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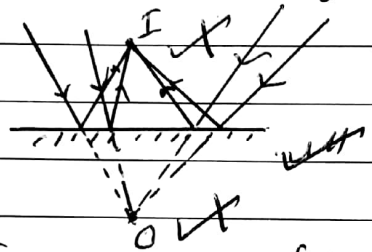
(1)

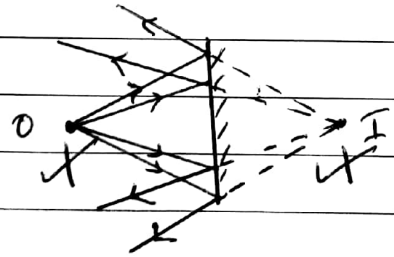
(1) a) The angle of incidence is to the angle of reflection
> The incident ray, the normal and the reflected ray at the point of incidence all lie in the same plane ✓ 01

ii) Real image is an image formed by actual intersection of light rays and can be formed on the screen.



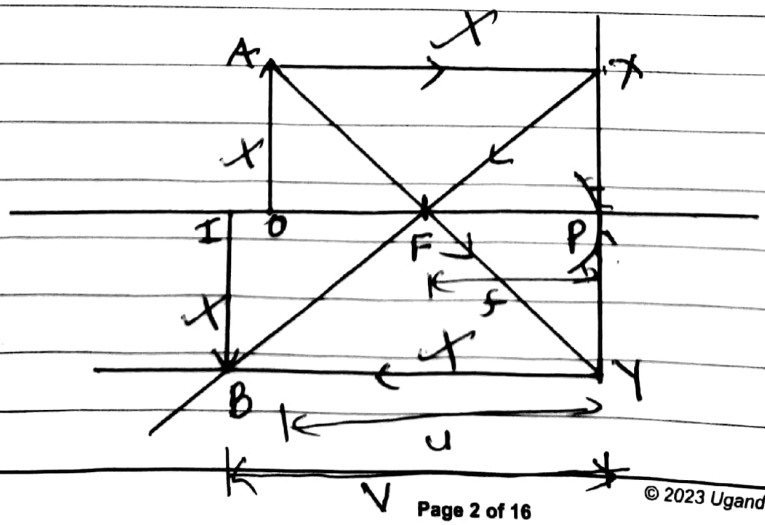
02

Virtual image is an image formed by apparent intersection of light rays and can not be produced on the screen.



02

b)



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(2)

ΔAOF and ΔFPY are similar:

$$\frac{OA}{PY} = \frac{OF}{FP} = \frac{OP-FP}{FP} = \frac{U-f}{f} \quad \text{— ①}$$

ΔXFP and ΔBIF are similar;

$$\frac{XP}{IB} = \frac{OA}{PY} = \frac{FP}{IF} = \frac{FP}{IP-FP} = \frac{f}{V-f} \quad \text{— ②}$$

$$① = ② \Rightarrow \frac{U-f}{f} = \frac{f}{V-f} \Rightarrow (U-f)(V-f) = f^2.$$

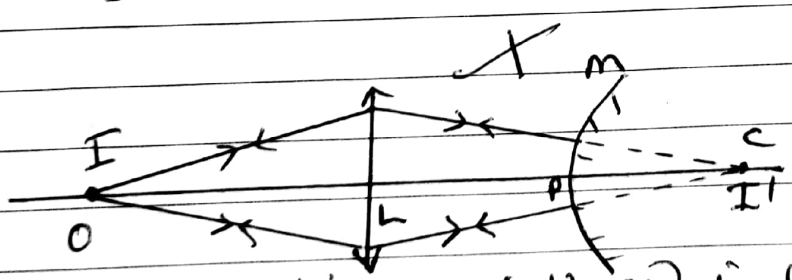
$UV - Uf - fV + f^2 = f^2 \Rightarrow UV = Uf + fV$

dividing through by UVf.

$$\frac{UV}{UVf} = \frac{Uf}{UVf} + \frac{Vf}{UVf} \Rightarrow \frac{1}{f} = \frac{1}{V} + \frac{1}{U}.$$

but $\frac{1}{f} = \frac{2}{r} \Rightarrow \frac{2}{r} = \frac{1}{V} + \frac{1}{U}.$

c)



- An illuminated object, O is placed in front of a convex lens L and the screen is adjusted to form a clear image I' on it
- The distance LI' is measured and recorded
- A convex mirror m is now placed between L and I' and it is adjusted until the final image coincides with O

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(1) > The distance Lp between the lens and the mirror is measured and recorded.

> The ~~focal length~~ radius of curvature is got from

$f =$

$r = -(LI' - LP)$. 04

d) $u = 20cm, \quad m = 3$

$u = \left(\frac{1}{m} + 1\right) f \Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$20 = \left(\frac{1}{3} + 1\right) f \Rightarrow f = \frac{60}{4} = 15cm$

$\Rightarrow u = \left(\frac{1}{-3} + 1\right) \times 15$

$= \left(\frac{-1+3}{3}\right) \times 15 = \frac{2}{3} \times 15$ 04

$= \frac{30}{3}$

$= 10cm.$

20

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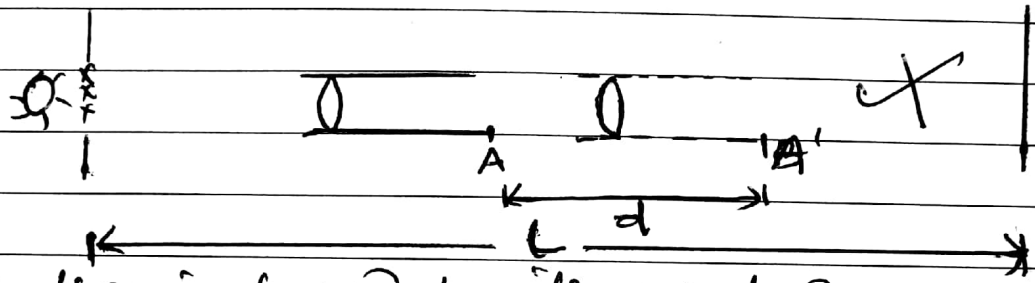
(4)

(2a) i) focal point is the point on the principal axis where all rays initially parallel and close to the principal axis converge or diverge after passing through the lens. ✓

ii) radii of curvature are distances from the lens to the centres of curvature. ✓ 01

b)



