant is C. Write down an equation relating the moment of the couple mentioned in (c) and the deflection of the galvanometer.

BIbln = $C\theta$ or.
$BIAn = C\theta$ 01
defining A is n/n.

(e) The r
galva
do

(e) The resistance across the terminals of such a galvanometer is measured and found to be 2 Ω. How does this resistance arise?

It is the resistance of the coil. 01

(f) The full scale deflection of the galvanometer mentioned in (e) is 15 mA. Is it possible to connect this galvanometer directly across a source of e.m.f. of 60 mV and internal resistance 1 Ω, and measure the current in the circuit? Explain your answer.

No.

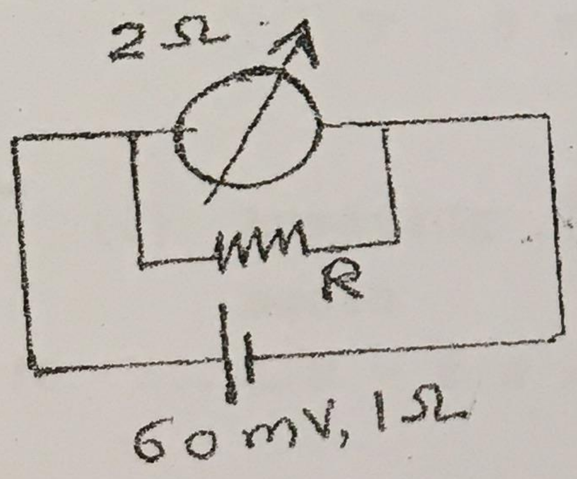
Explanation : Current in the circuit =

$$\frac{60}{3} = 20\text{mA}$$ 01

This value is larger than the full scale deflection of the galvanometer. 01

Give this mark even if the calculation is not there.

(g) If you wish to see the galvanometer reading exactly 15 mA, when it is connected as in (f) how would you achieve?



A resistance R, has to be connected in parallel (or shunt) with the galvanometer 01

OR

a suitable diagram to that effect.

Calculation of R: (~~for the final answer~~) ..... ~~01~~

When the shunt is used potential difference across the galvanometer = 15x2 = 30mV

Using E = Ir + V

Total current in the circuit = $\frac{60-30}{1}$ = 30mA

$$R = \frac{30\text{mV}}{(30-15)\text{mA}} = 2\Omega$$ 01

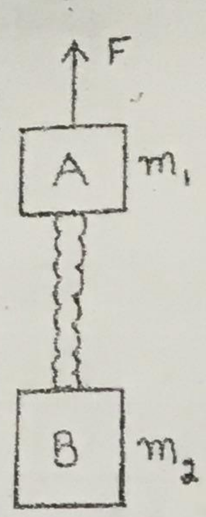
OR

(Any other correct method).

Total 10

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

(a) State Newton's laws of motion.



Two bodies A and B of masses m_1 and m_2 respectively connected to a uniform, light, inextensible rope are pulled vertically upwards by a constant force F as shown in the figure.

(i) Indicate the forces acting on A, B and the rope in **three separate diagrams.**

(ii) Calculate the acceleration of the system if $m_1 = 2$ kg, $m_2 = 8$ kg and $F = 110$ N.

(iii) Calculate the tensions in the rope at its top and bottom ends.

(iv) Repeat the parts (ii) and (iii) if the rope has a mass of 1 kg, and also determine the tension in the rope at its mid point.

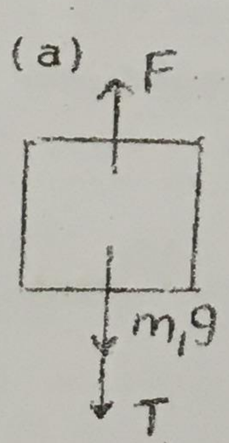
1. (a) Newton's laws

1. Every body continues in its state of rest or uniform velocity motion in a straight line unless impressed forces act on it. 01

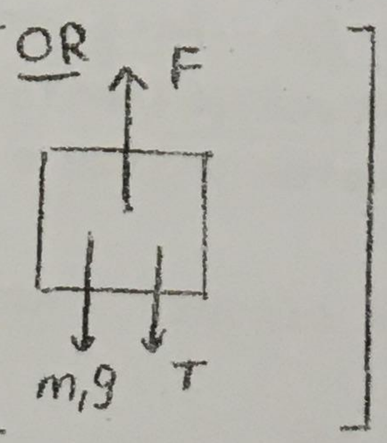
2. The change of momentum per unit time (or rate of change of momentum) is proportional to the impressed (resultant or unbalanced) (external force) force, and takes place in the direction of the straight line along which the force acts. 01

3. Every action has an equal and opposite reaction. 01

(i) (a)



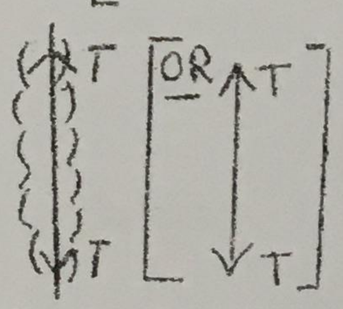
OR



separate diagrams required

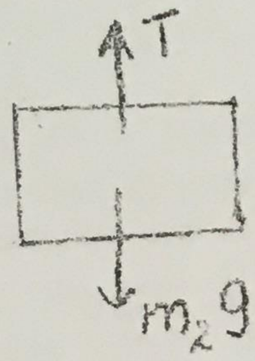
g should be there deduct marks in one place only.

..... 01



..... 01

(b) (Deduct this mark if the same symbol T as in diagram (a) is not used)



..... 01

(Deduct this mark if the same symbol T as in diagram (b) is not used)

(ii) Applying $\uparrow P = mf$ for the system

$110 - 8 \times 10 - 2 \times 10 = 10f$ 01

$f = 1 ms^{-2}$ ~~in~~ unit should be there 01

(Deduct this mark if the unit is wrong)

(iii) Applying $\uparrow P = mf$ for 2 kg

$110 - 2 \times 10 - T = 2 \times 1$

$T = 88$ N 01

(Since the rope is massless) tension along the rope is same. 01

} unit should be there at least in one place.

$\therefore$ the tension at the bottom end = 88 N

[OR Applying $\uparrow P = mf$ for 8kg

$T - 8 \times 10 = 8 \times 1$

$T = 88$ N]

(iv) Applying $\uparrow P = mf$ for the system again

$110 - 8 \times 10 - 2 \times 10 - 1 \times 10 = 11f^1$

$f^1 = 0$ 01

Let T^1, T^{11} be the tensions in the rope at its top and bottom ends,

Applying $\uparrow P = mf$ for 2 kg

$110 - 2 \times 10 - T^1 = 0$

$T^1 = 90$ N 01

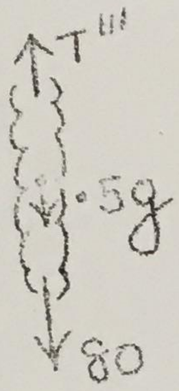
Applying $\uparrow P = mf$ for 8 kg

$T^{11} - 8 \times 10 = 0$

$T^{11} = 80$ N 01

[OR Applying $\uparrow P = mf$ for the rope

$90 - T^{11} - 1 \times 10 = 0$)]



Consider lower half of the rope.

Applying $\uparrow P = mf$

$T^{111} - 5 \times 10 - 80 = 0$ 01

$T^{111} = 85$ N 01

When calculating T^{111}

One can also consider

(i) lower half with the 8kg OR
(ii) upper half of the rope OR
(iii) upper half with the 2kg.

$= \frac{T' + T''}{2}$ 01

$= 85$ N 01

Since the rope is uniform, the tension at the mid point can be calculated by taking the average of the tensions at two ends.

Award full 02 marks for this approach.

Total 15

(b) State Hooke's law.

Show that the energy stored in a stroched wire = ½ (tension × extension).

A steel wire of length 2 m and diameter 1.6 mm is fixed at the ends to two rigid supports, 2 m apart at 30°C. If the temperature of the wire is then reduced from 30 °C to 0°C.

(i) what is the tension in the wire at 0°C if the elastic limit is not exceeded?

(ii) Calculate the mechanical energy stored in the wire, at 0°C.

(iii) Using a rough sketch of the stress versus strain curve describe briefly how the tension in the wire calculated in (i) will be affected if the elastic limit is exceeded (No calculation is necessary. Assume that the wire has not reached its breaking point.)

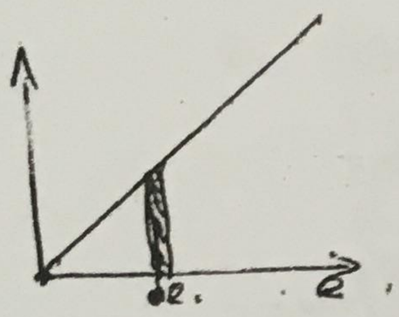
Young's modulus of steel = 2×10^{11} N m^{-2}.

Linear expansivity of steel = 1.1×10^{-5} °C^{-1}.

