ACEITEKA MOCK EXAMINATIONS 2024

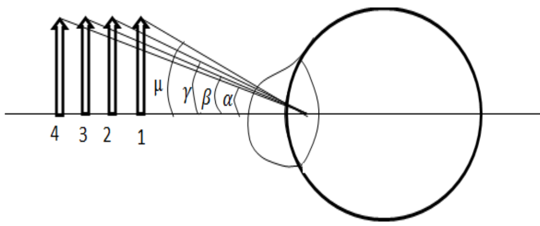
S.6 PHYSICS P510/2

PROPOSED MARKING GUIDE

1.(a) (i) It is the angle subtended at the eye by the object. ***(01)***

(ii) It is the ratio of the angle subtended at the eye by the final image when an optical instrument is used to the angle subtended by the object at the eye when no optical instrument is used. ***(01)***

(b)

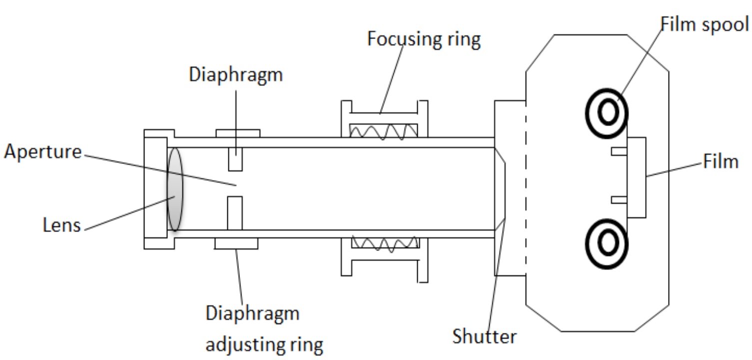


Consider 4 poles of the same height placed at different positions from an observer's eye at O.

The poles that are near to the observer subtend a bigger angle at the observer's eye than the furthest poles.

Since the apparent size (image) of the object is proportional to the angle it subtends at the eye, then the furthest pole appears shortest. ***(03)***

(c) (i)



- The lens focuses the image of the object on the film.
- The diaphragm controls the amount of light entering the camera.
- The focusing ring alters the distance of the lens from the film.

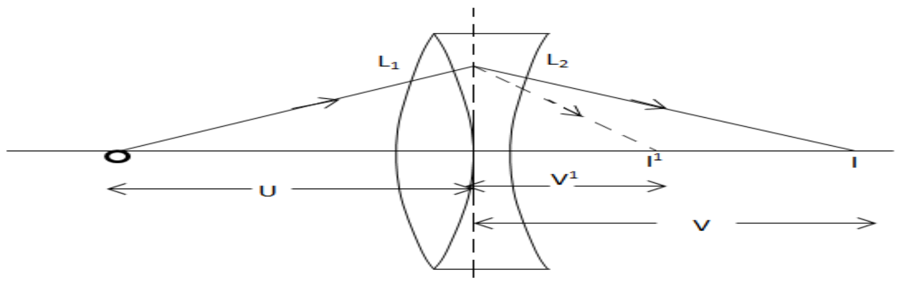
- Aperture has a variable diameter controlled by the diaphragm adjusting ring and also regulates the amount of light entering the camera.
- The film has chemicals that are photosensitive where images are formed.
- The film spool is where the film is fixed.
- Shutter regulates the time for which the film is exposed to light. ***(05)***

(ii)

Lens camera	Pin hole camera
• Uses a lens to focus images of objects	• Uses a pin hole to focus images of objects
• Requires focusing	• Does not require focusing

(02)

(d)



In either of the two methods; - $\frac{1}{f} = \frac{1}{U} + \frac{1}{V}$

Referring to method 1; - $\frac{1}{f_1} = \frac{1}{U_1} + \frac{1}{V_1}$ but U_1 = U and $V_1 = V^1$ with respect to lens L_1. $\Rightarrow \frac{1}{f_1} = \frac{1}{U} + \frac{1}{V^1}$ .... **(i)**

Also $\frac{1}{f_2} = \frac{1}{U_2} + \frac{1}{V_2}$ but $U_2 = -V^1$ and V_2 = V with respect to lens L_1.

➢ $\frac{1}{f_2} = \frac{1}{-V^1} + \frac{1}{V} \Rightarrow \frac{1}{f_2} = \frac{1}{V} - \frac{1}{V^1}$ .... **(ii)**

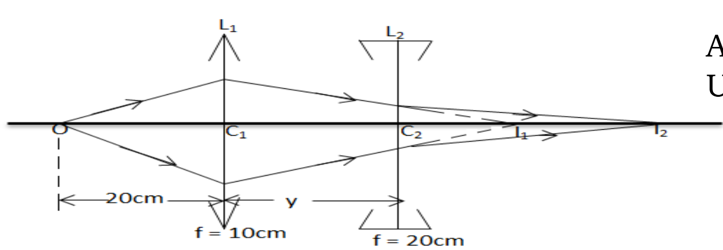
(i) + (ii) gives $\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{U} + \frac{1}{V^1} + \frac{1}{V} - \frac{1}{V^1}$

$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{U} + \frac{1}{V}$ but $\frac{1}{U} + \frac{1}{V} = \frac{1}{F}$ where F if the focal length of the combination of the lenses

➢ $\mathbf{\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}}$

(04)

(e)



Action of the converging lens, U_1 = 20cm, V_1= ?? f = 10cm

$\frac{1}{f} = \frac{1}{U_1} + \frac{1}{V_1} \Rightarrow \frac{1}{10} = \frac{1}{20} + \frac{1}{V_1}$

$\Rightarrow V_1 = 20\text{cm}$

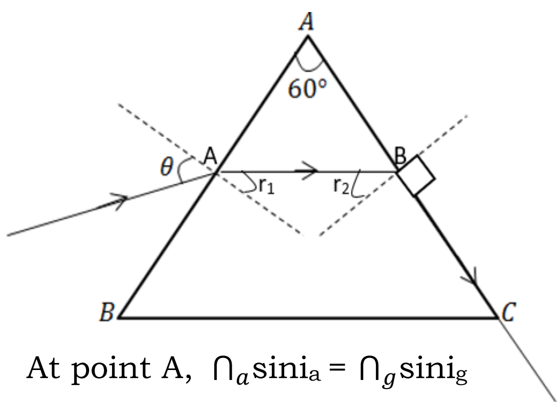
Action of the diverging lens, V_2 = 20cm, U_2 =?? f = - 20cm

$$\frac{1}{f} = \frac{1}{U_2} + \frac{1}{V_2} \Rightarrow \frac{1}{-20} = \frac{1}{U_2} + \frac{1}{20} \Rightarrow U_2 = -10\text{cm}$$