> A lens is fixed inside a cylindrical tube and the tube is placed in front of an illuminated object and the screen is placed at distance L from the object. ✓

> The tube is moved from the object until a magnified image is formed on the screen. ✓

> The end A of the tube is marked on the table. ✓

> Keeping the screen and the object fixed, the tube is again moved towards the screen until diminished clear image of wires is formed on the screen. ✓

> The end A' of the tube is marked on the table. ✓

> The distance d between two marks AA' is measured and recorded. ✓ 05

> The focal length of the lens is got from

$$f = \frac{L^2 - d^2}{4L}$$ ✓

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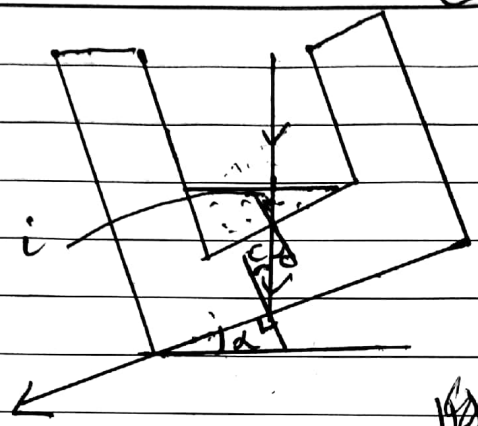
c)



i) $C = \sin^{-1}\left(\frac{1}{n_g}\right)$

$= \sin^{-1}\left(\frac{1}{1.50}\right)$

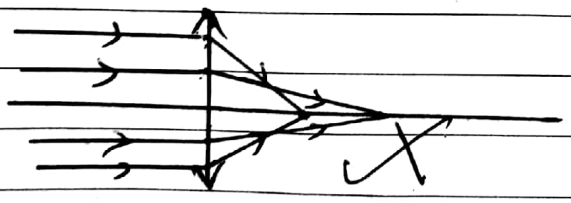
$= 41.8°$ i

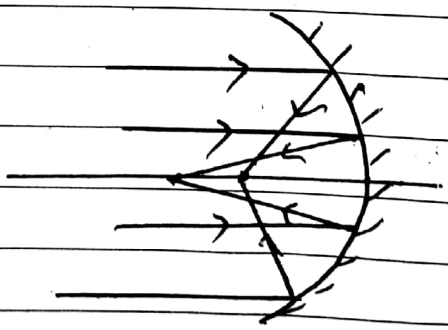
ii) $n_g \sin i = n_g \sin r = 1$

$i = \sin^{-1}\left(\frac{1}{1.37}\right)$

$= 48.75°$

d) ~~Chromatic~~ spherical aberration occurs when a wide beam of light falls on a lens or ~~curved~~ concave mirror of wider aperture. The marginal rays converge near the while paraxial rays converge far resulting into formation of blurred images.





Or

chromatic aberration is a defect which occurs in the lens only and occurs when a white beam of light fall on the lens such that different colours converge at different points along the principal axis.

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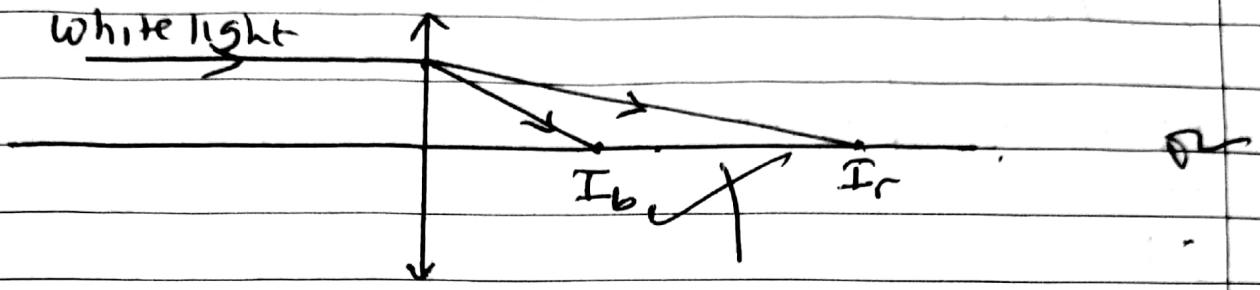

ii) In photographic cameras chromatic by
- Using a chromatic doublet. 03
-
-

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(3) a) i) Amplitude is the maximum displacement of the wave particle. 01

ii) Frequency is the number of cycles made in one second. 01

b) When two sound notes of nearly equal frequencies but similar amplitude are sounded together they interfere.
When they meet in phase, a loud soud is heard and this is constructive interference.
When they meet out of phase, a soft or no sound at all is heard and this is destructive interference.
The result is periodic rise and fall in the intensity of sound. This is known as beats. 03

ii) To measure the unknown frequency of a note.
A note of known frequency f_2 is sounded together with a note of unknown frequency f_1 and the beat frequency f_b is obtained by counting the number made in a given time.
Since f_b is the difference between f_2 and f_1 it follows that $f_1 = f_2 - f_b$ or $f_1 = f_2 + f_b$.
To decide which equation of f_1 to use, one prongs of tuning fork producing a frequency f_2 is loaded with plasticine which diminishes the frequency a little and two notes are sounded again and the new beat frequency f_b' is obtained.

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(8)

If $f_b' > f_b$, then $f_2 > f_1$, then $f_1 = f_2 - f_b$ ✓
If the beats are increased, then $f_2 < f_1$, then $f_1 = f_2 + f_b$ ✓ 04

Or Tuning a musical instrument to a desired frequency

c) $y = a \sin\left(2000\pi t - \frac{\pi x}{0.17}\right) m$

In form $y = a \sin\left(2\pi f t - \frac{2\pi x}{\lambda}\right)$

$\Rightarrow f = \frac{2000}{2} = 1000\ Hz$ ✓

$\frac{\pi}{0.17} = \frac{2\pi}{\lambda}$, $\lambda = 0.34\ m$ ✓ 03

$v = f\lambda = 0.34 \times 1000 = 340\ m s^{-1}$ ✓

ii) $y_1 = a \sin\left(2000\pi t - \frac{\pi x}{0.17}\right) m$.