1. (b) Hooke's law

(proportional limit)

If the elastic limit is not exceeded, the strain (or extension) is (directly) proportional to the stress (or tension) ..... 02 or sec



Suppose the extension increases from 0 to e as the tension increases from 0 to T.

work done = T × δe — 01

Σ Tδe = Area under the curve. — 01

= ½ Te — 01

The average force in the wire during the extension = T/2 01

The work done = (T/2) x e 01

The energy stored in the wire = (1/2)T e 01

(for any other method give full 03 marks) Area under the f vs e curve is accepted.

(i) $l_{30} = 2m$, $\alpha = 1.1 \times 10^{-5}\ {}^{0}C^{-1}$,

$E = 2 \times 10^{11}$ Nm^{-2}

If the wire was not fixed, the new length of the wire at $0^{0}C = l_{30}(1 + \alpha \times 30)$ 01

T. E. A ∝ θ — 01 with definitions + 01

substitution — 01

final answer — 01

Since the wire is fixed, the extension of the wire, $e = l_{30} \times \alpha \times 30$ 01

(If this is written directly award 02 marks)

Using,

$$E = \text{stress/strain}$$

$$2 \times 10^{11} = \frac{T/\pi \times (0.8 \times 10^{-3})^2}{l_{30} \times \alpha \times 30 / l_{30}} \quad \text{..... 01}$$

Tension, $T = 2 \times 10^{11} \times 1.1 \times 10^{-5} \times 30 \times \pi \times (0.8 \times 10^{-3})^2$. 01

$= 132.8$N or 133

unit is n/n.

(ii) Energy stored in the wire

$(1/2)\times 132.8\times 2\times 1.1\times 10^{-5}\times 30$ ..... OR

$l_0 = 2$ or 1.9999 = 0.044 J 02

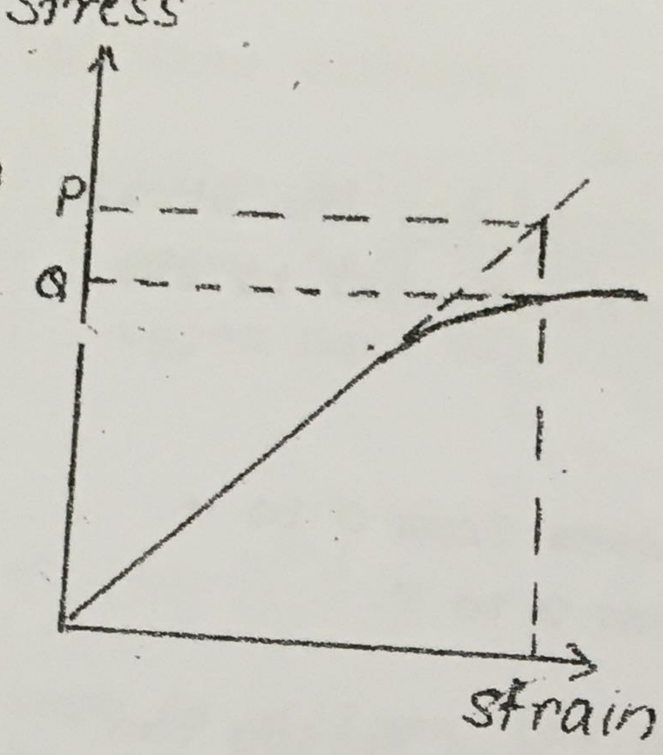
======

deduct one mark if the unit is wrong.

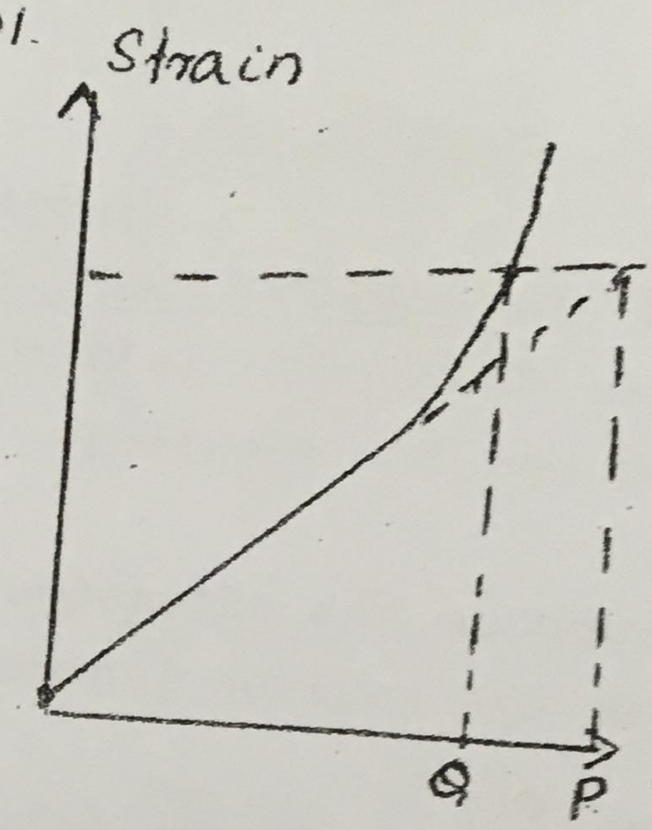
$\frac{1}{2} \times 132.8 \times l_0 \times 1.1 \times 10^{-5} \times 30$ ——— 02

0.044 J ——— 01

(iii)



OR



deduct one mark if the axes are not ~~marked~~ marked.

..... 02

As shown in the figure the calculated value of the tension (P) is <u>greater than</u> the actual value (Q).

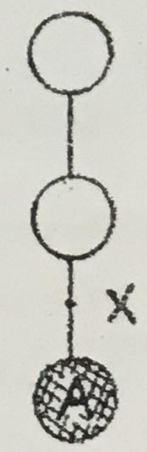
..... <u>01</u>

Total 15

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understood by 'terminal velocity' of an object falling vertically through a eneous viscous liquid ? (Derivation is not necessary)

etal sphere A of mass 0.01 kg has a radius of 0.01 m. This sphere is connected two spherical shells of same size but each having a mass of 0.004 kg, by eans of light inextensible threads as shown in the figure, and the system is dropped into a deep tank of glycerol.



(i) Calculate the terminal velocity of the system in glycerol. (Assume $\pi = 3$ in all your calculations).

(ii) If the thread is cut at the point X after the system has reached its terminal velocity, determine the magnitude and the direction of the new terminal velocity of the system containing only the two spherical shells.

Density of glycerol = 1 260 kg m^{-3}
Viscosity of glycerol = 0.6 N s m^{-2}

(Turn over.

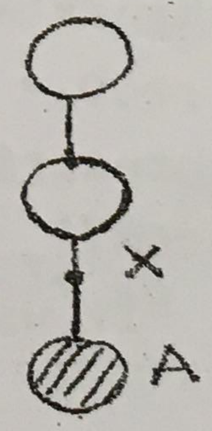
2. Terminal velocity of an object falling through a viscous medium.
When an object is falling through a viscous medium it will attain a constant velocity after travelling some distance. This is called the terminal velocity
Initially velocity of the object increases with 02 or zero.
time and as this velocity increases the viscous force, which opposes the motion of the object will also increase. 01

After some time the viscous force, upthrust and the gravitational force will balance in equilibrium. 01

Then the object will attain a constant velocity called terminal velocity. 01

(i) Volume of a sphere = $\frac{4}{3} \times 3\ (10^{-2})^3\ m^3$

$= 4 \times 10^{-6}\ m^3$



Total weight of the system = (0.01 + 0.008)kg
= 0.018 kg
= 0.018 x 10N 01

Viscous force acting on a sphere = $6\pi\eta rv$ 01
$6 \times 3 \times 10^{-2} \times 0.6\ v$ 01

Where v is the terminal velocity of the system.

Upthrust acting on a sphere = $4 \times 10^{-6} \times 1260 \times 10$.....

When the system reaches its terminal velocity

Total weight = upthrust + viscous force 01

$0.018 \times 10 = \underline{3} \times 4 \times 10^{-6} \times 1260 \times 10 + \underline{3} \times 6 \times 3 \times 10^{-2} \times 0.6\, v$ 02

Correct expression

(any $\underline{3}$ missing deduct 01 mark)

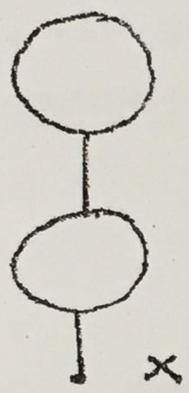
$0.18 = 0.1512 + 54 \times 6 \times 10^{-3}\, v$

$v = \frac{.0288}{54 \times 6} \times 10^{3}$ 01

$v = \frac{4}{45}\ ms^{-1} = .088\ ms^{-1}$ 01

(Do not deduct marks for wrong units)

(ii)



Let V^1 be the terminal velocity of the new system.

Total weight of the system = 0.008×10 N

= 0.08 N

Upthrust acting on the system = $2 \times 4 \times 10^{-6} \times 1260 \times 10$

= 0.1008 N

Upthrust is greater than weight of the system.

