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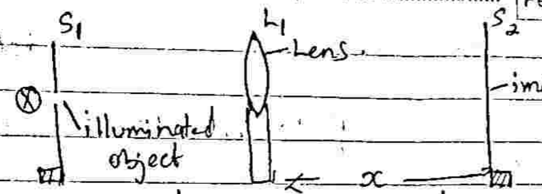
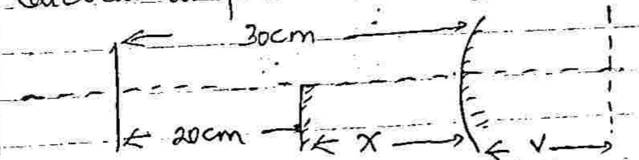
1(a)(i)



The illuminated object is placed at a distance greater than the focal length of the lens and the apparatus are set as shown above. The screen S_2 is adjusted until a sharp image is formed on it. The distance x btn L_1 and S_2 is measured. The convex mirror whose focal length is required is placed coaxially between L_1 and S_2.
The mirror is adjusted until a sharp image is formed on S_1 adjacent to the object. The distance y between L_1 and the mirror is measured. The focal length f is calculated from $f = \frac{x-y}{2}$ (04)

(ii)



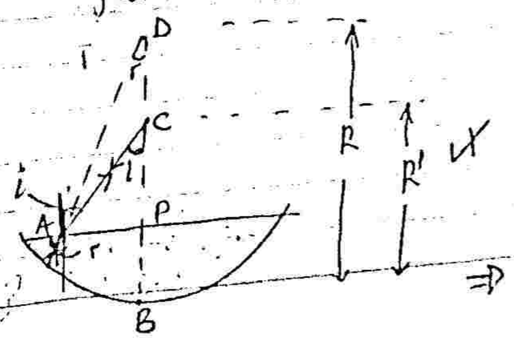
$v = 20 - x$
$= 20 - (30 - 20)$
$= 10\text{cm}$

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$\frac{1}{f} = \frac{1}{-30} + \frac{1}{-10}$

$f = -15\text{cm}$ (04)

(b)



At A, $n_L = \frac{\sin i}{\sin r}$

From diagram $\sin i = \frac{AP}{AC}$

$\sin r = \frac{AP}{AD}$

$\Rightarrow n_L = \frac{AP}{AC} / \frac{AP}{AD} = \frac{AD}{AC}$

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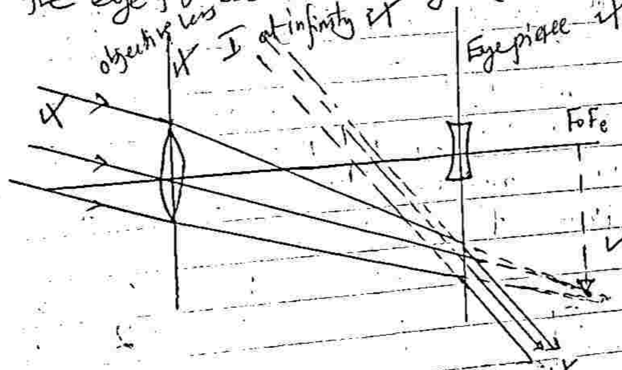
For small angles, $\sin\theta_1 \simeq \theta$ rad, $\therefore AD \simeq PD$ and $AC \simeq PC$ (04)

Also for small thin layer of Liquid $PD \simeq BD$ and $PC \simeq BC$

$\Rightarrow n_L = \frac{BD}{BC} = \frac{R}{R'}$

(c)(i) Eye ring is the (circular) image of the objective formed by the eyepiece. It is the best position for the eye to observe image (in details) (02)

(ii)



(03)

(iii) Advantages.

- It forms erect image with only two lenses
- The distance between the lenses is $f_o - f_e$ so it is short and therefore portable.

(03)

Disadvantage (inaccessible)

- It has a virtual eyering hence limited field of view.

T = 20

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2a) i Light is said to be passing through a prism symmetrically when the angle of incidence is equal to the angle of emergence. (01)
or Minimum deviation occurs.