$y = C_1I_1 - C_2I_1 = 20 - 10 = \mathbf{10cm}$ ***(04)***

2 (a) (i) By definition, $\cap_g = \frac{C}{V} = \frac{3.0X10^8}{2.0X10^8} = 1.5$ ***(02)***

(ii)



At point B, $\cap_a \sin i_a = \cap_g \sin i_g$

$1\sin 90° = 1.5\sin r_2$

$r_2 = \sin^{-1}\left(\frac{1}{1.5}\right) = 41.8°$

But $r_1 + r_2 = 60°$

$r_1 + 41.8° = 60°$

$r_1 = 18.2°$

At point A, $\cap_a \sin i_a = \cap_g \sin i_g$

$1\sin\theta = 1.5\sin 18.2°$

$\sin\theta = 1.5 sin 18.2°$

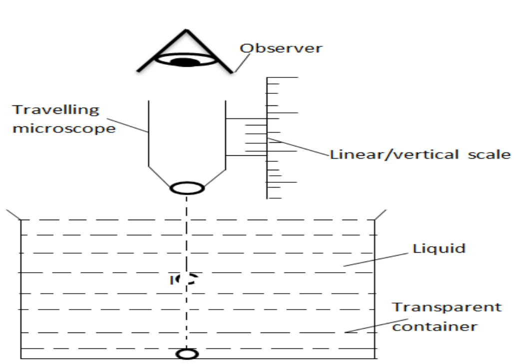
$\theta = \sin^{-1}(1.5 sin 18.2°) = \mathbf{27.9°}$

(03)

(iii) When angle θ is increased, angle r_2 increases beyond the critical angle of glass ie 41.8° and so, there will be total internal reflection of the light at face B

(02)

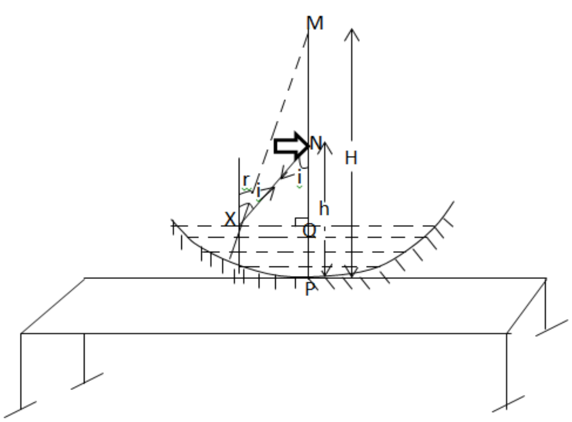
(b)



- ✓ An object, **O** is placed at the bottom of an empty transparent container whose material is of negligible refractive index.
- ✓ The object is focused using a travelling microscope and the reading from the venier scale is noted and recorded as, **a**.
- ✓ With the object still at the bottom, a liquid whose refractive index, n_L is to be determined is poured in the container.

- ✓ The object is focused again by the microscope until its image, **I** can be through the liquid.
- ✓ At this point, the Vernier scale reading is noted and recorded as, **b**.
- ✓ The object is then removed from the bottom of the liquid and a similar object that can float on the liquid is placed on top of it and the travelling microscope is focused again.
- ✓ The Vernier scale reading is noted and recorded as, **c**
- ✓ The refractive index of the liquid is then obtained from the expression;- $\cap_L = \frac{a - c}{b - c}$ ***(05)***

(c)



At point X, $\cap_a \sin i_a = \cap_l \sin i_L$

$\Rightarrow 1\sin i = \cap_l \text{Sinr}$

$\sin i = \cap_l \text{Sinr}$……… ***(i)***

Considering triangle XNQ,

$\sin i = \frac{XQ}{XN}$ …………… ***(x)***

Considering triangle XMQ,

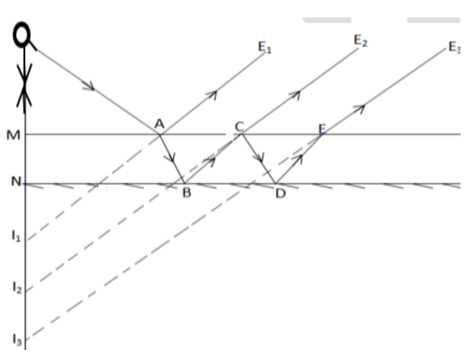
$\sin r = \frac{XQ}{XM}$ …………… ***(ii)***

(x) and (xx) in (i) gives $\frac{XQ}{XN} = \cap_L X \frac{XQ}{XM} \Longrightarrow \cap_L = \frac{XM}{XN}$

But the liquid is of negligible depth such that as X approaches Q, XM = MP and XN = NP

$\cap_L = \frac{MP}{NP} \Longrightarrow \cap_L = \frac{H}{h}$. However, H = K and h = K^1 Thus $\cap_L = \frac{K}{K^1}$ as stated ***(04)***

(d)

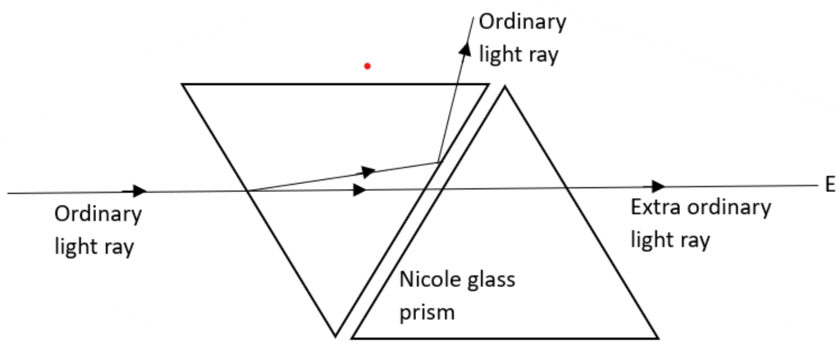


A thick plane mirror has plane surfaces M and N. The incident light is partially reflected and transmitted (refracted) at A. The reflected light leads to the formation of image I_1. The transmitted (refracted) light AB undergoes reflection at B while at C, light undergoes both reflection and refraction. The refracted light CE_2 leads to the formation of image I_2. It is these successive reflections and refractions that bring about the formation of multiple images in thick plane mirrors. ***(04)***