$y_2 = a \sin\left(2000\pi t + \frac{\pi x}{0.17}\right)$ ✓

$y = y_1 + y_2 = a \sin\left(2000\pi t - \frac{\pi x}{0.17}\right) + a \sin\left(2000\pi t + \frac{\pi x}{0.17}\right)$

$y = a\left[\sin 2000\pi t \cos\frac{\pi x}{0.17} - \cos 2000\pi t \sin\frac{\pi x}{0.17} + \sin 2000\pi t \cos\frac{\pi x}{0.17} + \cos 2000\pi t \sin\frac{\pi x}{0.17}\right]$ 04

$y = 2a \cos\frac{\pi x}{0.17} \sin 2000\pi t = A \sin 2000\pi t$ ✓

hence $A = 2a \cos\frac{\pi x}{0.17}$

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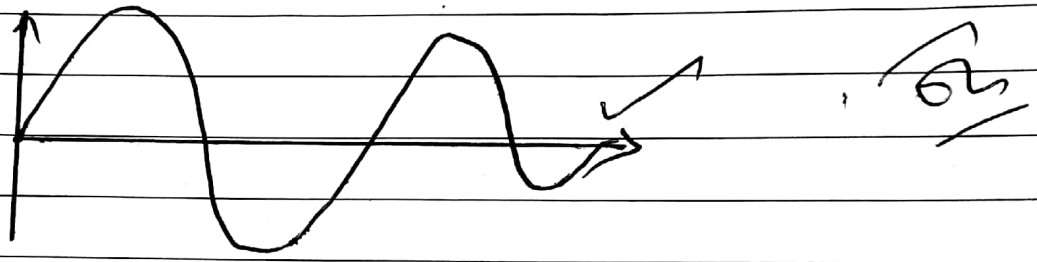
(9)

d) Damped vibrations are vibration in which energy of the system is lost to the surrounding and amplitude decreases.



Free vibrations are vibrations which occur in absence of dissipative forces, energy is not lost and amplitude does not decrease.

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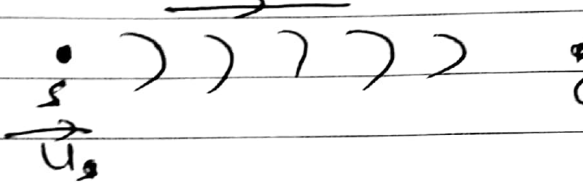
4 a) i) Harmonics are notes whose frequencies are integral multiple of a fundamental frequency produced by a musical instrument. 01

ii) Overtones are notes of higher frequencies than fundamental frequencies produced by a musical instruments. 01

b) i)



The wavelength λ' of its waves reaching its observer $= \frac{c-v}{f}$

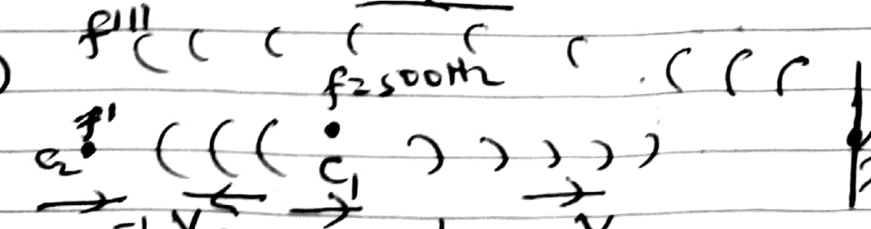
The speed of sound waves relative to the source is $c-v$

The apparent change in frequency of waves reaching the observer 04

$f' = \frac{\text{velocity of sound relative to observer}}{\text{wavelength of waves reaching observer.}}$

$f' = \frac{c}{\lambda'} \Rightarrow f' = \left(\frac{c}{c-v}\right) f$

ii)



(iv)

from $f' = \left(\frac{V \pm U_o}{V \pm U_s}\right) f$.

Case 1: waves recieved from the first car;

$f' = \left(\frac{V + U_o}{V + U_s}\right) f = \left(\frac{330 + 20}{330 + 10}\right) \times 500$

$= 514.7\ Hz$ ✓

case 2: waves reaching the bridge:

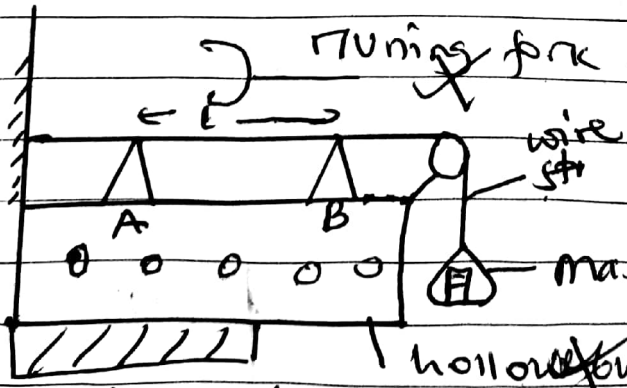
$f'' = \left(\frac{V}{V - U_s}\right) \times f = \left(\frac{330}{330 - 10}\right) \times 500$ ✗

$= 515.6\ Hz$ ✓ 05

Case 3: waves recieved as echo: ✗

$f''' = \left(\frac{V + U_o}{V}\right) \times f'' = \left(\frac{330 + 20}{330}\right) \times 515.6$

$= 546.8\ Hz$ ✓



A – fixed bridge.
B – movable bridge.

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> The wire is weighed to determine its mass and its length is measured and recorded.
> The mass per unit length is calculated $\mu = m/l$
> The wire is fixed on the sonometer as shown above
> Suitable masses are suspended to keep the wire under a suitable tension.
> A sounding tuning fork is brought near the wire as the wire is plucked in the middle.
> The bridge B is adjusted until a loud sound is heard.
> The distance l between the bridges is measured and recorded.
> The frequency, f, of the sounding tuning fork is also noted.
> The experiment is repeated using other wires of different mass per unit length.
> The results are tabulated including μ, $\sqrt{\mu}$, $\frac{1}{\sqrt{\mu}}$, $\frac{1}{l}$
> A graph of $\frac{1}{l}$ against $\frac{1}{\sqrt{\mu}}$ is plotted and a straight line passing through the origin is obtained implying $\frac{1}{l} \propto \sqrt{\mu}$, since $f \propto \frac{1}{l}$ it follows that $f \propto \frac{1}{\sqrt{\mu}}$.