It will move upwards 01

The new terminal velocity V^1 of the system is given by

$0.08 + 2 \times 6 \times 3 \times 10^{-2} \times 0.6 V^1 = 0.1008$ 01

(Correct Substitution)

$V^1 = \frac{0.0208}{36 \times 6} \times 10^{3}$ 01

$= \frac{13}{135}\ ms^{-1}$ 01

15

'Method of Mixtures' technique is used to determine,

(i) the specific heat capacity of metal and

(ii) the specific heat capacity of rubber.

Explain why for one of these experiments it would generally be desirable to use a sophisticated method to estimate the heat loss.

0.03 kg of ice and 0.20 kg of water at 0°C are in a container. Steam at 100°C is passed in until all the ice is just melted. How much water is now in the container ?

(Specific latent heat of steam = 2.3×10^6 J kg^{-1}
Specific latent heat of ice = 3.4×10^5 J kg^{-1}
Specific heat capacity of water = 4.2×10^3 J kg^{-1} K^{-1})

Explain why it is necessary to have a mixture of ice and water in this experiment.

Why is that in this calculation the specific heat capacity of the material of the container is not necessary ?

It was observed that the container had a thin film of mist on its outer surface during the time that steam was passed. Does this affect your calculatons ? Explain.

Rubber is a poor conductor

(a) Rubber takes a long time to give out heat
and reach the temperature of mixture.
Heat is lost to the surroundings for
a long time and it is desirable
to use a sophisticated method
to estimate this loss. 02

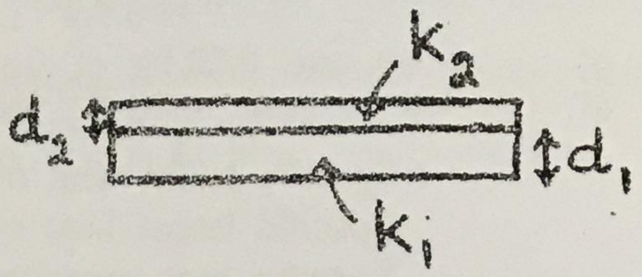
(b) Heat absorbed by ice = $.03 \times 3.4 \times 10^5$ J 02
Heat lost by steam (at 100^0C) = $m \times 2.3 \times 10^6$ J 02
Heat lost by water in cooling from
100^0 to 0^0 C = $m \times 4.2 \times 10^3 \times 100$ J 02
$(m \times 2.3 \times 10^6) + (m \times 4.2 \times 10^3 \times 100) = .03 \times 3.4 \times 10^5$ 01
$m = .00375$ kg 01
Total mass of water = $.00375 + 0.2 + 0.03$ 01
$= \underline{0.23375}$ kg 01
OR 0.234 kg

(c) To keep the mixture at 0^0C 01
To ensure proper mixing of steam 01
The temperature of container does not
change (or container does not absorb
or give heat) 02
No. The film remains throughout and
does not contribute to any heat change 01
Total 15

OR.
yes.
If a candidate assumes that the mist is formed during the experiment and argues that this process will also contribute for melting ice — 01 do not deduct marks for wrong units

4. Define thermal conductivity.

A thin slab of metal of thickness d_1 and thermal conductivity k_1 is laminated with another thin slab of different metal having thickness d_2, thermal conductivity k_2 and same area of cross section as shown in the figure. The upper and lower faces of the compound slab are kept at temperatures θ_1 and θ_2 respectively $(\theta_2 > \theta_1)$ so that it is in steady state. Show that the rate of flow of heat through the slab per unit area (R) can be written as

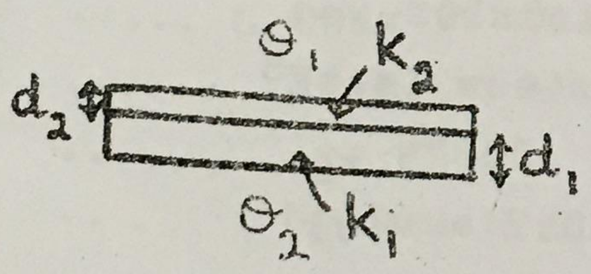


$$R = \frac{\theta_2 - \theta_1}{\frac{d_1}{k_1} + \frac{d_2}{k_2}}$$

The lower face of the bottom of a cylindrical stainless steel kettle is laminated with a thin slab of aluminium having same area of cross-section as the stainless steel bottom. The thicknesses of stainless steel and aluminium are 0.5 mm and 2 mm respectively. If the temperatures of the upper and the lower faces of the compound bottom are 100°C and 150°C respectively estimate the mass of water that boils off the kettle per unit area of the water surface per second. State all the assumptions that you have made in the calculation.

Thermal conductivity of stainless steel = 50 $Jm^{-1}s^{-1}K^{-1}$
Thermal conductivity of aluminium = 205 $Jm^{-1}s^{-1}K^{-1}$
Specific latent heat of steam = 2.3×10^6 $J\ kg^{-1}$

4. When heat flows in the steady state through a substance at (right angles) to its faces, (Ragged sideways) axial flow. then the heat flow per unit area, per unit temperature gredient per unit time is equal to the thermal conductivity of that substance. ..... 03 or zero.



Let θ_m be the temperature at the common surface then at steady state.

$$R = K_1\frac{(\theta_2 - \theta_m)}{d_1} \quad (1)$$ 01

$$R = K_2\frac{(\theta_m - \theta_1)}{d_2} \quad (2)$$ 01

..... 01

From (1) $\frac{Rd_1}{K_1} = \theta_2 - \theta_m$ (3) 01

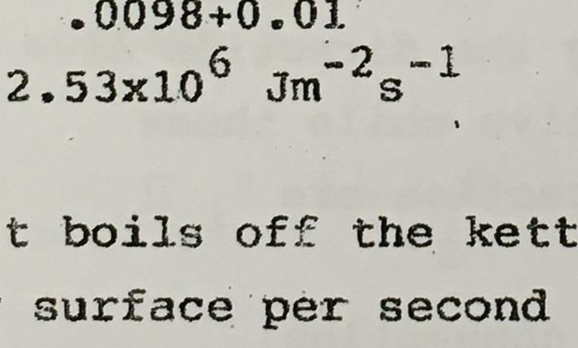
(2) $\frac{Rd_2}{K_2} = \theta_m - \theta_1$ (4)

(3) + (4) $R\left[\frac{d_1}{K_1} + \frac{d_2}{K_2}\right] = \theta_2 - \theta_1$

Simplication leading to the correct expression 02

$$R = \frac{\theta_2 - \theta_1}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$$

* [Students may write $Q = K_1 \frac{(\theta_2 - \theta_M)}{d_1}$ At and then define $R = \frac{Q}{At}$]



0.5mm = d_2

2mm = d_1

Rate of flow of heat through the bottom per unit area per unit time

$$R = \frac{(150 - 100)}{\frac{2\times10^{-3}}{205} + \frac{0.5\times10^{-3}}{50}}$$

(If milimeters are..... 02 not converted into meters deduct 01 mark)

$$R = \frac{50\times 10^3}{.0098+0.01}$$

$$R = 2.53\times10^6 \ Jm^{-2}s^{-1}$$

Water that boils off the kettle per unit area of the water surface per second = $\frac{2.53\times10^6}{2.3 \times 10^6}$ $kgm^{-2}s^{-1}$ 02

(Award this 02 marks even if the value of R is wrong)

= 1.1 $kgm^{-2}s^{-1}$ (or kg) 01

Assumptions:

(1) There is no loss of heat from the sides of the kettle. (OR Heat that flows through the bottom is totaly absorbed by water) 01

(2) The boiling point of water is 100^0C 01

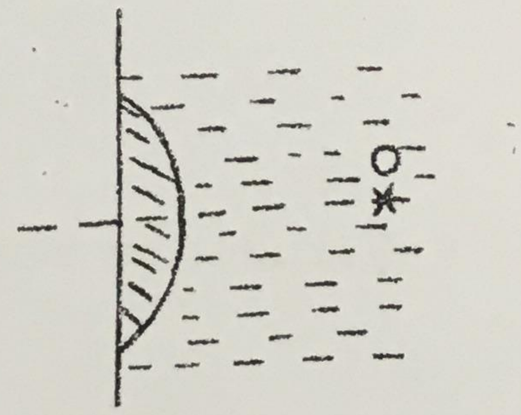
15

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

(a) An object is placed in a medium of refractive index n_1 at a distance u from a spherical surface of radius of curvature R separating a medium of refractive index n_2. Write down an expression relating the image distance v, u, n_1, n_2 and R. (Derivation is not necessary). State clearly the sign convention you used.

Use the above relationship to derive an expression for the focal length of a thin convex lens in air in terms of the radii of curvature and the refractive index of the lens material.

A thin plano-convex lens of focal length 10 cm in air is fixed onto the wall of a large water tank made of thin glass as shown in the figure. An object O is placed inside the water at a distance 10 cm from the lens.