3a(i) Diffraction is the spreading of waves beyond its geometrical shadow/boundary leading to interference ***(01)***

(ii) One whose vibrations only take place in one plane ***(01)***

(b) (i)



- A narrow beam of ordinary light ray is made incident on one side of a Nicole glass prism and then observed from opposite side through another Nicole prism called an analyser
- The angle of incidence is varied and for each angle of incidence, the analyser is rotated about the line of view
- Beyond some of incidence, the intensity of light received reduces until the light is extinguished
- This emergent light is completely plane polarized ***(05)***

(ii) Used to determine the concentration of sugar in the solution

Used in sun glasses to reduce glare

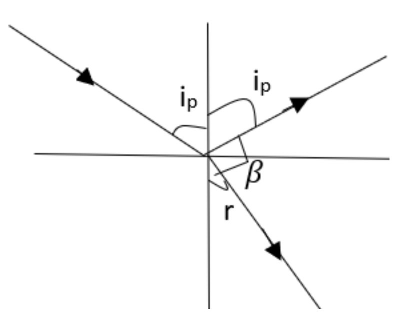
Used in photo elasticity to identify regions of stress in a material ***(02)***

(iii) By Brewster's law. If the reflected light is polarized,

then $\tan i_p = n$

$\tan i_p = 1.62$

$i_p = 58.9°$



From the above diagram, $r = 90° - i_p$

$= 90° - 58.9° = 31.7°$ ***(03)***

(c) A diffraction grating is a transparent plate with many small parallel lines drawn on it using a diamond pencil. ***(01)***

(d)

Prism	**Diffraction grating**
○ Produce single spectrum at a time	○ Produce many spectra at a time
○ Shorter wavelength are deviated most	○ Longer wavelength are deviated most
○ Produce less pure spectrum	○ Produce more pure spectrum

(03)

4 (a) (i) - It is a note of frequency higher than the fundamental frequency. ***(01)***

(ii) It is a note whose frequency is an integral multiple of the fundamental frequency. ***(01)***

(b) (i) $y_2 = a\sin(\omega t - kx)$ ***(01)***

(ii) $\boldsymbol{y = y_1 + y_2}$

$$y = a\sin(\omega t - kx) + a\sin(\omega t + kx)$$

$$y = a[\sin(\omega t - kx) + \sin(\omega t + kx)]$$

$$y = a\left[2\sin\left(\frac{\omega t - kx + \omega t + kx}{2}\right)\cos\left(\frac{\omega t - kx - \omega t - kx}{2}\right)\right]$$

$$y = 2a\sin\omega t\cos(-kx)\ \ But\ \ \cos(-kx) = \cos kx$$

$$\Rightarrow y = 2a\sin\omega t\cos kx$$

$$\therefore y = 2a\cos kx\sin\omega t$$

As a sine wave, $y = A\sin\omega t$ where $A = 2a\cos kx$ is the amplitude of the resulting stationary wave.

$$\Rightarrow A = 2a\, cos\frac{2\pi}{\lambda}x \quad \Rightarrow \quad \therefore y = A\sin\omega t\ \ hence\ a\ stationary\ wave$$ ***(04)***

(iii) From $A = 2a\cos\frac{2\pi}{\lambda}x$

Antinodes occur if the displacement is maximum

For $A = 2a\cos\frac{2\pi}{\lambda}x$ to be maximum,

- $\cos\frac{2\pi}{\lambda}x = \pm 1$
- $\frac{2\pi}{\lambda}x = \cos^{-1}(\pm 1)$
- $\frac{2\pi}{\lambda}x = 0, \pi, 2\pi, 3\pi, 4\pi$…………………

Thus, for an antinode, $\frac{2\pi}{\lambda}x = 0, \pi, 2\pi, 3\pi, 4\pi$

For first antinode
$\frac{2\pi}{\lambda}x_1 = 0$
$x_1 = 0$

For second antinode
$\frac{2\pi}{\lambda}x_2 = \pi$
$x_2 = \frac{\lambda}{2}$

For third antinode
$\frac{2\pi}{\lambda}x_3 = 2\pi$
$x_3 = \lambda$

Distance between two successive antinodes, $x = x_2 - x_1$

$$\boldsymbol{x = \frac{\lambda}{2} - 0 = \frac{\lambda}{2}} \qquad \boxed{\mathbf{A - A = \frac{\lambda}{2}}}$$ ***(03)***

(c) As the wave progresses, some energy is absorbed by the transmitting medium. Also, as the wave spreads out, the energy is spread out over a wider area. Thus, as the distance from the source increases, there is a decrease in intensity of the wave (sound) received by the observer, since from the inverse square law, $I\alpha\frac{1}{r^2}$ but $I\ \alpha\ A^2$ implying that $A^2\alpha\frac{1}{r^2} \Rightarrow A\alpha\frac{1}{r}$.Therefore, the amplitude (A) is inversely proportional to the distance from the source. Thus, increasing the distance leads to a reduction in amplitude of vibration. ***(03)***

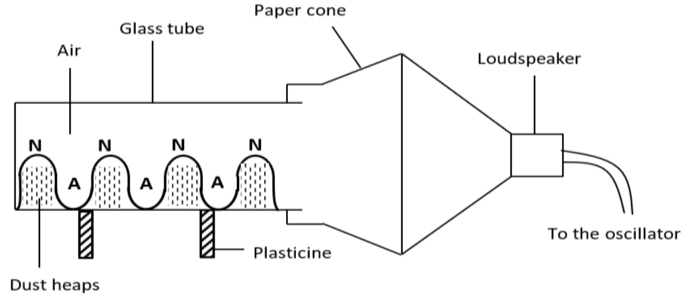
(d) For a closed pipe, $l + E = \frac{1}{4}\lambda \Rightarrow l + E = \frac{V}{4f_c} \Rightarrow E = \frac{V}{4f_c} - l$

For an open pipe, $l + 2E = \frac{1}{2}\lambda \Rightarrow l + 2E = \frac{V}{2f_o} \Rightarrow E = \frac{1}{2}\left(\frac{V}{2f_0} - l\right)$

$\Rightarrow \frac{V}{4f_c} - l = \frac{1}{2}\left(\frac{V}{2f_0} - l\right) \Rightarrow \frac{2V}{4f_c} - 2l = \frac{V}{2f_0} - l \Rightarrow \frac{V}{2}\left(\frac{1}{f_c} - \frac{1}{f_o}\right) = l$

$\Rightarrow \frac{V}{2}\left(\frac{1}{86.2} - \frac{1}{171}\right) = 1 \Rightarrow \mathbf{V = 347.65ms^{-1}}$ ***(03)***

(e)



- A long glass tube is made to lie horizontally.
- Chalk dust is sprinkled evenly on the inside of the tube.
- A paper cone attached to a loud speaker is fitted over the open end of the tube.