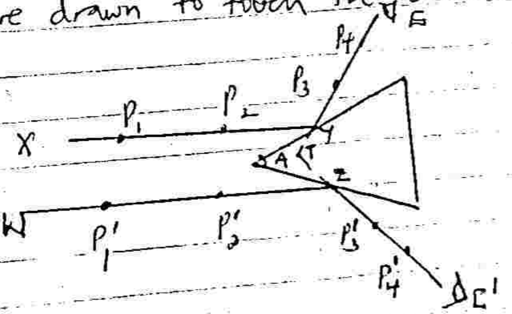
ii) for snell's law $\frac{\sin i}{\sin r} = 1.5$

But $r = \frac{A}{2}$, $\sin i = 1.5 \sin \frac{A}{2} = 1.5 \sin 30$ (03)

$i = 48.6°$

(iii) As the angle of incidence is being increased to 48.6°, the deviation decreases to a minimum and then increases as the angle of incidence is increased beyond 48.6° (02)

(b) The prism is placed on a white sheet of paper on a soft board and its outline is drawn. The prism is removed and two parallel lines XY and WZ are drawn to touch the outline as shown below



The prism is placed back on its outlines. Two pins P1 and P4 are stuck on line XY. Looking through the prism, two pins P3 and P4 are placed such that they appear to be in line with images of P1 and P2.

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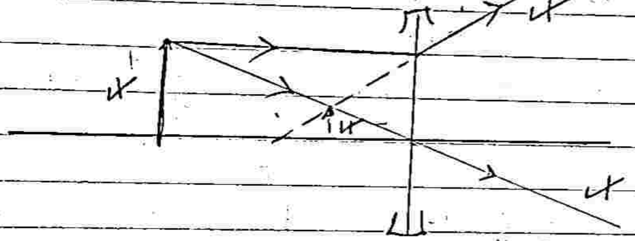
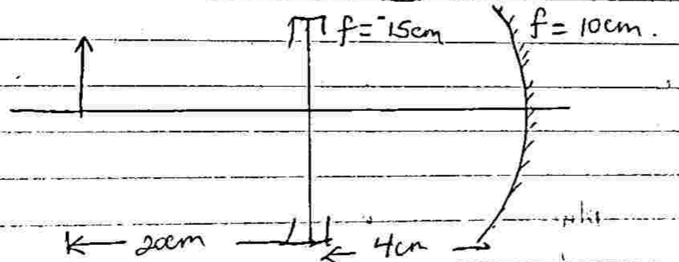
The procedure is repeated for the other line ✓
The prism is removed and line EY through P_3 and P_4 is drawn to meet the line E'Z through P_3' and P_4' at T. ✓ The angle $Y\hat{T}Z$ is measured ✓
The refracting angle A is obtained from $A = \frac{Y\hat{T}Z}{2}$ ✓ (05)

c (i)



(02)

(ii)

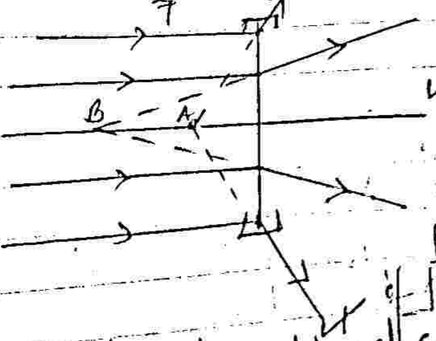


Action of concave lens.
$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = -\frac{1}{15} - \frac{1}{20}$ ✓
$v = \frac{-60}{7} = 8.6$ cm

Action of concave mirror.
$u = \frac{60}{7} + 4 = \frac{88}{7} = 12.6$
$f = 10$cm.
$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{10} - \frac{1}{12.6}$ ✓
$v = 48.5$cm ✓

Action of the lens
$u = -(48.5 - 4)$
$= -44.5$
$f = -15$
$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$ ✓
$= -\frac{1}{15} - -\frac{1}{44.5}$
$v = -22.6$cm ✓ (4)

(d)



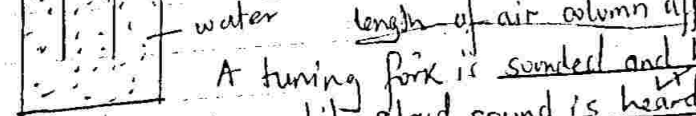
✓ When a wide beam of light ✓ falls on the lens, marginal rays are refracted and appear to come from a point different from that of the central rays. The image formed is thus blurred (distorted). This is called spherical aberration. It is minimised by use of an opaque disc with a central hole covering the lens. ✓ (03)

⑤

3a(i) Resonance is said to occur when a body is set to vibrate at its natural frequency due to impulses received from a nearby source of the same frequency (01)