(i) What is the radius of curvature of the curved surface of the lens ?

(ii) Determine the position of the image of the object O formed by the lens.

Refractive index of the lens material = $\frac{3}{2}$

Refractive index of water = $\frac{4}{3}$

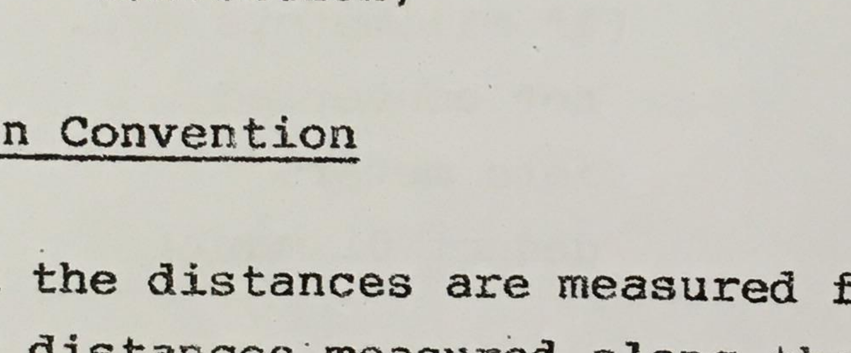
5. (a) $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ ..... 02 or zero

(or any other expression with correct sign convention)

Sign Convention

All the distances are measured from the pole. The distances measured along the direction of the incident light are negative while those measured in the opposite direction are positive.

(no marks only for the sign convention) 01



..... 01

for the first surface,

$$\frac{n}{-f'} \quad \frac{-1}{\infty} = \frac{(n-1)}{-r_1} \qquad (1)$$

..... 01

for the second surface,

$$\frac{1}{-f} - \frac{n}{-f^1} = \frac{(1-n)}{r_2} \qquad (2) \qquad \ldots\ldots 01$$

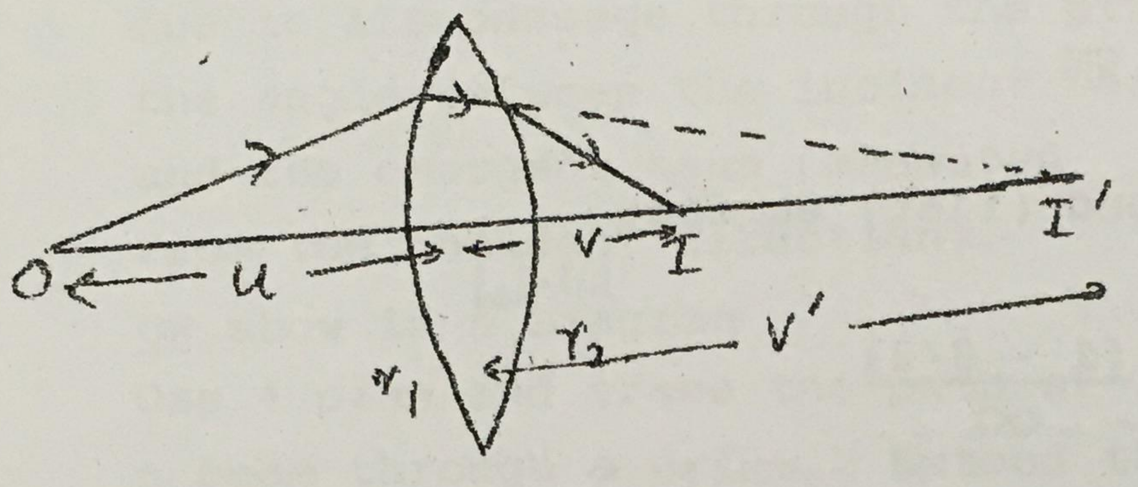
$$(1) + (2) \quad = \quad 1/f = (n-1)(1/r_1 + 1/r_2)$$

By applying the sign convention

$$1/f = (n-1)(1/r_1 - 1/r_2) \qquad \ldots\ldots 01$$

One mark for just writing the expⁿ.

OR



.... 01

first surface.

$$\frac{n}{-v^1} - \frac{1}{u} = \frac{(n-1)}{-r_1} \qquad (1) \qquad \ldots\ldots 01$$

second surface,

$$\frac{1}{-v} - \frac{n}{-v^1} = \frac{(1-n)}{r_2} \qquad (2) \qquad \ldots\ldots 01$$

$$(1) + (2) = \frac{1}{v} + \frac{1}{u} = (n-1)(1/r_1 + 1/r_2)$$

$u = \infty$, $v = f$

$$1/f = (n-1)(1/r_1 + 1/r_2)$$

By applying the sign convention

$$1/f = (n-1)(1/r_1 - 1/r_2) \qquad \text{If only the final equation is given give 01 mark.} \quad \ldots\ldots 01$$

(Award full marks for the correct derivation without introducing the sign convention)

(i) $f = -10\text{cm}$, $n = 3/2$

$$-\frac{1}{10} = \left(\frac{3}{2} - 1\right)\left(\frac{1}{\infty} - \frac{1}{r}\right) \quad \ldots\ldots$$

$\ldots\ldots$ 01

$r = 5$ cm

(ii) for the first surface,

$$\frac{3/2}{v} - \frac{4/3}{10} = \frac{(3/2 - 4/3)}{-5} \quad \ldots\ldots 02$$

$v = 15$ cm $\ldots\ldots$ 01

for the second (flat) surface

$$\frac{1}{v} - \frac{3/2}{15} = \frac{(1 - 3/2)}{\infty} \quad \ldots\ldots 01$$

(OR using $n = \dfrac{\text{real depth}}{\text{apparent depth}}$)

$v = 10$ cm $\ldots\ldots$ 01

15

Let f be the focal length of the lens in water.

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$= (\omega\mu_g - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$

$= \left(\frac{3/2}{4/3} - 1\right)\left(\frac{1}{\infty} - \frac{1}{5}\right)$ ……01

considering the flat surface of the lens

$= \left(\frac{9}{8} - 1\right)\left(-\frac{1}{5}\right) = -\frac{1}{40}$.

$\therefore f = -40$ cm. ……01

considering both sides of the lens of water.

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$.

$\frac{1}{v} - \frac{1}{10} = -\frac{1}{40}$ ……01

$\frac{1}{v} = \frac{1}{10} - \frac{1}{40}$

$= \frac{4-1}{40} = \frac{3}{40}$

$v = \frac{40}{3}$. ……01

$\frac{\text{real depth}}{\text{apparent depth}} = \frac{4}{3}$ ……01

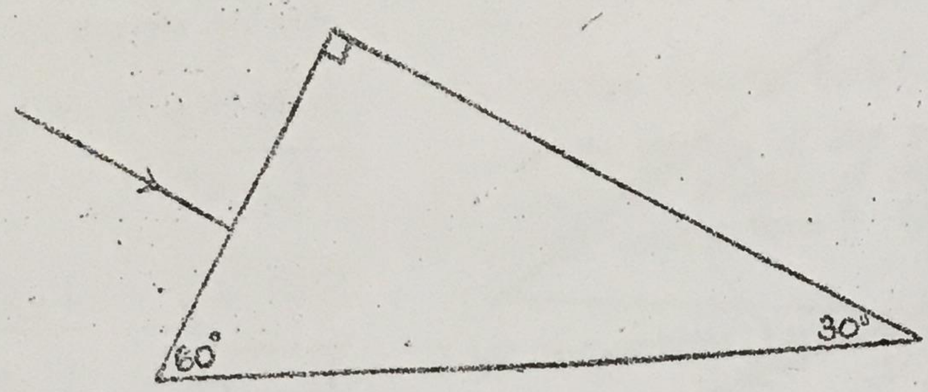
$\frac{40/3}{x} = \frac{4}{3}$.

$4x = \frac{40}{3} \times 3$

$x = 10$ cm. —01

5) What is understood by the angle of deviation of a narrow beam of light caused by a prism ? Describe briefly how you would determine this angle experimentally.

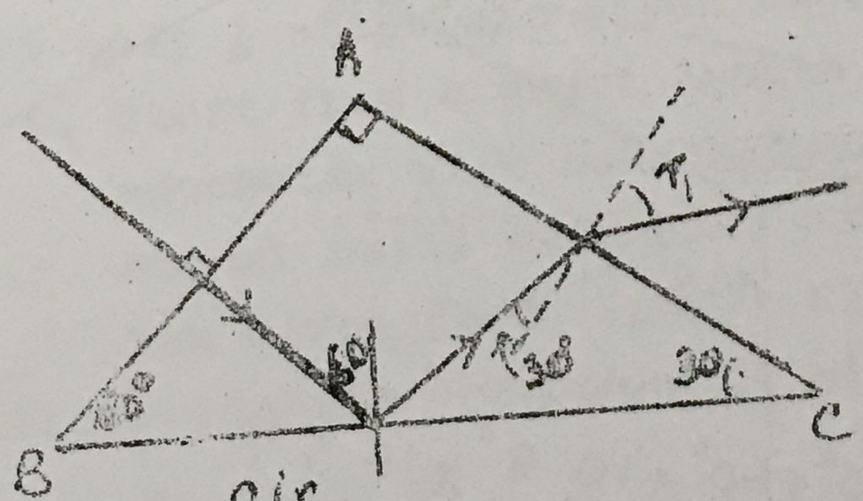
A narrow beam of light is incident normally on one face of a prism (refractive index 1.45) as shown, and finally emerges from the prism. Copy the given diagram on the answer sheet and draw the complete path of the beam.