- The loudspeaker is connected to a sensitive oscillator of known frequency, f.
- The oscillator is turned on and its frequency is slowly increased until the dust particles finally settle in regularly spaced heaps in the glass tube. ***(03)***
- The distance, l between two successive heaps is measured and recorded.
- The velocity, V of sound in air is then found from the expression, $V = 2fl$

5(a) (i) When the armature / coil of an electric motor is rotating, it cuts the lines of force (magnetic field) and an emf is induced in it. The direction of the induced emf is such that it opposes that of the applied p.d. This induced emf is called ***back emf.*** ***(02)***

(ii) It provides the mechanical power for the motor to do work.

It limits current which flows in the coils since a large current would burn them out. ***(02)***

(b) (i) $From\ V = E_b + I_a r_a$

$when\ I_a = 4A,$ ***(02)***

$240 = E_{b_1} + (4 \times 0.75)$

$\boldsymbol{E_{b_1} = 237V}$

(ii) $when\ I_a = 60A$

$240 = E_{b_2} + (0.75 \times 60)$

$E_{b_2} = 195V$

$But\ E_b \propto W$

$E_b = KW$

$But\ for\ E_{b_1} = 237V,\ and\ W_1 = 400 revmin^{-1}$

$237 = 400K$ **.................. (i)**

$For\ E_{b_2} = 80V, W_2 = ??$

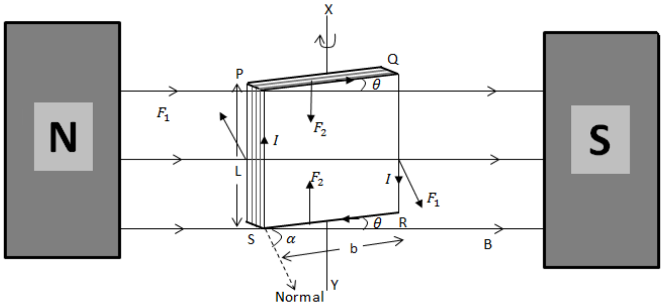
$195 = KW_2$ **.................. (ii)**

$(i) \div (ii)\ gives$

$\frac{237}{195} = \frac{400K}{W_2 K}$ ***(03)***

$\boldsymbol{W_2 = 329.11\ revmin^{-1}}$

(c)



The forces F_1 on the sides PS and QR are still given by $\boldsymbol{F_1 = BILN}$ because PS and QR are perpendicular to B.

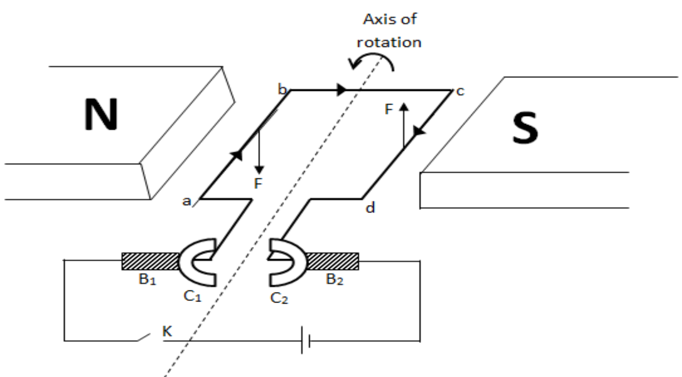
But this time, the forces F_1 are not separated by a perpendicular distance, b, the breadth of the coil but rather a perpendicular distance P which is less than, b given by;-

$$\mathbf{P = b\cos\theta}$$

So, in this case, Torque $\tau = F_1 \times P \quad \Rightarrow \quad \tau = BILN \times b\cos\theta$

$\tau = BIN\ Lb\cos\theta$ $\boxed{\boldsymbol{\tau = BINA\cos\theta}}$ ***(05)***

(d)



a, b, c, d.......Rectangular coil

C_1, C_2 ....Commutators

B_1, B_2...........Carbon brushes

Structure

- ✓ a, b, c, d is a rectangular coil that rotates about an axis between the North and South poles of a strong permanent magnet.
- ✓ The ends of the coil are connected to half split rings of copper called commutators C_1 and C_2 by pressing them tightly against carbon brushes B_1 and B_2.

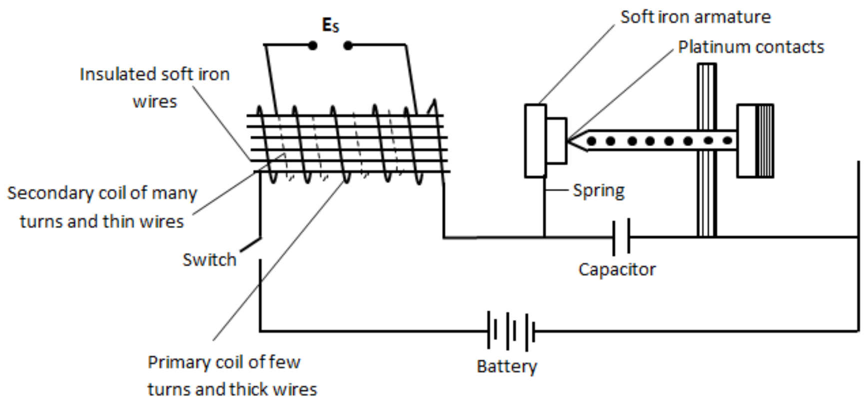
Mode of operation

- When Switch, K is closed, current flows in the direction abcd.
- As a result, side ab experiences a downward force, F while side cd an equal but upward force, F in accordance to F.L.H.R.
- These two forces constitute a couple, thus the coil rotates.
- When the coil is in the vertical position with side ab up and cd down, the brushes lose contact with the commutator halves and current is cut off momentarily.
- However, the inertia of the coil carries it beyond this position so that the commutators automatically change contact i.e. C_1 to B_2 and C_2 to B_1.
- The current flows around the coil in the same direction and also its rotation continues in the same direction. ***(06)***