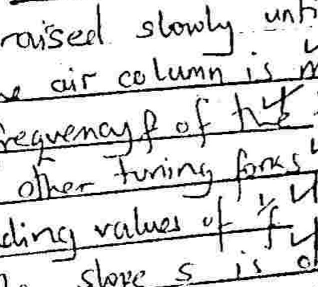
(ii) Frequency is the number of cycles made by a wave per second. or the no of waves produced per second (01)

(b) When air is blown into a pipe, it vibrates in many different modes, producing notes of different frequencies. The note of lowest frequency is the dominant one and is called the fundamental note. The other notes have frequencies higher than that of the fundamental note and are usually less intense. They are called overtones. (05)



and others

(c)



A large glass trough is filled with water and a resonance tube is lowered into it until a short length of air column appears above it (05)

A tuning fork is sounded and held above T. T is raised slowly until a loud sound is heard. The length l of the air column is measured and recorded together with the frequency f of the tuning fork. The exp't is repeated with other tuning forks and the results recorded in a table including values of $\frac{1}{f}$. A graph of $\frac{1}{f}$ against l is plotted and the slope s is obtained. The velocity v of sound is now obtained from $v = \frac{4}{s}$

d (i) When two notes of slightly different frequencies but similiar amplitudes are sounded together they superpose (interfere), producing a note whose intensity increases and reduces periodically. This phenomenon is called beats. (02)

(ii) Consider two notes of frequencies f_1 and f_2 sounded together. Suppose the wave of frequency f_1 makes one cycle more than that of f_2 in time T.
In time, T, the number of waves of f_1 is f_1T
number of waves of f_2 is f_2T
Therefore $f_1T - f_2T = 1$

$\Rightarrow f_1 - f_2 = \frac{1}{T}$ but $\frac{1}{T} = f$ (03)

$\therefore f_1 - f_2 = f$ beat frequency

(e) A hears a note of freq 750 Hz due to its own source
He also hears a note of freq f' due to B.
But $f' = \frac{v}{\lambda'} = \left(\frac{v}{v+u}\right)f$ where $\lambda' = \frac{v+u}{f}$

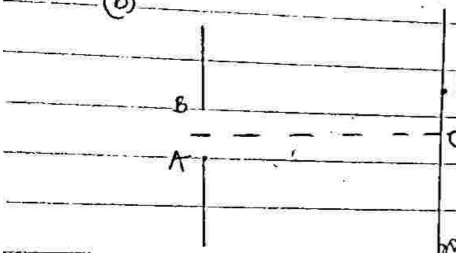
$\Rightarrow f' = \left(\frac{330}{330+2}\right) \times 750$ (03)

$= 745.5\,Hz$

Beat frequency $f = f_A - f' = 750 - 745.5$
$= 4.5\,Hz$

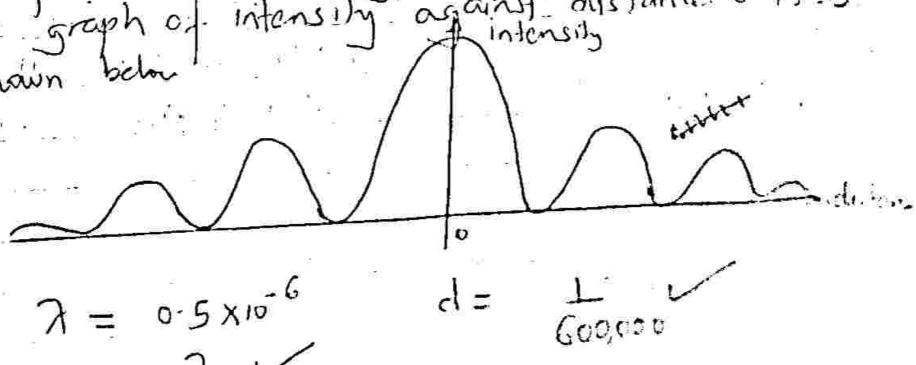
4(a) Diffraction is the spreading of (light) waves beyond their geometrical boundaries leading to interference (2)

(b)



Consider straight wavefront incident on a narrow gap AB. Each point on the wavefront in the gap act as a secondary source of wavelets that propagate in the forward direction..