The prism is now surrounded by water (refractive index 1.33). Draw the new path of the beam, and find the angle between the two emergent beams in the two cases.

The angle through which the beam turns due to its passage through the prism OR the angle between the incident beam and the emergent beam (measured from the incident direction). 02 01 02

OR show in a labeled Diagram
Use 4 pins and trace the path of a beam through a prism. Extend the emergent beam backwards and measure the angle of deviation. ----------01
OR use the spectrometer to locate the direct incident beam and the emergent beam after placing the prism. 01 02
(Mere mentioning carries only 1 mark)
(Spectrometer adjustments carry no marks)

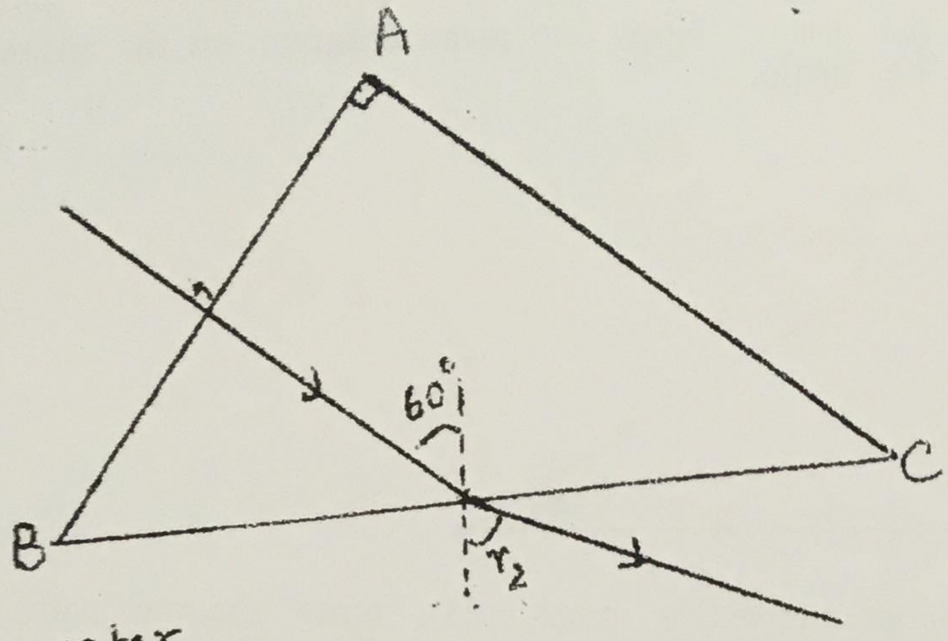


Path showing no deviation at AB 01
Total internal reflection at BC 01
Deviation away from normal at AC 01

Angle of incidence at AC is 30^0 01

$\frac{\text{Sin } r_1}{\text{Sin } 30} = 1.45$ (OR 1.5) 01

$r_1 = 46.5^0$ OR $46^0 30'$ or 48.6° } 01



Path showing
deviation away
from normal at BC 0

$\frac{\text{Sin } r_2}{\text{Sin } 60} = {}^{w}n_g$ 01

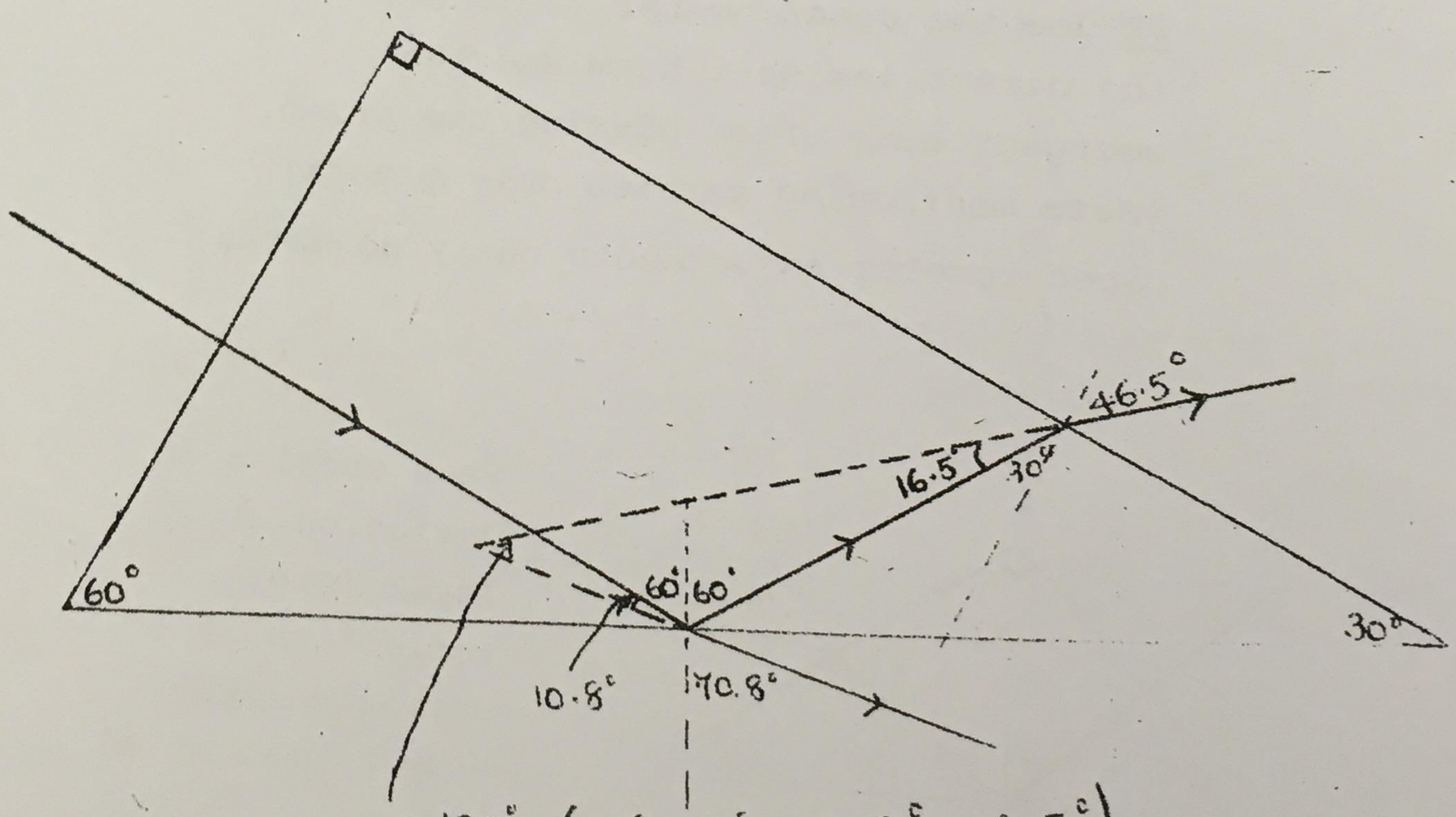
$\frac{\text{Sin } r_2}{\text{Sin } 60} = \frac{1.45}{1.33}$ or $\frac{1.5}{1.33}$ 01

$r_2 = 70.8^0$
OR $70^0 48'$, ... 01

Angle between two emergent rays =
$(90^0-46.5^0)-(70.8^0-60^0)$ $[(180^0-120^0)-(46.5^0-30^0)$
$= 32.7^0$ OR $32^0\ 42'$ $-(70.8^0-60^0)]$ 01
$\pm 6'$ .....

(OR Any other geometrical calculation
using a diagram).

$\underline{33.8^0}$ if $n = 1.5$ Total 15



$= 180^0 - (60^0+60^0+10.8^0+16.5^0)$

$= 180^0 - 147.3^0 = 32.7^0$

Final answer can be obtained by using 1.5 instead of 1.45

the conditions under which the superposition of progressive waves can give rise to (*a*) beats (*b*) stationary waves. Explain briefly how each may be used with a sonometer wire in the determination of the frequency of a tuning fork.

(A) A tuning fork vibrates at a frequency of 440 Hz. A second tuning fork when sounded closer to the first, a beat frequency of 2 Hz is produced.

(i) What are the possible frequencies of the second tuning fork?

(ii) When a small piece of wax is fixed to one of the prongs of the second tuning fork and both forks are sounded, the beat frequency decreases. Which of the frequencies in (i) was the actual frequency of vibration of the second tuning fork ? Explain how you arrived at your answer.