05

d) $T = \frac{EAe}{L}$ but $\frac{e}{l}$ = strain = $\frac{1}{100} = 0.01$

$\mu = m/l = \frac{\rho V}{l} = \frac{\rho A l}{l} = \rho A$

$\Rightarrow T = 0.01EA$, but $f = \frac{1}{2l}\sqrt{\frac{I}{\mu}} = \frac{1}{2l}\sqrt{\frac{0.01EA}{\rho A}} = \frac{1}{2l}\sqrt{\frac{0.01E}{\rho}}$

$E = \frac{f^2 \times 4l^2\rho}{0.01} = \frac{4 \times 170^2 \times 2^2 \times 800}{0.01} = 3.7 \times 10^{11}$ Pa.

04

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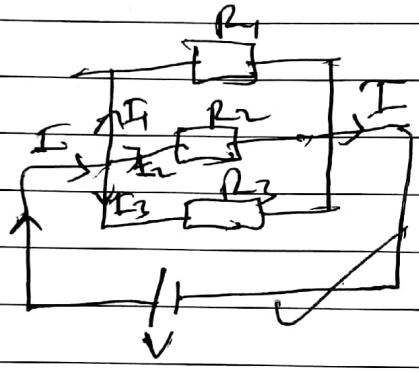
10 a) i) α is the fractional increase (change) in the resistance at 0°C per 1°C or 1K rise in temp.

ii) Internal resistance is the opposition to the flow of current inside the cell due to chemical composition inside the cell.

b)



p.d is the same,

Total current $I = I_1 + I_2 + I_3$

but $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$

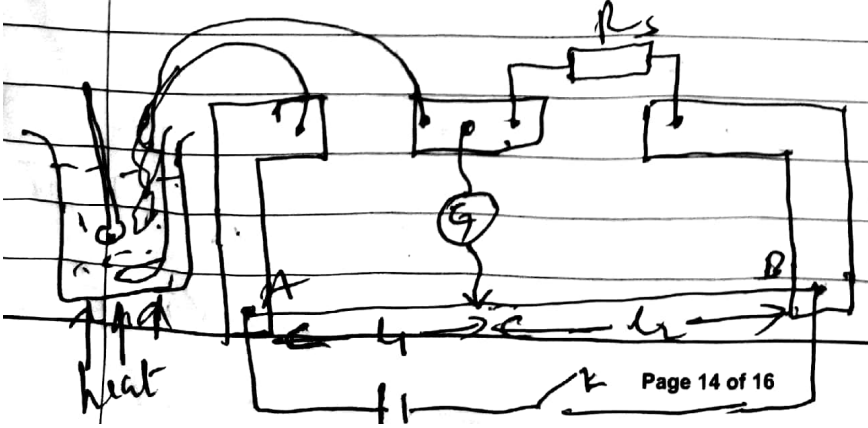
$I_3 = \frac{V}{R_3}$,

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad \text{but } \frac{I}{V} = \frac{1}{R}$$

Where R is effective resistance.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$



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- The circuit is connected as shown above with standard resistor connected in the right-hand gap and specimen fine resistance wire made into a coil immersed in a water bath connect in the left hand gap.
- The water bath is heated to a temp θ_1.
- The switch K is closed and the jockey is tapped along the wire till AB until Galvanometer shows no deflection
- The balance lengths l_1 and l_2 are measured and recorded.
- The resistance R_0 of the coil is got from

$$R_0 = \frac{l_2}{l_1} R_s$$

- The expt is repeated for different values of θ.
- The results are tabulated.
- The graph of R_0 against θ is plotted and slope found
- The intercept R_0 on R_0-axis is noted.
- The TCR is got from $\lambda = 5/R_0$ ✓ 06

4) $R_T = 2.4 + 2 = 4.4\ \Omega$

$$I = V/R = \frac{4}{4.4} = \frac{10}{11} A$$ ✓

$$V_{AB} = IR_{AB} = \frac{10}{11} \times 2 = \frac{20}{11} V$$ ✓ 04

$$k = \frac{20}{11}\Big/\frac{100}{100} = \frac{20}{1100} = \frac{2}{110}\ \Omega cm^{-1}$$ ✓ 04

Emf = p.d across AC

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$1.5 = \frac{2}{110} \times L$, $L = \frac{1.5 \times 110}{2}$

$= 82.5\text{cm}$

ii) at C, $R_{BC} = 1\Omega$.

2.95Ω.

$R_T = 1 + \frac{1 \times 20}{20+1} + 1 = 2 + \frac{20}{21} = \frac{41}{21}\Omega$.

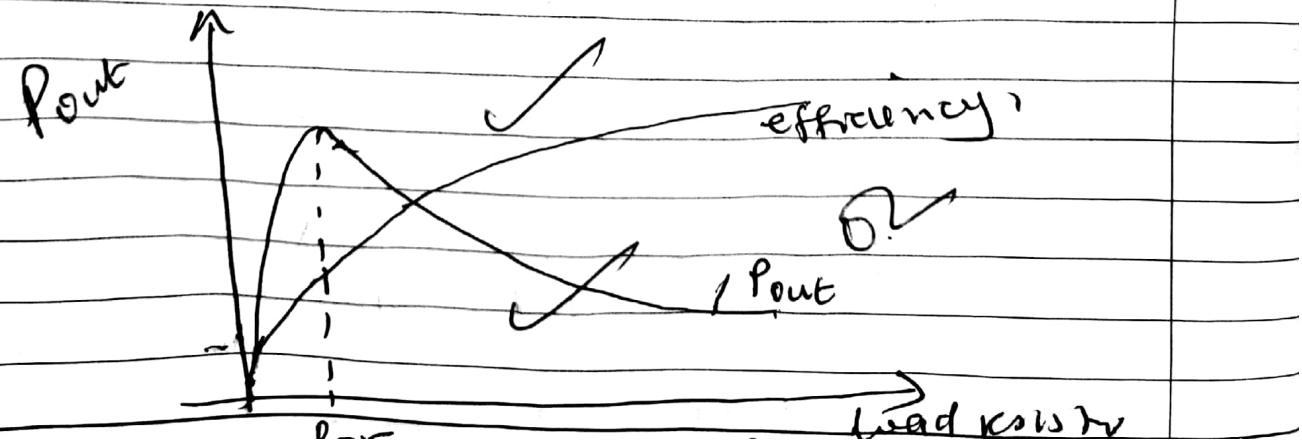
$I = V/R = \frac{4}{41/21} = \frac{84}{41} = 2.05A$