At, O, to each of the wavelet there is another wavelet which has travelled an equal path length and so all the wavelets arrive in phase. Constructive interference occurs and this is a position of the central bright band. Outwards from O, and increasing number of wavelets arrive out of phase and hence the bright band reduces in intensity. Between the bright bands, all corresponding wavelets arrive out of phase and interference destructively forming dark bands. The graph of intensity against distance O is as shown below



(c) $\lambda = 0.5 \times 10^{-6}$ $\qquad d = \dfrac{1}{600{,}000}$

$\sin\theta = \dfrac{n\lambda}{d}$ (04)

$1 = 1 \times n \times 0.5 \times 10^{-6} \times 600000$

$n = \dfrac{1}{0.5 \times 10^{-6} \times 600{,}000} = \dfrac{1}{5 \times 6 \times 10^{-2}} = \dfrac{100}{30} = 3\frac{1}{3}$

$\therefore n = 3$

(06)

d (i) Plane of polarisation of light is one in which the electric vector of the polarised light varies or vibrates (02)

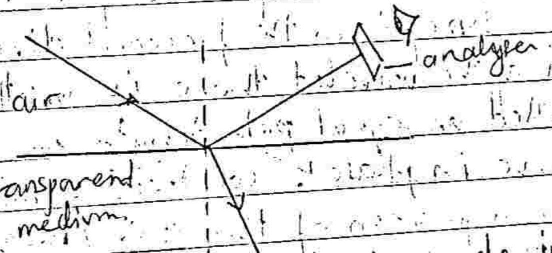
(ii) From Brewster's law

$i_p = \tan^{-1}(n)$

$= \tan^{-1}(1.3)$ (02)

$= 52.4°$

e (i)

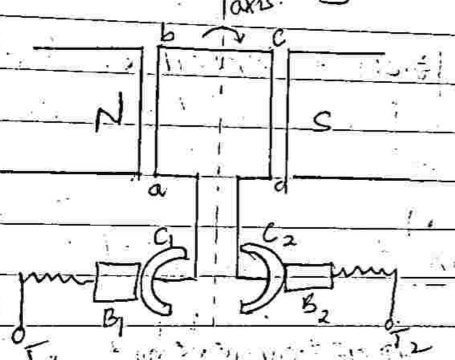


A narrow beam of light is made incident on a transparent medium. The reflected light is observed through a polaroid. The angle of incidence is varied. At each angle of incidence, the polaroid is rotated about the axis along the light incident on it. At one angle of incidence, the light gets cut off from the observer as the polaroid is rotated. The reflected ray is now completely plane polarised. (03)

(ii) - Stress analysis (02)
- determination of concentration of sugar in a solution

5a (i) A dyamo converts mechanical energy to electrical energy while a motor converts electrical energy to mechanical energy. ✓ (01)

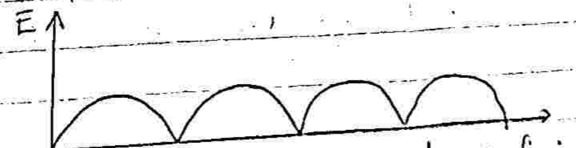
(ii)



abcd - rectangular coil ✓
C_1C_2 - halves of split ring commutator ✓
B_1B_2 - Carbon brushes ✓
T_1T_2 - output terminals.
N, S - north and south poles of a strong permanent magnet. ✓

The coil is rotated with uniform angular frequency ω. As it rotates it cuts through the lines of magnetic flux producing an induced emf in it. When the coil passes the vertical position, the induced emf in the coil changes direction and at same time the commutator halves change contacts i.e. C_1 to B_2 and C_2 to B_1. So the Emf at the terminals T_1 and T_2 remains in the same direction. ✓ (06)

OR. The variation of the output voltage with time is as shown below



(iii) The peak value of induced Emf increases with an increase in - The no of turns of the coil ✓
- The area of the coil ✓
- The strength of the magnetic field ✓
- The frequency of rotation of the coil ✓

any three

(iv) To convert a d.c generator to an a.c generator, The ends of the rectangular coil are connected to a pair of slip rings instead of the commutators ✓ (01)

b (i) Let F_1 and F_2 be the forces exerted on the long wire due to currents in CD and AB respectively

$$F_1 = \frac{\mu_0 I_1 I_2}{2\pi r_1} \times CD \checkmark$$

$$= \frac{4\pi \times 10^{-7} \times 10 \times 15 \times 5 \times 10^{-2}}{2\pi \times 2 \times 10^{-2}} = 7.5 \times 10^{-5} N \checkmark$$

$$F_2 = \frac{\mu_0 I_1 I_2}{2\pi r_2} \times AB = \frac{4\pi \times 10^{-7} \times 10 \times 15 \times 5 \times 10^{-2}}{2\pi \times (2+3) \times 10^{-2}} = 3 \times 10^{-5} N \ (06)$$

Net force $= F_1 - F_2 = 7.5 \times 10^{-5} - 3.0 \times 10^{-5} = 4.5 \times 10^{-5} N$ ✓ toward CD