(B) Calculate the lengths of open and closed pipes respectively for a fundamental frequency of 550 Hz (speed of sound = 340 m s^{-1})

Beats are produced by the superposition of two progressive waves of frequancies very close to each other. 02

A stationary wave is produced by the superposition of two identical waves OR two waves of same frequency, wavelength/speed and (amplitude) travelling in opposite directions. 02

(a) Experiments:

i. Start from a short length of Sonometer wire and gradually increase.

ii. Sound together with the given turning fork.

iii. Beats appear when frequencies are nearly equal and disappear when they are equal.

iv. Calculate frequency for the wire measuring T, ℓ and m. 02

(If only 3 steps are given award 1 mark)

(b) i. Start from a short length of sonometer wire and gradually increase.

ii. Adjust until resonance occurs with the given fork. (paper rider method) 01

iii. Calculate frequency of wire measuring 01

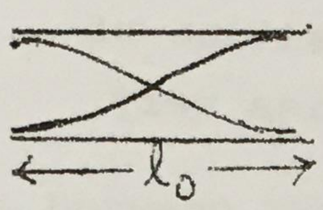
T, l and m.

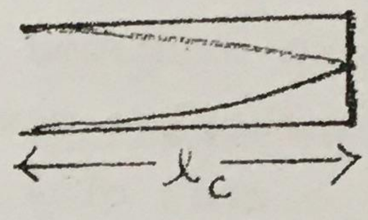
A. i. The possibilities are 442 Hz. 0
438 Hz 01

ii. Wax decreases the frequency 01

iii. Since the beat frequency decreases the actual frequency should be equal to 442 Hz. 01

B.





i. $340 = 550 \times \lambda_o$ and $\frac{\lambda_o}{2} = l_0$ 01

$340 = 550 \times 2 \times l_0$

or, $l_0 = 30.9\text{cm}$ 01

ii. $\frac{\lambda_e}{4} = l_c$ 01

$340 = 550 \times 4 \times l_c$

or, $l_c = 15.5$ cm 01

Total 15

"The potentiometer acts as an infinite-resistance voltmeter". Explain this statement using an example.

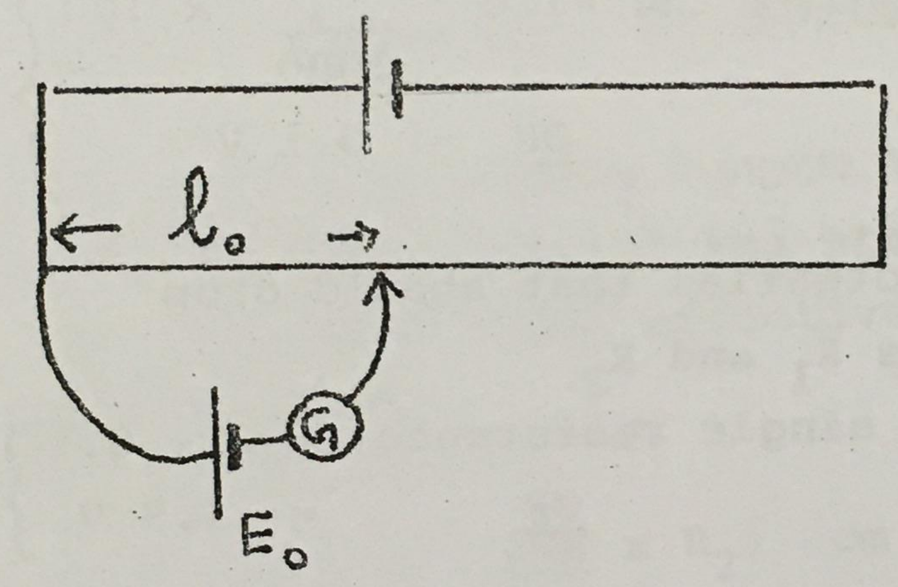
In potentiometer experiments how would you check that you have maintained a constant potential gradient along the wire throughout the experiment ?

A slide wire potentiometer consisting of 2 V accumulator and a 1 m long wire of resistance 2Ω is to be used to measure the e.m.f. and the resistance of a thermocouple when one of its junctions is maintained at 100°C and the other junction at 0°C.

(i) How would you modify and calibrate the above potentiometer to have a potential gradient of approximately 1 mV / cm along the wire ?

(ii) Describe briefly how you would use the modified potentiometer to measure the e.m.f. and the resistance of the thermocouple.

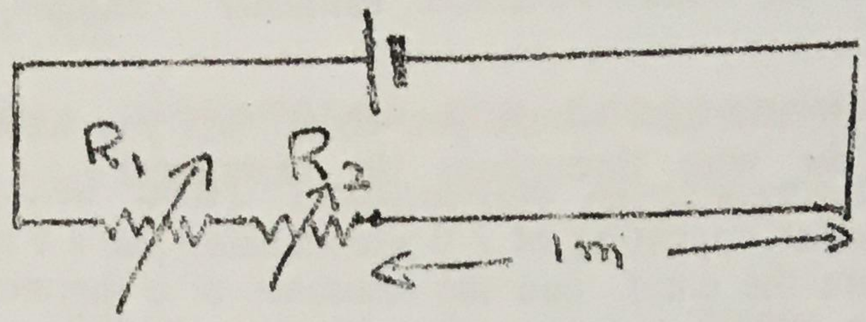
7. (a) a_1 As an example consider the measurement of an e.m.f. (E_0) of a cell using a potentiometer.



When E_0 is measured using a potentiometer the <u>current through the cell is zero.</u> If a voltmeter with infinite internal resistances is connected across the cell to measure E_0 again the <u>current through cell is zero.</u> Both situations are therefore identical. 01

a_2 This is done by comparing the potential drops per unit length of the wire before and after the experiment. 01

(i) Modification:



Instead of R_1 & R_2 one resistance can be used.

diagram 01

(Award this mark even if a single resistance is used instead of two resistances R_1 and R_2)

The total potential drop that has to be maintained across the wire = $\frac{1}{1000} \times 100$

OR = 0.1 V } 01

The potential that should drop across R_1 and R_2 (or a single resistance) = 2 - 0.1

OR = 1.9 V } 01

Current through the wire = $\frac{0.1}{2}$

OR = $\frac{1}{20}$ A } 01

$R_1 + R_2$ (or the value of a single resistance) = $\frac{1.9}{\frac{1}{20}} = 38\Omega$ 01

Calibration:

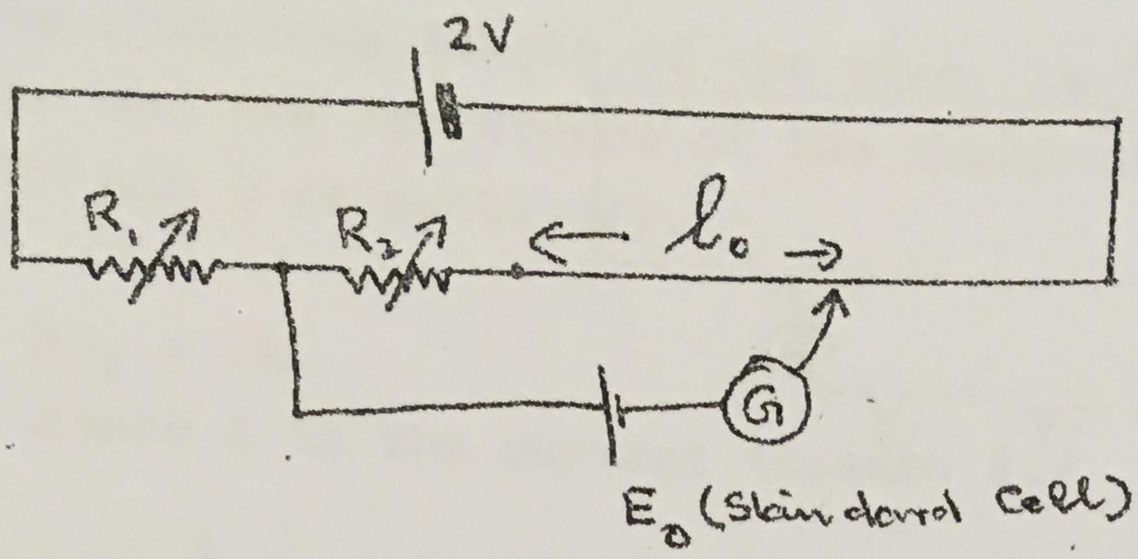


diagram 01

(Award this mark only if the positive terminal of the standard cell is connected to the junction between two resistors $R_1 + R_2$)

Balancing length is obtained by changing R_2 while keeping $R_1 + R_2$ constant 01

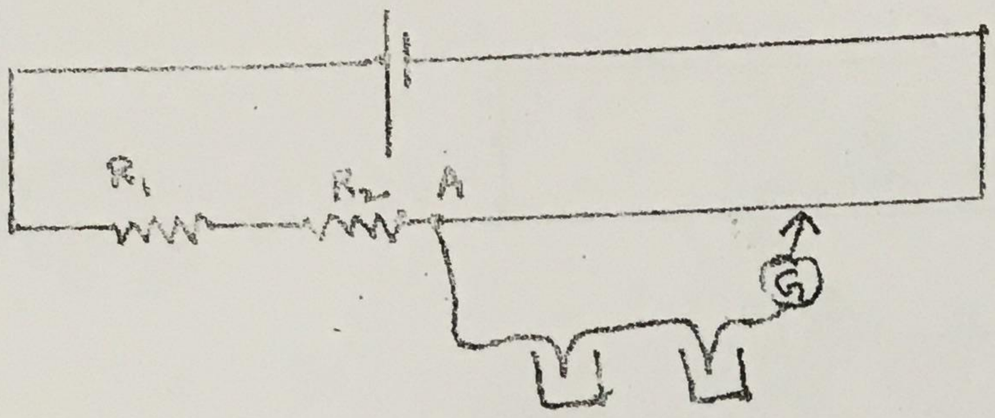
If l_0 is the balancing length of the wire and E_0 is the e.m.f. of the standard cell then the (total) effective balancing length will be

$$(l_0 + \frac{100}{2} \times R_2) \text{ cm} \quad \ldots\ldots 01$$

If k is the potential gradient down the wire then $k(l_0 + \frac{100}{2} \times R_2) = E_0$ 01

Hence k

(ii) e.m.f. of thermocouple.