$= \frac{4}{2.95} = 1.356A$

$V_p = IR_p$, $R_1 = \frac{1 \times 20}{1+20} = \frac{20}{21}\Omega$

$\Rightarrow V_p = \frac{2.05 \times 20}{21} = 1.95V$

$= 1.356 \times \frac{20}{21} = 1.29V$



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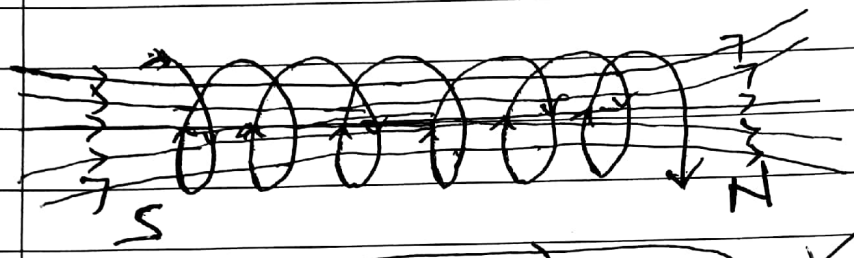
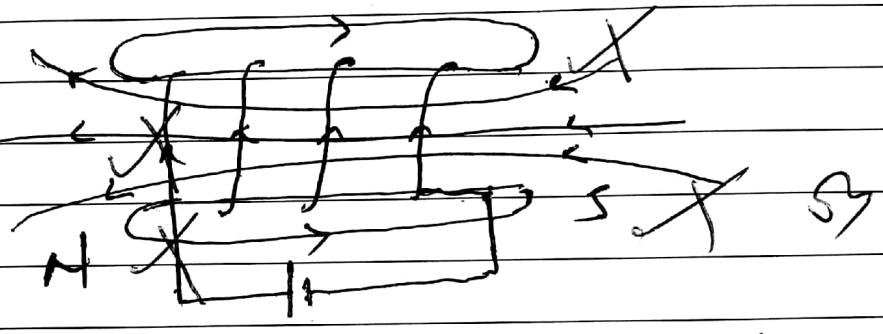
5a) Is the region/space around a magnet where magnetic forces are concentrated. ✓ = 1



or



✓ ½

- $B = \frac{\mu_0 NI}{2L}$ or $\frac{\mu_0 nI}{2}$ ✓

b) i) $F = BIL$ where L is the length of the conductor. ✓ of

ii) The magnetic field lines (flux) due to the current in the conductor which ~~are~~ interact with the external magnetic field due to poles. The resultant field has a greater flux density above than below. The conductor experiences a force and moves from a region of greater density to a region of smaller density. ½

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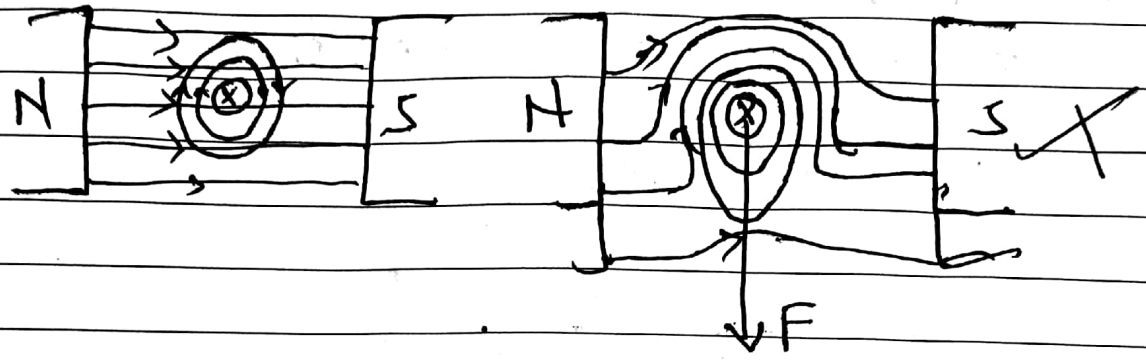
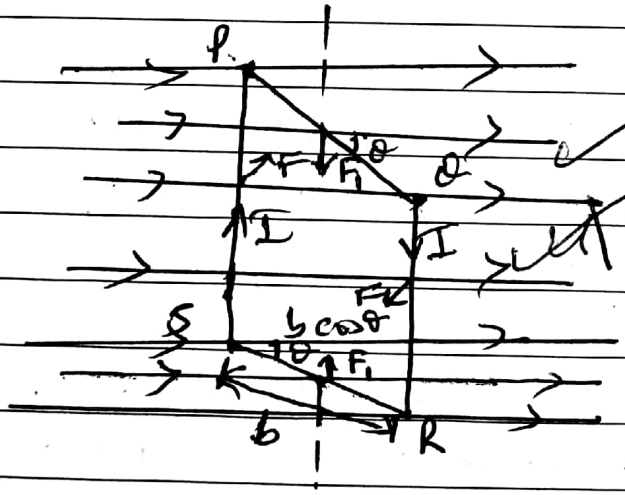


c) i) Magnetic torque is the product of one of the forces that constitute a couple and perpendicular distance between the forces.

ii)



The sides PS of length L experiences a force $F = BILN$ inwards.

Side QR experiences $F = BILN$ outwards.

Forces on PQ and SR are equal and opposite and they cancel out.

The two forces on PS and QR form couple and tend to turn the coil. The moment of couple or torque is given by $\tau = F \times b\cos\theta$

$\tau = (BIL.b\cos\theta)N$ but $L \times b =$ Area A, of the coil

$\tau = BINA\cos\theta$

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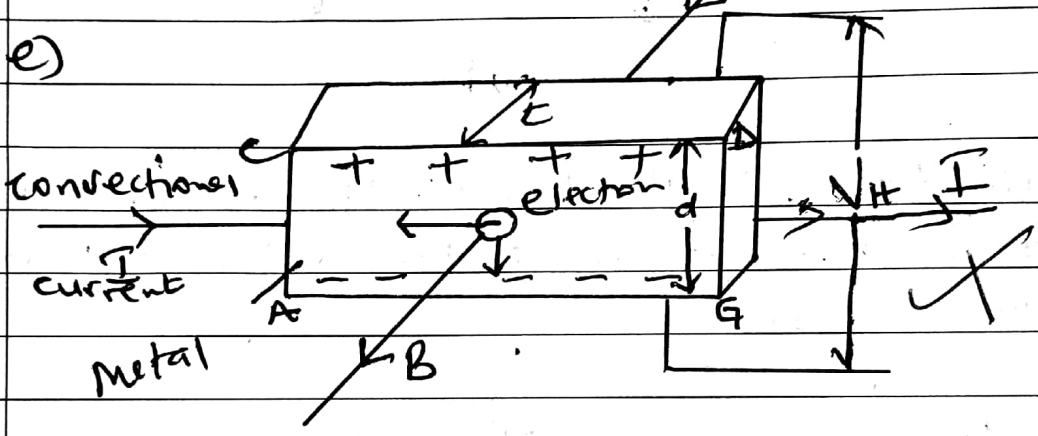
d) $\tau = BINA$