(ii)

pattern ✓
N - neutral point
direction

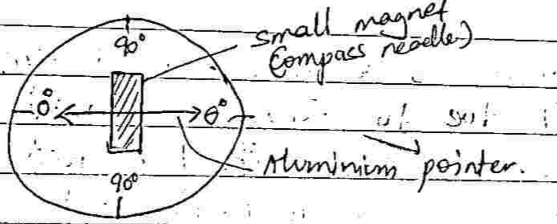
[deduct if field lines of 15A are not > than field of 10A]

A neutral point is a place where two magnetic fields are equal and opposite and the resultant force is zero. ✓ (03)

6 (a) (i) Magnetic meridian is a vertical plane in which a freely suspended magnet sets itself. ✓
OR a vertical plane containing the earth's magnetic axis (01)

(ii) Magnetic variation is the angle between the magnetic and geographical meridians. ✓ (01)
OR angle b/tn the earth's magnetic axis and geographical axis

(b) It consists of a small compass needle (a small magnet) which is pivoted on a vertical axis and carries a light aluminium pointer ½✓ (can be scored on diag)
Pointer can rotate over a circular scale ½✓



The deflection magnetometer is used to compare two magnetic fields flux densities one being the horizontal component of the earth's flux density ½✓ B_H.
The two fields i.e. B_H and any other field B to be compared are arranged at right angles to each other. ½✓ The compass needle then sets itself at angle θ to its initial direction when it was in the field B_H alone ✓ The needle now points in the direction of the resultant field of B_H and B. (06)
The angles of deflection θ_1 and θ_2 of the needle are measured ½✓. The average deflection $\theta = \frac{\theta_1+\theta_2}{2}$ is determined ½✓.
The ratio $\frac{B}{B_H} = \tan\theta$ is obtained ✓

(c) $B_C = \frac{\mu_0 N I}{2r} = \frac{4\pi \times 10^{-7} \times 4 \times 0.35}{2 \times 5.5 \times 10^{-2}}$ ✓

$= 1.6 \times 10^{-5}\,T$ ✓ (due E or W).

Let the resultant field be B_R

$\Rightarrow B_R = \sqrt{B_C^2 + B_H^2}$

$= \sqrt{(1.6\times10^{-5})^2 + (1.6\times10^{-5})^2}$ (04)

$= 2.26 \times 10^{-5}\,T$ ✓

$\tan\theta = \frac{B_C}{B_H} = \frac{1.6\times10^{-5}}{1.6\times10^{-5}} = 1$

$\Rightarrow \theta = 45°$ ✓

d(i) Self induction is the generation of emf in a circuit (coil) due to change in ~~circuit~~ current in the same circuit and mutual induction is generation of an emf in a circuit (coil) due to change in current in an adjacent but separate circuit ✓ (02)

(ii) - Ohmic loss ✓ - minimised by use of thick copper wires ✓
- Eddy currents ✓ - minimised by use of a laminated core ✓
- Hysteresis loss ✓ - minimised by use of magnetically soft material ✓ (04)
- Magnetic flux leakage ✓ - minimised by winding secondary coil on the primary coil ✓

(iii) When a load is connected to the secondary winding, a current flows in it ✓. The current flows in such a direction as to reduce the flux in the ✓core. This reduces the back emf in the ✓primary coil hence the current increases ✓ (02)

7 (a) Root mean square (rms) value of an alternating voltage is the steady voltage which when maintained across given resistor dissipates electrical energy in the resistor at the same rate as the alternating voltage. (01)

b (i) $w = 2\pi f$

$120\pi = 2\pi f$ (01)

$\Rightarrow f = 60\,Hz$

(ii) $\langle P \rangle = \frac{V_{Rms}^2}{R} = \frac{V_0^2}{2R}$

$= \frac{20 \times 20}{2 \times 100}$ (03)

$= 2W$

C (i) $E_b = -L\frac{dI}{dt}$

But for finite current $V = -E_b$

$V = L\frac{dI}{dt}$ but $V = V_0 \sin 2\pi f t$

$\Rightarrow \frac{dI}{dt} = \frac{V_0}{L} \sin 2\pi f t$

$I = \frac{V_0}{I} \int \sin 2\pi f t \, dt$

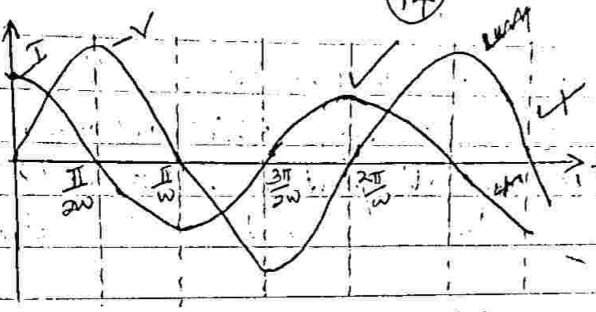
$\therefore I = \frac{-V_0}{2\pi f L} \cos 2\pi f t$