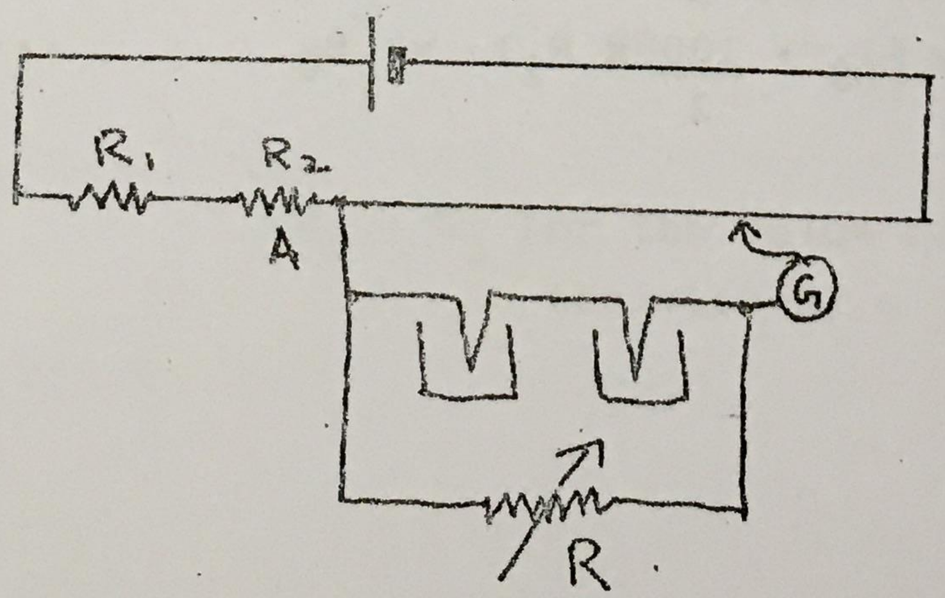
Note: Circuit diagram 01

(1) Award this mark even if a single resistor is used instead of R_1 and R_2.

(2) One end of the thermocouple should be connected to the point A of the wire.

If l_1 is the balancing length then the e.m.f. of the thermocouple is equal to kl_1 01

Resistance of the thermocouple:



Circuit diagram 01

(R should be connected in parallel with the thermocouple; and also follow the instructions given under the Note above to award this mark)

If the balancing length of the wire, is l_2 and e.m.f. and the resistance of the thermocouple are E' and r respectively.

$$kl_2 = IR$$

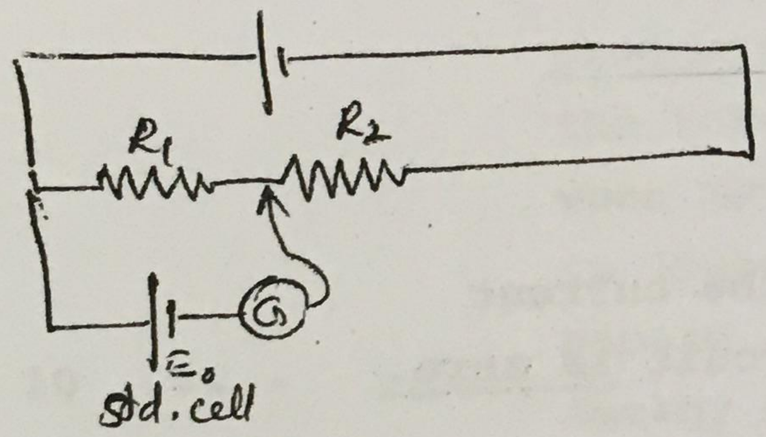
Where I is the current through R

$$I = \frac{E'}{r+R}$$

$$kl_2 = \frac{E'R}{r+R} \qquad \ldots\ldots 01$$

r can be determined from the above expression.

15



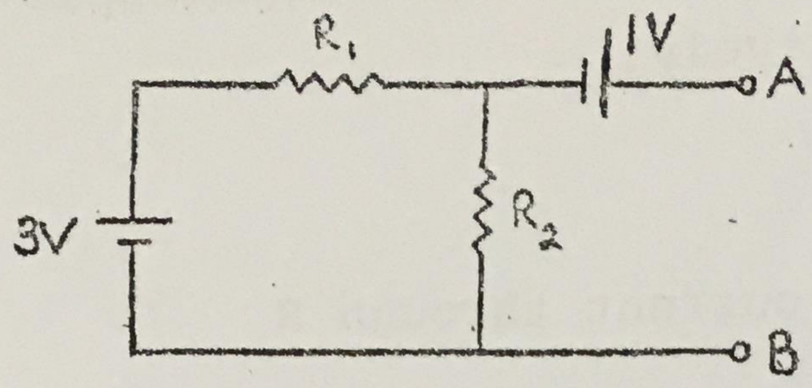
effective balancing length

$$= \frac{100}{2} \times R_1^{\#}$$

$$k\left(\frac{100}{2} \times R_1^{\#}\right) = E_0 \qquad \text{---------} \; 01$$

7 (b) State Kirchhoff's laws.

"Kirchhoff's first law is a statement of conservation of charge whereas the second law is a statement of conservation of energy". Explain this statement.



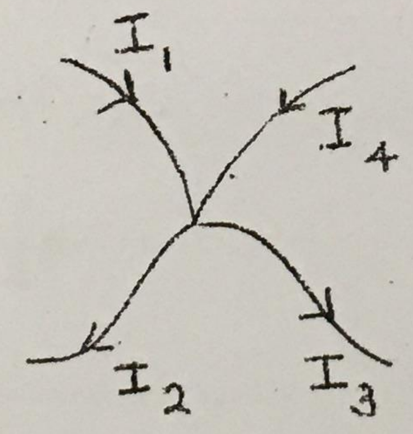
In the circuit shown both cells have negligible internal resistance. A voltmeter with infinite internal resistance when connected across AB indicates 3V, whereas an ammeter with negligible internal resistance when connected across AB reads 2.25 A. Deterimine R_1 and R_2.

(Turn over)

7. (b) Kirchhoff's laws

(1) The algebraic sum of the current at a junction of a circuit is zero. 01

OR



$I_1+I_4-I_2-I_3 = 0$

(2) In any closed circuit the algebraic sum of the IR products (potential drops) is equal to the algebraic sum of the electro-motive forces in the circuit. 01

$\Sigma E = \Sigma IR$ with the illustration of a circuit give one mark.

Explanations:

(i) Law 1:

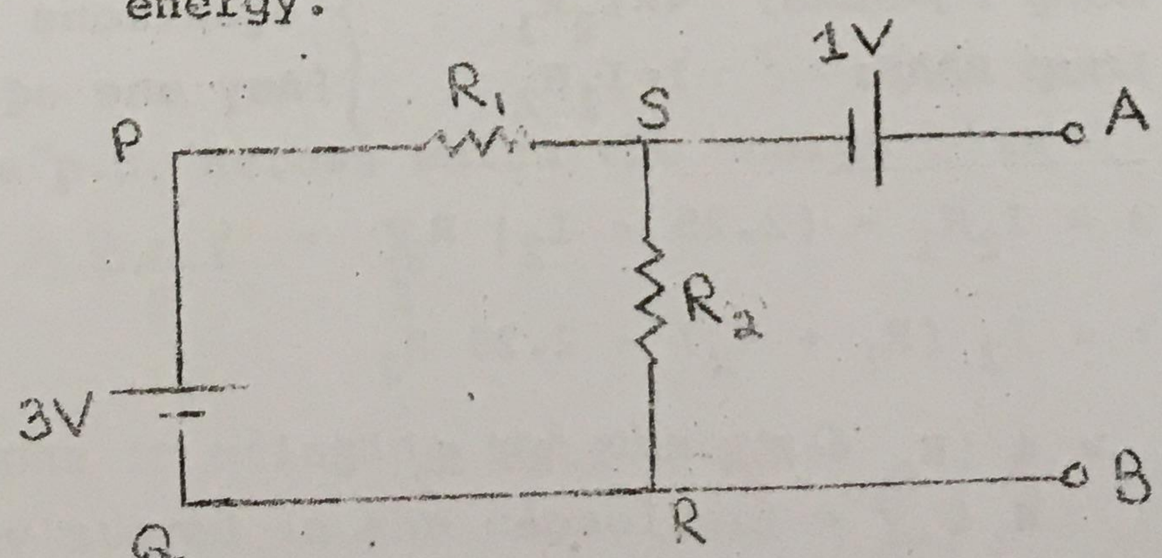
Current is the rate of flow of charge.