6 (a) Faraday's law / Neumann's law; - The induced emf in a coil is directly proportional to the rate of change of magnetic flux linking it ***(01)***

Lenz's law; - The induced emf flows always in such a direction as to oppose the change causing it. ***(01)***

(b)



Structure

- An induction coil is a device for getting a high voltage from a low one. It consists of a core of insulated soft iron wires around which is wrapped a coil of about a hundred turns of thick insulated wire called the primary.
- Round the primary is wound the secondary coil which has many thousands of turns of fine insulated wire.
- The primary is connected to a battery of accumulators via a make and break system (switch)

Mode of action

- When the switch is closed, current flows through the primary coil and magnetizes the soft iron wires / core.
- Attraction of the soft iron armature then occurs which causes the platinum contacts to separate and break the circuit.
- When this happens, the core becomes demagnetized and the armature is pulled back again by the spring on which it is mounted.
- After this, the whole process is repeated and as a result, the armature vibrates to and fro causing a rapid make and break of the primary current.
- Each time the primary current is broken, the magnetic flux through the core collapses suddenly and an emf is induced in the secondary.

Because the secondary has such a large number of turns, the induced emf is high (since $E \propto N$) and is sufficient to cause a spark across the gap. ***(07)***

(c) (i) $Power\ lost = 5\%\ of\ what\ is\ produced$

$= \frac{5}{100} \times 6000 = 300W$

$But\ power\ loss = I^2R$

$300 = I^2 \times R$

$But\ for\ R, \quad 1\ m = 0.2\Omega$

$2000m(2km) = (0.2 \times 2000)$

$= 400\Omega$

$300 = I^2 \times 400$

$I = 0.866A$

$But\ for\ a\ transformer\ that\ is\ 100\%, power\ output = power\ input$

$V_S I_S = V_P I_P\ But\ I_S = I = 0.866A$

$V_S(0.866) = 6000 \quad \Rightarrow \quad \boldsymbol{V_S = 6{,}928.41V}$ ***(05)***

(ii) Eddy current - Using laminated soft iron core

Hysteresis losses - Using soft iron core

Magnetic flux leakage - Winding the secondary coil on top of the primary

Ohmic losses / joule heating losses(I^2R) **-** Using a low resistance copper wire for winding ***(03)***

(d) When the circuit is broken, the current starts to fall very rapidly to zero in a short time. Consequently, a large emf called back emf is induced in the circuit. The large back emf makes the electric field intensity between the contact points of the switch high. This high electric field intensity ionizes the air between the contacts and when oppositely charged ions collide, a spark is produced. ***(03)***

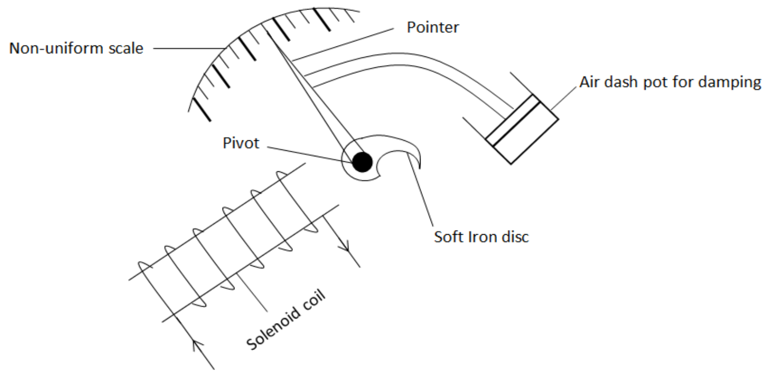
7(a) (i) *Resonant frequency* is the frequency at which current flowing in an a.c circuit containing reactive and resistive components is maximum.

OR

Resonant frequency is the frequency at which the resultant opposition to the flow of a.c in a circuit containing reactive and resistive components is minimum. ***(01)***

(ii) Impendence is the resultant opposition to the flow of alternating current in a circuit containing reactive and resistive components. ***(01)***

(b) (i)



Structure

It consists of a pivoted soft Iron disc having a pointer that deflects on a non-linear scale when current is passed through the solenoid.

Mode of operation

- ✓ Current I to be measured is passed through the solenoid thereby magnetizing it.
- ✓ The solenoid then attracts the pivoted soft Iron disc.
- ✓ This in turn causes the pointer attached to it to deflect/ move.
- ✓ The deflection of the pointer is proportional to the square of the average current i.e. $\theta \propto {I_{rms}}^2$ hence a non-linear/ uniform scale. ***(05)***

(ii)

Moving coil	Moving Iron
✓ Suitable for measuring direct current and voltage	✓ Suitable for measuring both direct and alternating currents and voltages
✓ Readings of currents and voltage are in amperes and voltages respectively	✓ Readings of current and voltages are in r.m.s values
✓ Have a linear/uniform scale	✓ Have a non-linear/non uniform scale
✓ Eddy current is the method of damping	✓ Air-friction is the method of damping

(02)

(c) Since the capacitor is charged, when the switch is closed, the charged capacitor starts to discharge and as a result, current flows. The flow of current causes a magnetic field to build up in the coil and in accordance with Lenz's law, an emf called back emf; E is induced in L as to oppose the current flow. This consequently makes the discharge process slow.

When the discharge is complete, the energy that was initially in the source (capacitor) is stored in the magnetic field of the coil, L. The emf induced in the coil makes it to act as a generator thereby returning the energy stored in its magnetic field to the source. So, the capacitor is recharged to its original state. The above processes keep on repeating ***(04)***

(d) (i) For an inductor

$$E = -L\frac{dI}{dt}$$

But for a pure inductor, $E = -V$

$$-V = -L\frac{dI}{dt}$$

$$V = L\frac{dI}{dt} \; But \; V = V_0 \sin \omega t$$

$$V_0 \sin \omega t = L\frac{dI}{dt}$$

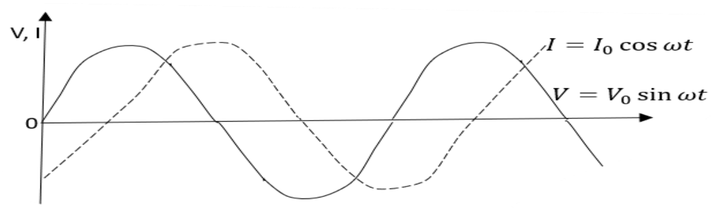
$$dI = \frac{V_0}{L} \sin \omega t \; dt$$

$$\int dI = \frac{V_0}{L}\int \sin \omega t \; dt$$

$$I = \frac{V_0}{L\omega}(-\cos \omega t)$$

$$I = -I_0 \cos \omega t \text{ where } I_0 = \frac{V_0}{L\omega}$$ ***(03)***

(ii)