$I = \frac{V_0}{2\pi f L} \sin\left(2\pi f t - \pi/2\right)$ or $\frac{-V_0}{2\pi f L} \sin\left(2\pi f t + \pi/2\right)$

$\Rightarrow I$ lags V by $\frac{\pi}{2}$ or 90°

(14)

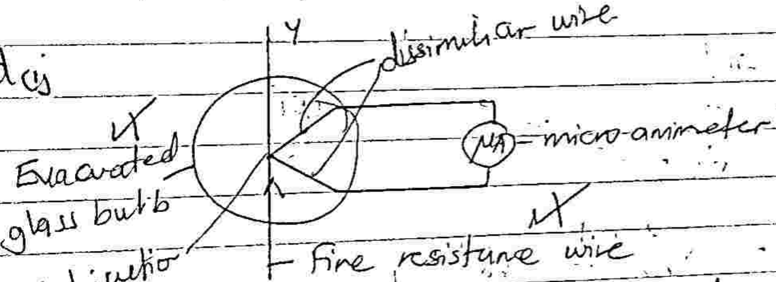
(ii)



incorrect phase with the 1st graph

(02)

d (i)



(04)

Current to be measured is passed through the fine wire XYZ. The wire heats up due to its resistance. Thermometric Emf therefore develops between the hot and cold junctions giving rise to a direct current through the microammeter. The deflection therefore is proportional to the square of the average current

(ii) The fine wire is enclosed in an evacuated glass bulb to shield it from draughts. If the wire was in the open, some heat would be given out to the surrounding so that the temp difference btn the hot and cold junctions (hence resulting current) would not be proportional to the power dissipated in the wire

e) $X_c = \frac{1}{2\pi f c} = \frac{10^6}{2\pi \times 40 \times 66}$

Voltage, $V_{rms} = I_{rms} \times X_c = \frac{2.2 \times 10^6}{2\pi \times 40 \times 66} = 146\,V$

15

8(a) i) Electrical resistivity is defined as the resistance across opposite faces of a 1m cube of a material (01)

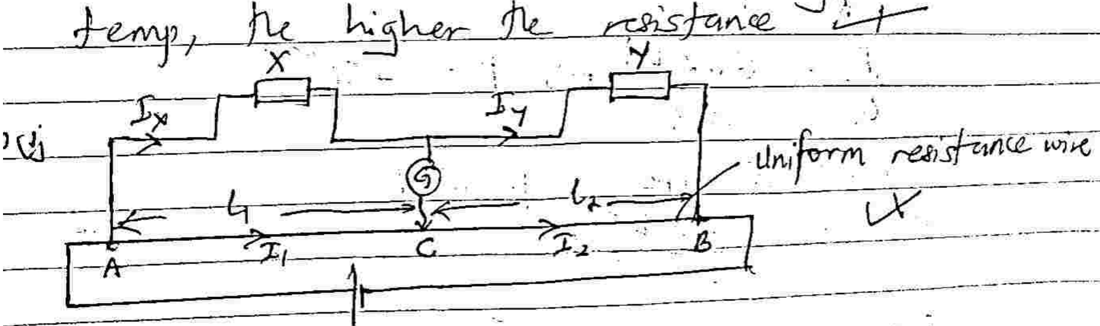
ii) Length – Increase in length leads to longer path for electrons. This means more collisions will occur with the metal ions. This leads to a reduction in current and hence increases in resistance. (02)

- Temperature – Increase in temperature increases the amplitude of vibration of the ions. This increases the rate of collision between the electrons and the ions. This will reduce the amount of current flowing, implying a higher resistance. (02)

iii) $T_2 > T_1$

At temperature T_1, the gradient is higher than that at T_2 (or at each voltage, the current flowing at temp T_1 is higher than that flowing at temp T_2). This implies that, the resistance at T_1 is lower than that at T_2. The higher the temp, the higher the resistance (03)

b) (i)