According to the first law the amount of charge flowing into a junction per unit time is equal to the amount leaving the junction during the same time.

(No generation or destruction of charges at a junction : ie. charge is conserved) 01

Law 2:

According the energy considerations the e.m.f. of a cell is equal to amount of energy supplied to a unit charge by the cell (through chemical reactions), whereas IR products (potential drops) represent the total work done by a unit charge when moving from higher potentials to lower potentials. Therefore the second law merely implies that the energy supplied to a unit charge is equal to the energy dissipated by the same charge. ie. it is a statement of law conservation of energy. 01



(Voltmeter reading indicates that) the voltage across R_2 is 3 - 1 = 2 V 01

Consider the closed circuit PQRS

As the current through 1V cell is zero, the entire voltage of the 3V cell is droped across R_1 and R_2 .....

$$\frac{R_1}{R_2} = \frac{1}{2} \quad \text{..... 02}$$

Alternative Method:

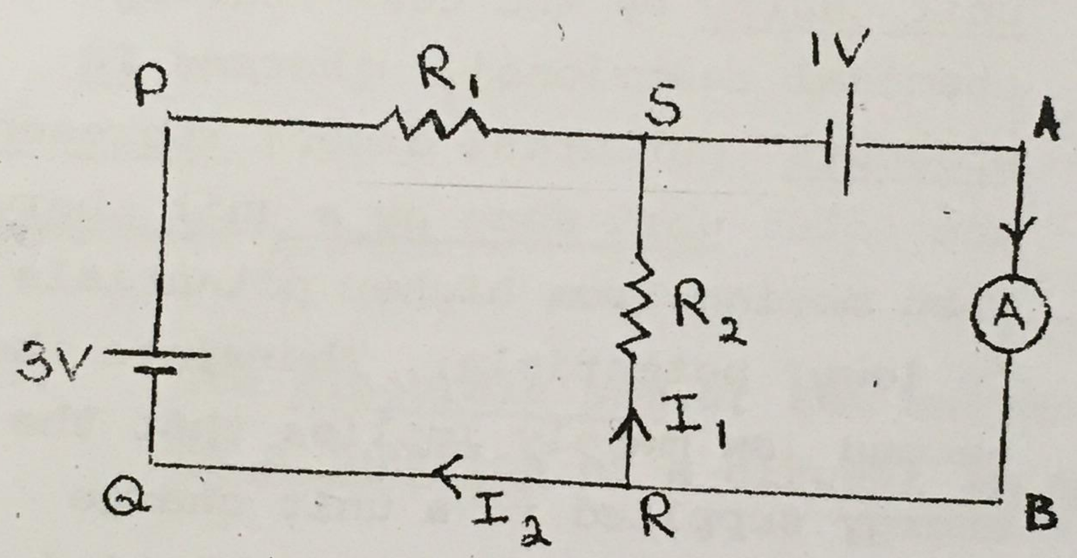
Current through 1V cell is Zero. 01

It I is the current in the circuit PQRS

then $3 = I(R_1 + R_2)$ 01

also $2 = IR_2$ 01

Using above equations, $\frac{R_1}{R_2} = \frac{1}{2}$ 01



$I_1 + I_2 = 2.25$ 01

Loop PQRS; $3 = I_2R_1 - I_1R_2$
Loop PQRSBAS; $4 = I_2R_1$
Loop RBAS; $1 = I_1R_2$

} Any two equations 03
(Any one equation - 02)

$3 = I_2R_1 - (2.25 - I_2) R_2$

$= I_2 (R_1 + R_2) - 2.25 R_2$

$= \frac{4}{R_1} (R_1 + R_2) - 2.25 R_2$

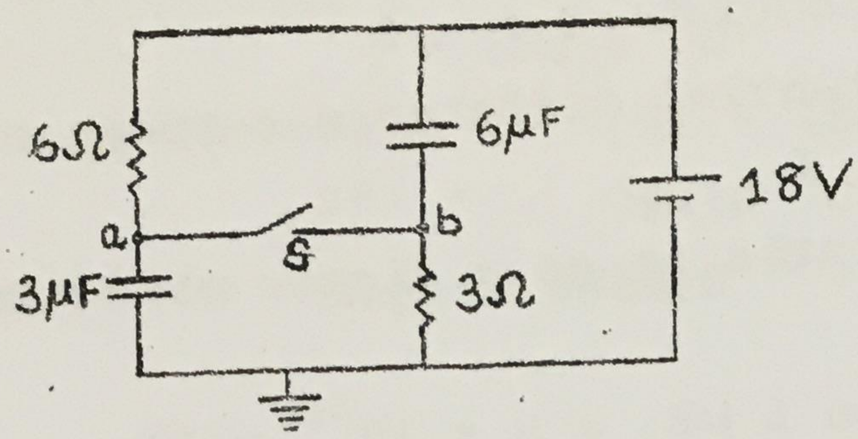
$= 4 (1 + 2) - 2.25 R_2$

$R_2 = \frac{9}{2.25} = 4\Omega$ 02

$R_1 = 2\Omega$ 01

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Show that the electrical energy stored in a capacitor of capacitance C is given by $\frac{1}{2}\frac{Q^2}{C}$ where Q is the amount of charge on the capacitor.



In the circuit shown the battery has negligible internal resistance.

(i) What is the potential difference between points a and b when the switch S is open ? Which one of the points, a and b, is at the higher potential ?

(ii) Find the charge and the energy stored in each of the capacitors when S is open.

(iii) What is the final potential of the point b when switch S is closed ?

(iv) By how much does the charge and the stored energy in each capacitor change when S is closed ?

(v) After charging the capacitors with the switch S open. the circuit is isolated from the battery and the switch S is closed. What will be the final charge on each capacitor ?

8. Initial potential difference across the plates of the capacitor = 0

Final p.d. across the plates after it is charged = V

Average p.d. across which the charge Q is stored = $\frac{0 + V}{2} = \frac{V}{2}$ 01

Work done in bringing the charge Q
(Energy stored in the capacitor) = $\frac{V}{2} Q$ 01

But Q = CV
$\therefore$ energy stored = $\frac{1}{2}\frac{Q^2}{C}$ 01

(Graphical method OR method of integration - 03)

(i) After capacitors are charged, there is no current through the resistors.

potential at a = 18V

potential at b = 0

potential difference between a and b = 18V 01

point a is at a higher potential 01

(ii) Charge on 6 μF $= 6 \times 10^{-6} \times 18$

$= 108 \times 10^{-6}$ C (108 μC) 01

Charge on 3 μF $= 3 \times 10^{-6} \times 18$

$= 54 \times 10^{-6}$ C(54 μC) 01

Energy stored in 6 μF $= \frac{1(108\times10^{-6})^2}{2 \times 6\times10^{-6}}$

$= 972 \times 10^{-6}$ J (972 μJ) 01

Energy stored in 3 μF $= \frac{1}{2} \frac{(54\times10^{-6})^2}{3\times10^{-6}}$

$= 486 \times 10^{-6}$ J (486 μJ)... 01

(StudentSmay use energy stored $\frac{1}{2}$ QV or $\frac{1}{2}$ CV^2)

(iii) hen 3 is closed resistors make a potential divider

Potential at point b $= \frac{18\times3}{9} = 6V$ 01

p.d. across 6 μF = 18 - 6 = 12V

charge on 6 μF $= 6\times10^{-6}\times12$

$= 72\times10^{-6}$C(72 μC)

Change in charge $= (108 - 72)10^{-6}$

$= 36 \times 10^{-6}$C (36μC).... 01

Change in energy $= 972\times10^{-6} - \frac{1}{2} \frac{(72\times10^{-6})^2}{6\times10^{-6}}$

OR

$= 540\times10^{-6}$ J(540μJ) 01

Charge on 3 μF = $3\times10^{-6}\times6$

= 18×10^{-6}C

Change in charge = $(54 - 18)10^{-6}$

= 36×10^{-6}C ($36\mu C$) 01

Change in energy = $486\times10^{-6} - \frac{1}{2}\frac{(18\times10^{-6})^2}{3\times10^{-6}}$

OR

$= 432\times10^{-6}$J ($432\mu J$) 01

(v) Final charge on each capacitor is zero 01
(All the charge leak through resistors)

Total 15