(02)

(e) $V_{rms} = 10V, C = 50 \times 10^{-6}F$

$From \; Q = CV$

$$Q_{max} = CV_{max}$$

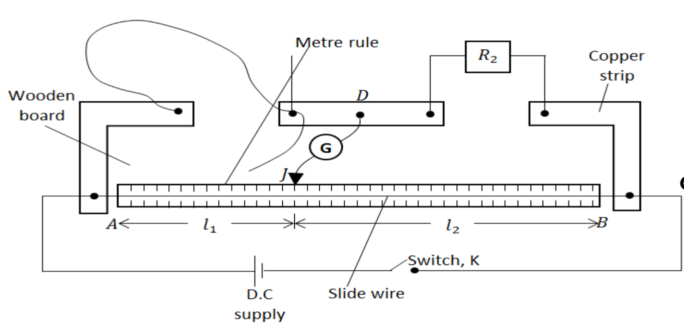
$$Q_{max} = CV_0$$

$$Q_{max} = CV_{rms}\sqrt{2}$$

$$= 50 \times 10^{-6} \times 10 \times \sqrt{2}$$

$$= \mathbf{7.07 \times 10^{-4}C}$$ ***(02)***

8 (a)



- The diameter of a specimen wire of known length x is measured at different points using a micrometer screw gauge and its mean diameter, d is determined.
- The cross-sectional area of the wire is then obtained from the expression; - $A = \frac{\pi d^2}{4}$
- The wire is then connected in the L.H.G and a standard resistor of known resistance R_S in the R.H.G of the metre bridge.

- Switch K is closed and the jockey, J is moved along the slide wire AB until a point when the galvanometer, G shows no deflection.
- At this point, the metre bridge is balanced and the balance lengths l_1 and l_2 are recorded.
- The experiment is repeated for various lengths x of the wire.
- The results are tabulated in a suitable table including values of $R_x = \left(\frac{l_1}{l_2}\right) R_S$
- A graph of R_x against x is plotted and its slope, S is determined.
- The resistivity, ρ of the wire is then obtained from the expression; - $\rho = \frac{\pi d^2}{4} S$

(07)

(b) No current is drawn from the circuit under test. Therefore, it can measure the emf of a cell accurately.

- It is a null deflection method and therefore the balance condition can be found with a high degree of accuracy and sensitivity.

-The scale of a potentiometer can be made long for maximum accuracy.

-Apart from measuring p.d, a potentiometer can be used for various purposes e.g. to measure the internal resistance of a cell, determining current through a wire among others. However, a voltmeter can only measure p.d ***(02)***

-The connecting wires may be thin since no current flows through them.

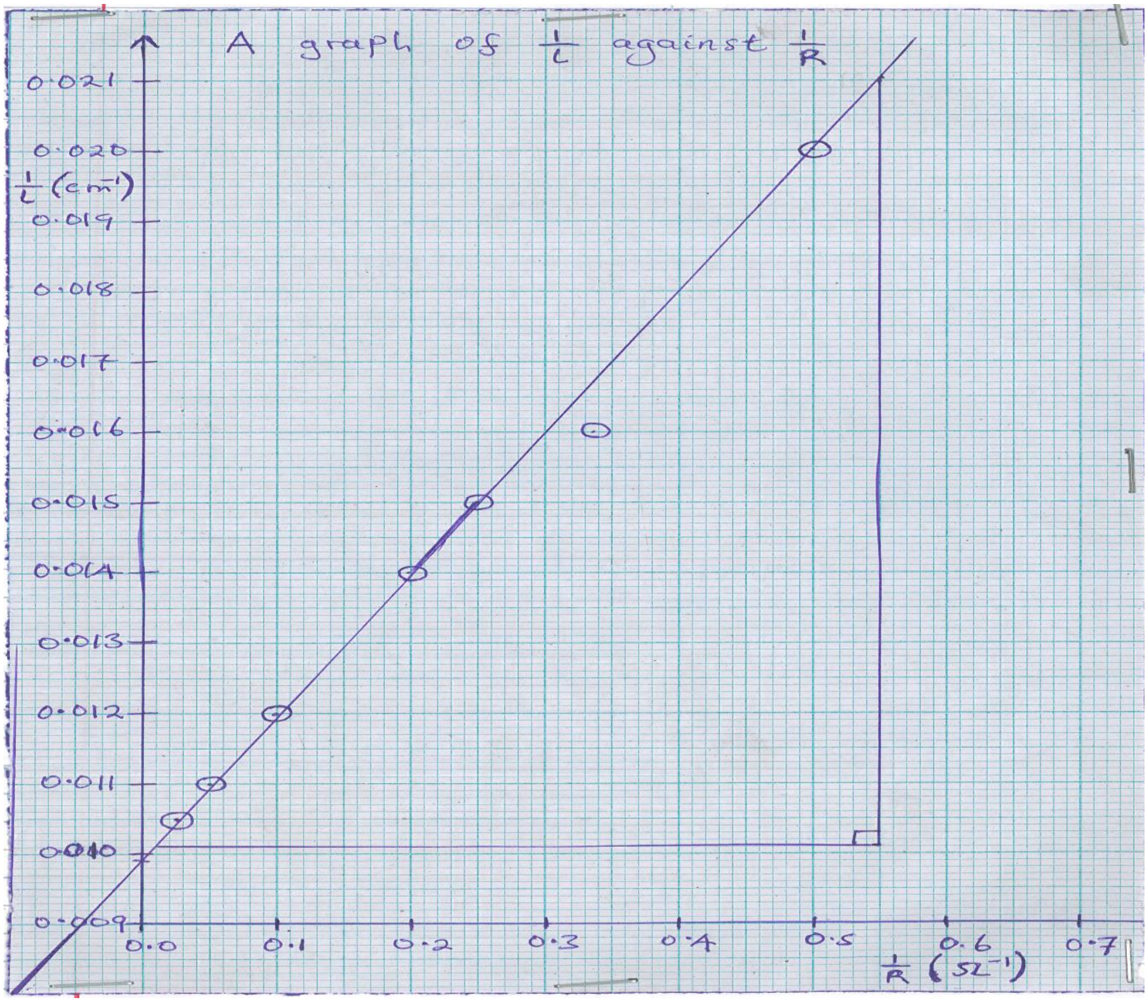
(c)