$= 0.02 \times 5 \times 10 \times (0.1 \times 0.05)$

$= 5 \times 10^{-3}$ Nm

e)



The metal is placed in magnetic field B at right angles to the face ADGC of the slab and directed out of the plane of the paper.

Each electron experiences a force given by Bev in the direction from CD to AG. This electrons accumulate on side AG, making side AG negatively charged and side CD positively charged. The potential of AG is lowered. So a potential difference develops across the slab which opposes the electron flow. The flow stops when the max voltage that develops when electrons stop flowing is called hall voltage.

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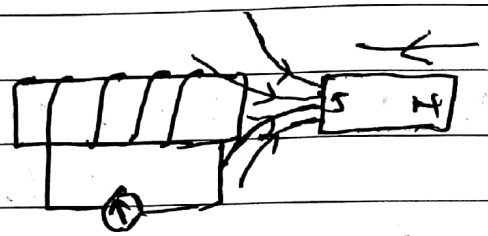
6 a) i) Lenz's law: The direction of induced current flows in such a direction as to oppose the change causing it.

Faraday's law: The magnitude of induced emf is directly proportional to the change causing it.

ii)



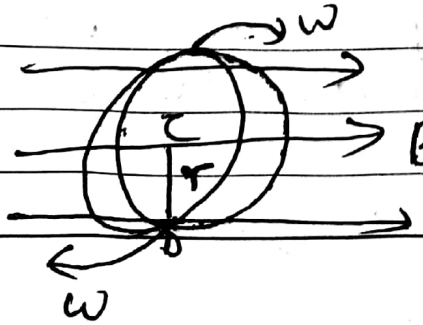
← Magnet plugged into the coil.

When a magnet is suddenly pushed with its south pole towards a coil connected to a galvanometer, the galvanometer shows a deflection showing that current has been induced in the coil.

On removal of the magnet from the coil, the galvanometer again deflects but in the opposite direction.

If the magnet and the coil are stationary, the galvanometer gives no deflection because there is no change in the magnetic flux.

b) Consider a disc of radius r rotating about its axis.



CD cuts magnetic flux continuously

Average velocity v of CD = $\frac{0+\omega r}{2}$

$v = \frac{\omega r}{2}$

Induced emf $E = BlV$

$= B \cdot r \cdot \frac{rw}{2}$

$= \frac{Br^2w}{2}$ but $w = 2\pi f$

$\therefore E = \frac{Br^2 \cdot 2\pi f}{2}$

$= Br^2\pi f \Rightarrow E = \pi r^2 Bf$ but $\pi r^2 = A$

$= BAf$

or Magnetic flux linking $\phi = AB$

Induced emf $E = -\frac{d\phi}{dt}$, $E = -\frac{B\,dB}{dt}$

$E = -\frac{B\,dA}{dt}$ but $\frac{dA}{dt} = \frac{\pi r^2}{T} = \pi r^2 f$

$|E| = B\pi r^2 f = BAf$.

c) The are currents which circulate in the coil when magnetic flux linking it changes.

ii)

> Electromagnetic brakes:

An electromagnet is used to generate magnetic field that induces eddy currents in a nearby conductive material. The eddy currents create an opposing force which slows down the moving object.

or used in damping of moving coil galvanometer.

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r Used in Metal detection and sorting.
Heat treatment
Magnetic resonance Imaging (E.MRI)
Electromagnetic Interference (EMI) shielding.
Wireless power transmission.

d) $Q = \frac{BAH}{R}$

$$\frac{2.5\times10^{-3} \times 3\times10^{-4} \times 200}{200}$$

$$= 1.5\times10^{-6}\,C$$

$$= 1.5\mu C$$

Damping:

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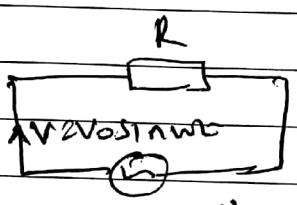
8 a) Is the one which varies periodically with time in magnitude and direction ✓ 0

b) i) Rms of alternating voltage is the direct voltage that dissipates heat in a given resistor at the same rate as the alternating voltage, ✓ Peak value is the maximum value of alternating voltage. ✓ 0

ii)



Instantaneous voltage $V = V_0 \sin \omega t$.

Instantaneous power $P = \frac{V^2}{R} = \frac{V_0^2 \sin^2 \omega t}{R}$

Average power $\langle P \rangle = \frac{\langle V_0^2 \sin^2 \omega t \rangle}{R} = \frac{V_0^2}{R} \langle \sin^2 \omega t \rangle$

but $\langle \sin^2 \omega t \rangle_T = \frac{1}{2}$.

$\langle P \rangle = \frac{V_0^2}{2R}$ ✓

for power d.c in the same resistor

$P_{dc} = \frac{V_{dc}^2}{R}$ but $V_{dc} = V_{rms}$ $P_{dc} = \frac{V_{rms}^2}{R}$

but $P_{ac} = P_{ac} \Rightarrow \frac{V_{rms}^2}{R} = \frac{V_0^2}{2R}$ ✓

$V_{rms} = \frac{V_0}{\sqrt{2}}$ ✓

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c) $Z = \sqrt{X_L^2 + R^2}$ $\quad \frac{V_{rms}}{I_{rms}}$