At balance, the galvanometer shows no deflection or $I_g = 0$

$\Rightarrow I_X = I_Y$ and $I_1 = I_2$

The p.d across X = p.d across AC

$\Rightarrow I_X X = I_1 r l_1$ (i)

Also, the p.d across Y = P.d across CB

$I_Y Y = I_2 r l_2$ (ii)

Dividing (i) by (ii) gives (04)

$$\frac{X}{Y} = \frac{l_1}{l_2}$$

(ii) - X must be chosen such that the balance point is near the middle of the wire AB. (02)

- After determining the balance lengths l_1 and l_2, X and Y should be interchanged in order to get the average values of the balance lengths.
- The resistance wire AB should not be scrapped by jockey. This is to avoid spoiling uniformity of the wire

(c) Let the combined resistance of P and X be R

$$\Rightarrow \frac{R}{Q} = \frac{l_1}{l_2}$$

$$\frac{R}{Q} = \frac{66.7}{33.3} \Rightarrow R = 4\Omega$$

(04)

Since P and X are in parallel

$$\Rightarrow R = \frac{5X}{5+X} = 4$$

$$\Rightarrow X = 20\Omega$$

from $\frac{XA}{\rho} = l$ $\frac{20 \times 1.0\times10^{-6}}{1.0\times10^{-5}} = 2.0m$

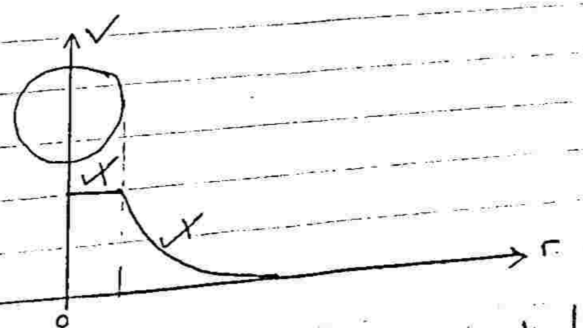
When a p.d is applied across a conductor, the free electrons are accelerated in the direction of the field. As they move, they collide with the metal ions which retard the motion. On average therefore, the electrons move with a steady velocity. (02)

9a (i) Equipotential surfaces is ~~one~~ on which the electric potential is the same (or constant) at all points. The work done to move a charge from one point to another along the surface is zero. This implies that the electric field is perpendicular to the surface. (E4)

(ii) The surface of a charged conductor (E1)
OR The surface of the earth
OR An imaginary surface containing points equidistant from a point charge.

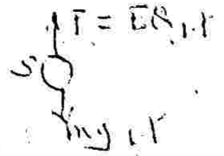
b (i) Coulomb's law states that the force between two point charges is directly proportional to the product of the magnitudes of the charges, and inversely proportional to the square of the distance between them (E1)

(ii)



Within the sphere, the electric potential is constant (C3)
There is no net charge inside
Outside the sphere, the potential is ~~inversely~~ inversely proportional to the distance r from the centre of the sphere

(19)



since the sphere is stationary

$\therefore T = mg$

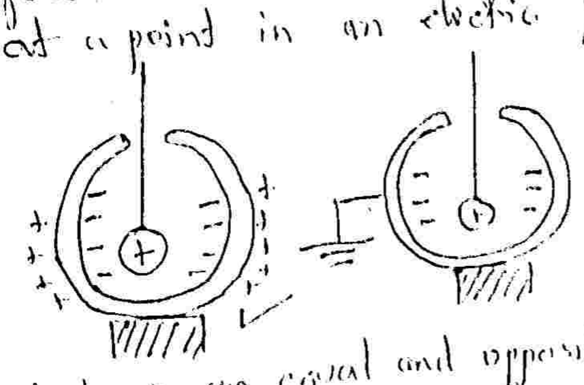
$\Rightarrow EQ = mg$ where Q is the charge on the sphere

$E = \dfrac{V}{d}$ $\therefore Q = \dfrac{mgd}{V}$

$Q = \dfrac{4 \times 10^{-3} \times 9.81 \times 20 \times 10^{-2}}{1.5 \times 500}$ $= 5.23 \times 10^{-6}$ C $= 5.23\,\mu$C (04)

(c) (i) Electric field intensity at a point is the force exerted on 1C of positive charge placed at a point in an electric field.