$R(\Omega)$	$\frac{1}{R}\ (\Omega^{-1})$	$l\ (cm)$	$\frac{1}{l}\ (cm^{-1})$
2	0.500	50.0	0.0200
3	0.333	60.6	0.0165
4	0.250	66.7	0.0150
5	0.200	71.4	0.0140
10	0.100	83.3	0.0120
20	0.050	90.9	0.0110
40	0.025	95.2	0.0105

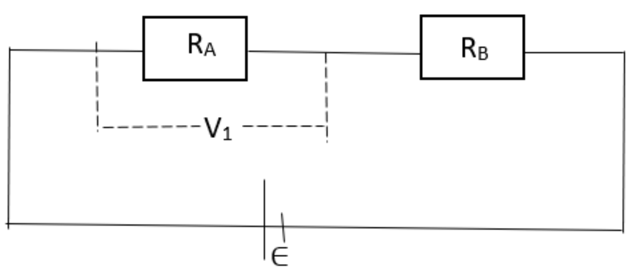
$$Slope, S = \frac{109 \times 0.0001}{54 \times 0.01} = \frac{0.0109}{0.54} = 0.020\Omega cm^{-1}$$

$$Intercept, C = 0.0099cm^{-1}$$

$$Internal\ resistance, r = \frac{S}{C} = \frac{0.020}{0.0099} = 2.0\Omega$$ ***(06)***



(d) let the resistance of the wires be R_A and R_B respectively



$V_1 = IR_A$ But $I = \frac{\epsilon}{R_T}$ and $R_T = R_A + R_B = \frac{\rho_{1L}}{A} + \frac{\rho_{2L}}{A} = \frac{L}{A}(\rho_1 + \rho_1)$

Now $V_1 = \frac{\epsilon R_A}{\frac{L}{A}(\rho_1+\rho_1)} = \frac{\epsilon A}{L(\rho_1+\rho_1)} \text{x} \frac{\rho_{1L}}{A} = \frac{\rho_1 \epsilon}{(\rho_1+\rho_1)}$ ***(03)***

(e). Length (l) of the conductor: The longer the conductor, the higher the resistance and the shorter the conductor, the smaller the resistance. Therefore, resistance is directly proportional to the length of the conductor i.e. $R \propto l$

Cross-sectional area (A) of the conductor: The bigger the cross-sectional area of the conductor, the less the resistance and the smaller the cross-sectional area of the conductor, the more the resistance. Therefore, resistance is inversely proportional to the cross-sectional area of the conductor.i.e. $R \propto \frac{1}{A}$

Temperature (T) of the conductor: The higher the temperature, the higher the resistance of the conductor and the lower the temperature the, the lower the resistance of the conductor. Therefore, temperature is proportional to resistance of a conductor. i.e. $R \propto T$

Nature (N) of the material of the conductor: Good conductors have low resistance whereas insulators have a very high resistance. ***(02)***

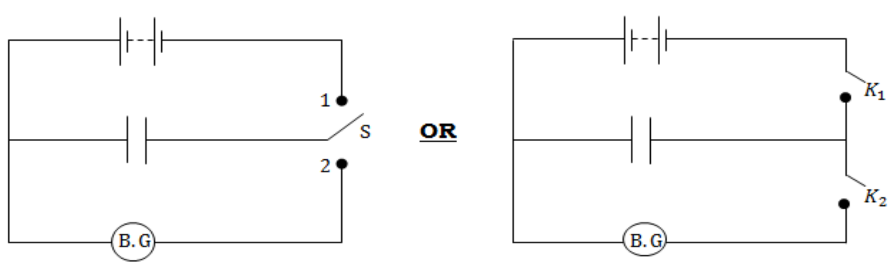
9 (a) (i) This is the maximum electric field intensity an insulator (dielectric) can withstand without its insulation breaking down/conducting.

OR

This is the maximum potential gradient an insulator (dielectric) can withstand without its insulation breaking down /conducting. ***(01)***

(ii) This is the ratio of the capacitance of a capacitor with a dielectric between its plates to the capacitance of the same capacitor with the space between its plates a vacuum/ air. ***(01)***

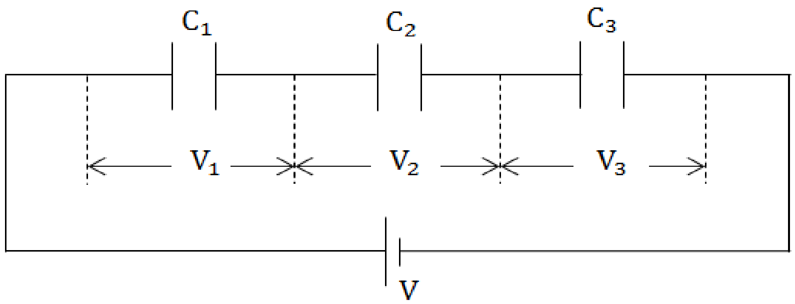
(b)



- ✔ The circuit is connected as shown above with air between the capacitor plates.
- ✔ The capacitor is charged to a p.d, V of the battery when S makes a contact at position 1. (when K_1 is closed and K_2 open).
- ✔ It is then discharged through a Ballistic Galvanometer (B.G) when S makes a contact at position 2 (when K_2 is closed and K_1 open).
- ✔ The maximum deflection, θ_0 of the B.G is noted and recorded.
- ✔ A test dielectric whose di-electric constant is to be determined is inserted between the capacitor plates and the above procedures are repeated.