$R_T = 450 + 50 = 500\Omega$

$\frac{100}{I_{rms}} = \sqrt{50^2 + 450^2}$, $X_L = 2\pi Lf$

$= 2 \times 3.14 \times 2 \times 50 = 628\Omega$

$I_{rms} = 0.22A \Rightarrow V = IX_L$

$R_T = 500\Omega$

$I_{rms} = \frac{100}{\sqrt{628^2 + 500^2}} = 0.125A$ B

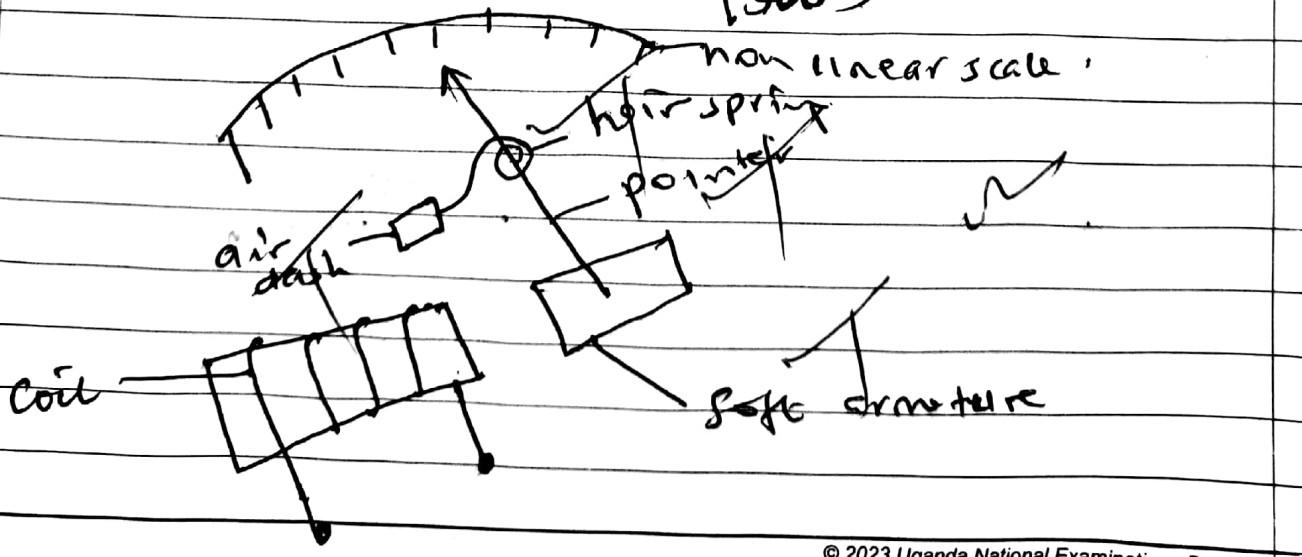
$V = 0.125 \times 628 = 78.5V$

$P = I^2R = 0.125^2 \times 500$ B

$= 7.8125W$

$\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{628}{500}\right) = 51.5^\circ$

d)



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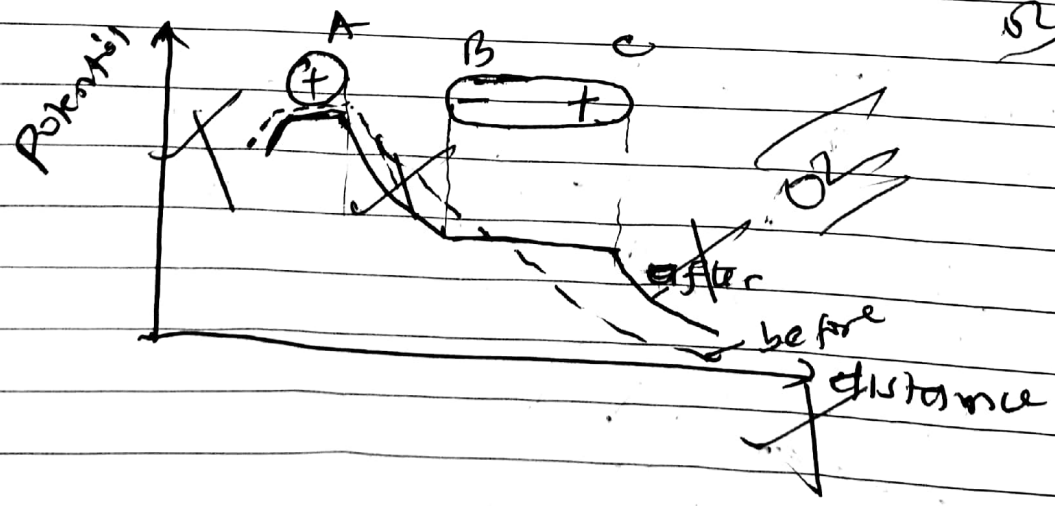
current to be measured is passed through the solenoid, the soft iron armature gets magnetized and is attracted towards the coil in what direction of current.
This causes the pointer to deflect over the scale until it is stopped by restoring couple of the hair spring.
The deflection θ is proportional to the attractive force hence $\theta \propto \langle I^2 \rangle$; hence non linear scale.

iii) When the sphere is brought near the neutral conductor, it induces a negative charge at B and positive charge is repelled at C. Since A and B are nearer than C and opposite to that on A, the potential between A and B reduces.



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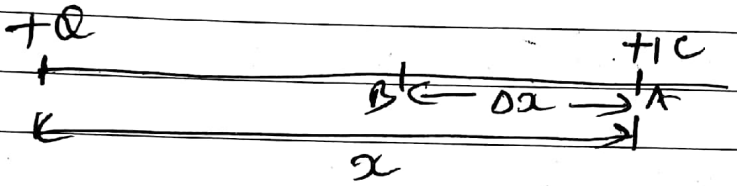
(8) a) i) Electric potential is the work done to move a positive 1C of charge from infinity to a point against electric force.

Electric field strength is the force acting on +1C placed in an electric field.

ii) Consider a +1C charge, x m away from +Q.