(ii)



The test material is suspended in an almost enclosed conducting can

It induces an equal and opposite charge inside the can and similar charge to its on the outer walls, such that the net charge inside the can is zero. Any external field only affects charge distribution on the outer surface of the can. Hence the material is shielded from the external field

Electrostatic shielding is the act of protecting a material from the influence of an electric field [or creating an electrically neutral space in an electric field]

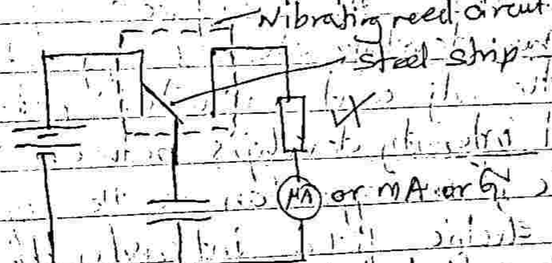
(20)

b When a neutral metal body is brought near a charged material, opposite charge is induced on the near side of the metal, and charge similiar to that of the charged body on the far side. Since opposite charges are now closer to each other the attraction force between the materials is greater than the repulsion force. Hence the metal body is attracted. (02)

time its opened and K_2 is closed. The first deflection θ_1 of the ballistic galvanometer (BG) is noted. The test dielectric is now inserted in the capacitor and the procedure is repeated. The first deflection θ_2 is noted. The relative permitivity is now calculated from

$$\varepsilon_r = \frac{\theta_2}{\theta_1}$$

OR



A capacitor is connected in a circuit above. The reed circuit is closed and the reading I of the milliammeter is noted. The switch is opened and a test dielectric is inserted in the capacitor. The switch is closed and the micrometer reading I' is noted. The relative permitivity ε_r is calculated from $\varepsilon_r = \frac{I'}{I}$

b (i) Effective capacitance in parallel
$= 50 + 70 = 120\mu F$

Net capacitance in the network
$C = \frac{120 \times 40}{120 + 40} = \frac{4800}{160} = 30\mu F$

(23)

Total charge in the network

$Q = CV = 30 \times 9 = 270\mu C$

Pd across the parallel combination

$V_p = \frac{Q}{C_{eff}} = \frac{270 \times 10^{-6}}{120 \times 10^{-6}} = 2.25V$ (05)

charge on the 50μF capacitor

$Q = C_o V_p = 50 \times 2.25 \times 10^{-6}$

$= 1.125 \times 10^{-4} C$

(ii) Energy stored in the 40μF capacitor

$E = \frac{Q^2}{2C} = \frac{(270 \times 10^{-6})^2}{2 \times 40 \times 10^{-6}}$ (03)

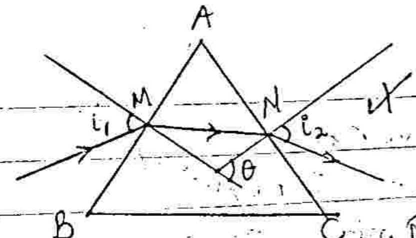
$= 9.11 \times 10^{-4} J$

c) On a pointed charged conductor, there is high charge density at the sharp point. The electric field intensity there is therefore very high. This causes air molecules around the sharp point to get ionised creating positive and negative ions. (03)

The charge similiar to that on the conductor is repelled while the opposite charge is attracted to the sharp point and neutralises some of the charge on the conductor

24

2b.



The prism is placed on a plane sheet of paper on a soft board and its out line is drawn. The prism is removed and a line normal is drawn at M on side AB of the prism. A line is drawn making angle i_1 to the normal. The prism is placed back on its outline, and two pins $P_1 P_2$ are placed on the line drawn as above. Looking through side AC, two other pins $P_3 P_4$ are placed on the paper so that they appear to be in straight line with $P_1 P_2$. The prism and the pins are removed. A line is drawn through pin $P_3 P_4$ to meet side AC at N. A normal to AC is drawn at N to meet normal through M. The angle θ between the normals is measured. The angle θ is the angle of the prism and is the angle

(05)

(a) (i) Capacitance of a capacitor is the ratio of the magnitude of charge on either plates of the capacitor to the potential difference between the plates. (01)

(ii) When a dielectric is inserted between the plates of a charge capacitor, its molecules get polarised. The surfaces of the dielectric thus develop charges opposite to those on the adjacent capacitor plates. An electric field intensity develops between the faces of dielectric, in opposition to the applied field. The electric field intensity between the plates therefore reduce implying the reduction in the p.d.
Since the p.d is now less than the terminal p.d of the battery, more charge is conducted to the capacitor until the p.d is again equal to that of the battery. Hence charge in the capacitor increases.

(iii)

The circuit is set up as above where C is capacitor with air between its plates. Switch K_1 is closed and after a short time