- ✓ The maximum deflection, θ of the B.G is noted and recorded.
- ✓ The relative permittivity, ε_r of the dielectric is then obtained from the expression; $\varepsilon_r = \frac{\theta}{\theta_0}$ ***(05)***

(c) (i)

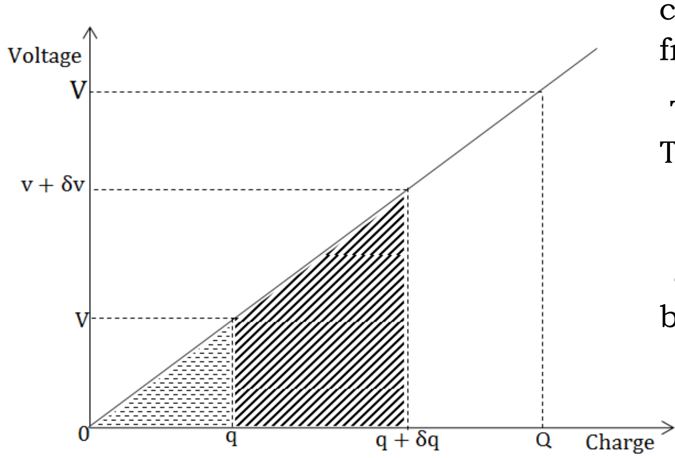


(02)

(ii) P.d $V_1 = \frac{Q}{C_1}$ but $Q = C_T V_o = \frac{C_1 C_2}{C_1 + C_2} V_o$

Now $V_1 = \frac{C_1 C_2}{C_1 + C_2} V_o \times \frac{1}{C_1} \Rightarrow C_2 = \frac{V_1 (C_1 + C_2)}{V_0}$ ***(03)***

(d)



When a small amount of charge δq is transferred from q, then;-

Total charge $= q + \delta q$ and
Total p.d $= v + \delta v$

Small work done,

$\delta W = (v + \delta v)\delta q = V\delta q + \delta V \delta q$
but $\delta V \delta q = 0$

$\Rightarrow \delta W \cong v\delta q$

Total work done to transfer a charge, Q on an uncharged capacitor is equal to the triangular area under the Voltage – Charge curve. i.e.

$$W = \frac{1}{2}\,b.h = \frac{1}{2} \times Q.V \text{ But } Q = CV \text{ and } V = \frac{Q}{C}$$

$$W = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$$ ***(04)***

(e). For equilibrium of the system above,

Moment of weight of mass = Momemt of Electric force

$$mg \times \frac{L}{2} = EQ \times \frac{L}{2} \text{ But } E = \frac{V}{d}$$

$$mg = \frac{VQ}{d} \quad \text{But from } C = \frac{Q}{V}, Q = CV = \frac{A\varepsilon_0 V}{d}$$

➢ $$mg = \frac{A\varepsilon_0 V.V}{d^2} \Rightarrow V = \sqrt{\frac{mgd^2}{A\varepsilon_0}} = \sqrt{\frac{9.8\times10^{-3}\times9.81\times(2\times10^{-3})^2}{412\times10^{-4}\times8.85\times10^{-12}}} = \mathbf{1.03\times10^3 V} \quad \textbf{\textit{(04)}}$$

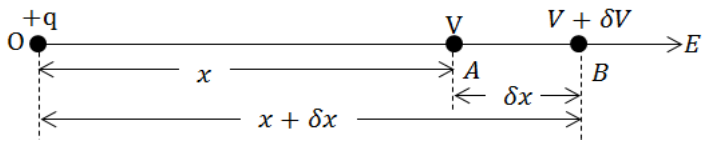
10 (a) Electric field intensity is a force acting on a positive charge of one coulomb placed at a point in an electric field. ***(01)***

Whereas

Electric potential at a point is the work done in moving a positive charge of one coulomb from infinity to that point in an electric field against electrostatic forces. ***(01)***

(b) (i) $E = \frac{-dV}{dx}$ ***(01)***

(ii) Consider two points, A and B in the field of a point charge $+q$.



If the potential at A is V and that at B is $V + \delta V$. The potential difference between A and B is;-

$V_{AB} = V_A - V_B = V - (V + \delta V) = V - V - \delta V = -\delta V$ **................** ***(i)***

But by definition, the work done to move 1C of charge from A to B = p.d between the points and is given by;-

V_{AB} = work done = F X distance. But F = EQ

V_{AB} = $Eq\delta x$. But again q = +1C

V_{AB} = $E\delta x$ **........................** ***(ii)***

This implies that (i) = (ii) $\Rightarrow -\delta V = E\delta x \quad \Rightarrow E = \frac{-\delta V}{\delta x}$

In the limit as $\delta x \rightarrow 0$, then $\boxed{E = \frac{-dV}{dx}}$ ***(04)***

(c) Work done = $V_m x Q_3$

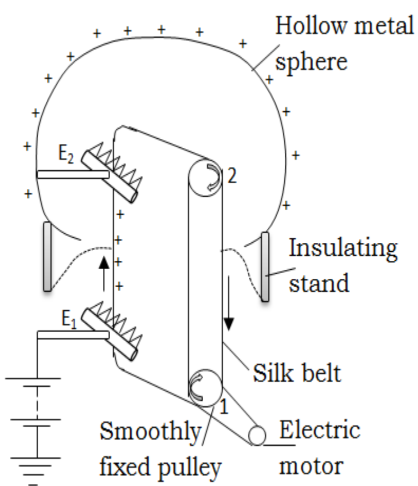
$$\text{But } V_m = K\left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3}\right] = 9.0\times10^9\left[\frac{2\times10^{-6}}{0.106} + \frac{5\times10^{-6}}{0.106} + \frac{(-3\times10^{-6})}{0.106}\right]$$

$$= \frac{9.0\times10^{9}\times10^{-6}}{0.106}[2+5-3] = 3.4\times10^{5}V$$

Now work done = $V_m x Q_3 = 3.4\times10^{5}$ x 5×10^{-6} = **1.7J** ***(04)***

(d) The motion of a vehicle causes its metallic part to get charged by friction. This dangling chain at the rear end has a sharp end on the end that is not in contact with the vehicle and so the would be charges on the vehicle get concentrated at this end. When the vehicle passes; say over a hump or pit hole, the chain makes a contact with the earth and discharges the whole vehicle rendering it safe. ***(03)***

(e)



- ✓ E_1 is made about 10,000V positive relative to the earth by a battery.
- ✓ As a result, positive charges accumulate at the sharp points of E_1 and ionization of air around it takes place such that positively charged ions are repelled onto the silk belt and carried up into the hollow sphere with the help of smooth-running pulleys.
- ✓ The belt induces negative charges on the spikes of E_2 and positive charges on the outer surface of the hollow metal sphere.
- ✓ This creates a very high charge density/electric field intensity at E_2 and hence ionization of air takes place such that negative ions are repelled onto the belt thereby discharging it.
- ✓ In this process, the electrode E_2 also becomes neutralized by the positive ions and the whole process is repeated over again.
- ✓ In this way, the sphere gradually becomes positively charged until its potential is about a million volts relative to the earth. ***(06)***

THE END