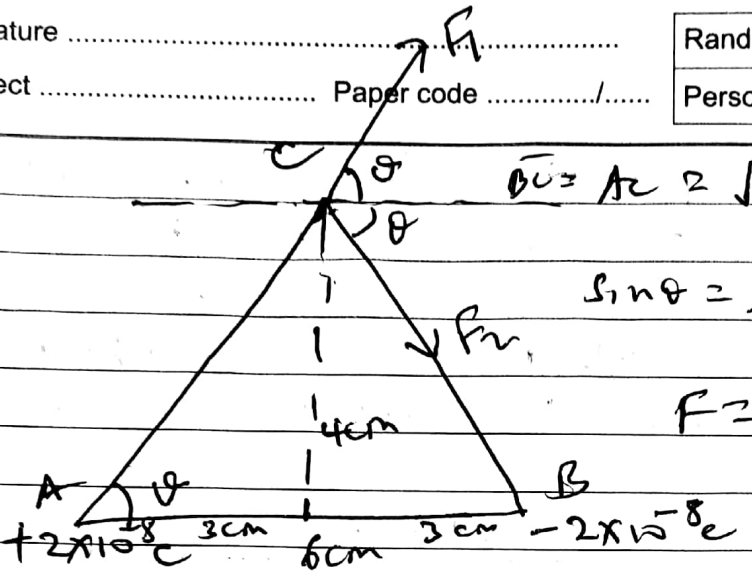


Work done to move the charge through δx against field $\delta W = -F\delta x$, but force on +1C, $F = \frac{kQ}{x^2}$

Total work $W = \int_{\infty}^{r} -\frac{kQ}{x^2}\,dx = -kQ\left[\frac{-1}{x}\right]_{\infty}^{r}$

$= -kQ\left[-\frac{1}{r} - \frac{1}{\infty}\right]$

$= \frac{kQ}{r}$, $\therefore V = \frac{Q}{4\pi\varepsilon_0 r}$



$\overline{BC} = AC = \sqrt{3^2+4^2} = 5\,cm$

$\sin\theta = \frac{4}{5}, \cos\theta = \frac{3}{5}$

$F = \frac{kq_1q_2}{r^2}$

$F_1 = \frac{9\times10^9 \times 2\times10^{-8}\times10^{-8}}{0.05^2} = 7.2\times10^{-4}\,N$

$F_2 = \frac{9\times10^9 \times 2\times10^{-8}\times10^{-8}}{0.05^2} = 7.2\times10^{-4}\,N$

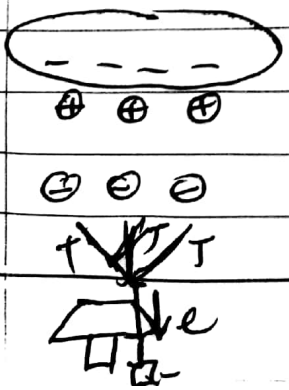
→ally, $F_x = F_1\cos\theta + F_2\cos\theta$
$= 2\times 180\times\frac{3}{5} = 216\,N = 2.16\times10^{-6}\,N$

↑ally: $F_y = F_1\sin\theta - F_2\sin\theta$
$(180\times\frac{4}{5} - 180\times\frac{4}{5})N = 0\,N$

net force of $F = \sqrt{(2.16\times10^{-6})^2 + 0^2} = 2.16\times10^{-6}\,N$ along $x - 9\times10^{9}$.

$F = \sqrt{(8.64\times10^{-4})^2 + 0^2} = 8.64\times10^{-4}\,N$

d) Lightening conductor.



When negatively charged cloud passes over a lightning conductor, it induces a large positive charge on the spike and electrons are repelled to the ground. Due to high charge density, air around

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is ionised producing positive and negative ions.

The positive ions are repelled upwards and discharge the cloud.

The negative ions are attracted to the spikes and neutralise the charge on the spike. hence the horse is protected from being struck. Q3

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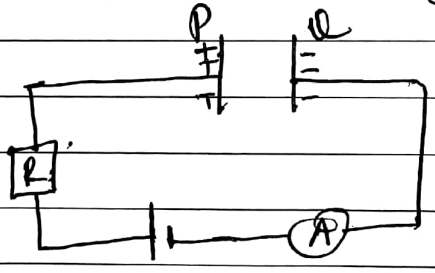
(9)

a) i) Faraday is the capacitance of a capacitor when a charge of 1C is stored on either plates and the p.d across the plates is 1V.

ii) capacitance is the ratio of magnitude of charge on either plates to the p.d across the plates.

b) i) storing large quantities of charge
preventing sparking in large industrial switches
Tuning in radio and TV circuits.
Ignition circuit in automobiles
Smoothing and filtering process in rectification

ii)



When a capacitor is connected as shown above, the electrons flow from the negative terminal to the adjacent plate Q of the capacitor and at the same time the electrons flow from plate P to the positive terminal of the battery leaving the plate P with positive charge. The positive and negative charge therefore appear on the plates and oppose the further flow of electrons.
As the charge accumulate the p.d between the plates increases and current drops to zero when the p.d between the plates is equal to the e.m.f of charging battery and the capacitor is fully charged.

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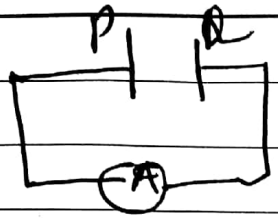
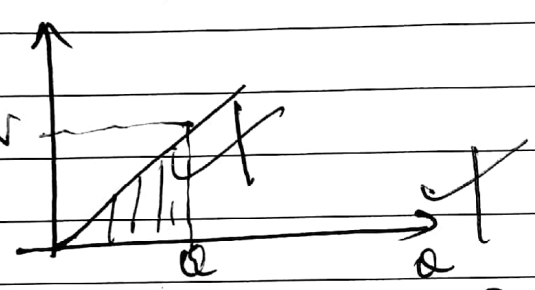


During discharging process the wire is connected from P to Q such that the electrons flow through the connecting wire until when all charges on P have been neutralised and ammeter reading drop to zero, hence the capacitor is discharged.

ii) $C = Q/V$, $V = Q/C \Rightarrow V \propto Q$.



Energy = Area under the graph.
$E = \frac{1}{2} \times Q \times V$ but $Q = CV$
$\frac{1}{2} \times CV \times V$
$= \frac{1}{2} CV^2$

d) i) $Q = CV$ Also $Q = It$ where $t = 1/n$
$\Rightarrow Q = I/n$.
$\Rightarrow CV = \frac{I}{n}$, $I = nCV$.

ii) When working, S touches the left and right wires. When touches left wire it is charged and discharges when touches right hand side wire.
The micrometer reading I and Voltmeter reading V are noted. If f is the Av. frequency of the source, then capacitance is got from $C = \frac{I}{nV}$

e) $\frac{1}{2} CV^2 = mc(\theta_2 - \theta_1) \Rightarrow \frac{1}{2} \times C \times 200^2 = 0.1 \times 2.5 \times 10^2 \times 0.4$

$C = \frac{10}{20000} = 5 \times 10^{-4} C$