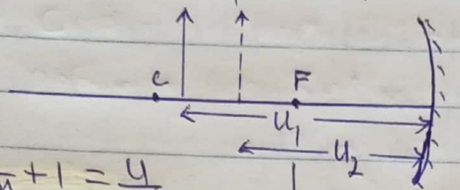
S6 Physics Seminar Sept. 2022

Physics Paper two (P510/2)

1(a) (i) It is the point on the principal axis where rays of light originally parallel and close to the principal axis appear to diverge from after reflection.

(ii) It is the reflecting surface of the mirror or width of the reflecting surface.

(b)



$m_1 = 2$
$m_2 = 2.5$
$u_1 - u_2 = 6\text{ cm}$.

From $\frac{1}{m} + 1 = \frac{u}{f}$

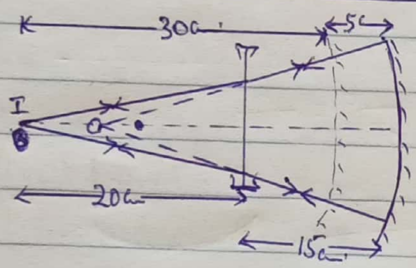
$\frac{u_1}{f} = \frac{1}{2} + 1 = \frac{3}{2}$ —(1)

$\frac{u_2}{f} = \frac{2}{5} + 1 = \frac{7}{5}$ —(2)

$\therefore \frac{u_1 - u_2}{f} = \frac{3}{2} - \frac{7}{5} = \frac{15-14}{10}$

$\Rightarrow \frac{6}{f} = \frac{1}{10}$ $\quad \therefore f = 60\text{ cm}$

(c) (i)



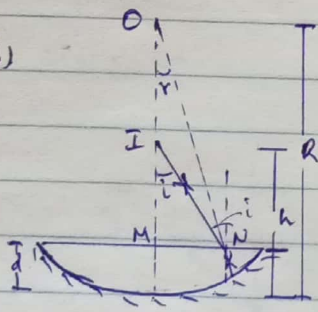
(ii) Action of the lens.

$u = -(30-15) = -15\text{ cm}$.

$v = 20\text{ cm}$

$f = \frac{uv}{u+v} = \frac{-15 \times 20}{-15+20} = -60\text{ cm}$

(d) (i)



Consider a ray of light from I incident on the liquid surface at N, it is refracted ~~along~~ parallel to ON. Refractive index n is

$n = \frac{\sin i}{\sin r}$, But $\sin i = \frac{MN}{IN}$, $\sin r = \frac{MN}{ON}$.

$\Rightarrow \frac{\sin i}{\sin r} = \frac{MN}{IN} \times \frac{ON}{MN} = \frac{ON}{IN}$

Since N is very close to M, $\overline{ON} \simeq \overline{OM}$ and $\overline{IN} \simeq \overline{IM}$.

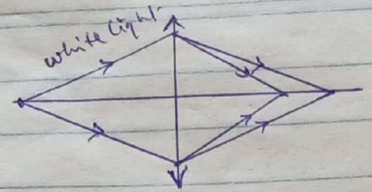
$\therefore \frac{\sin i}{\sin r} \simeq \frac{OM}{ON} = \frac{R-d}{h}$. Since the liquid is very small, $d \simeq 0$.

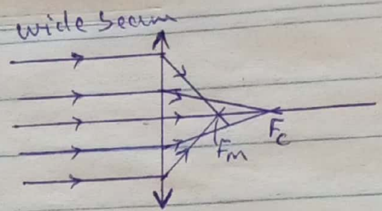
$\therefore n = \frac{R}{h}$.

(ii) $R = 15\text{ cm}$, $d = 3\text{ cm}$, $h + d = 12.6\text{ cm}$.

$\therefore$ using $n = \frac{R-d}{h} = \frac{15-3}{12.6-3} = 1.25$

2(a) (i)





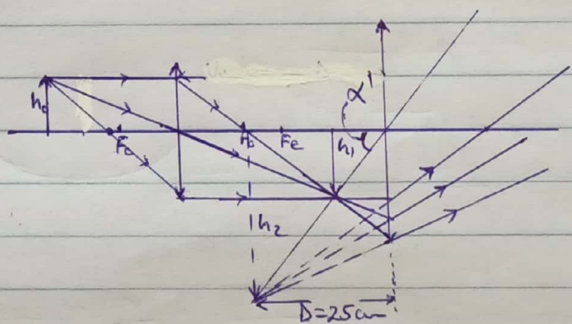
In chromatic aberration a white beam of light incident on a lens, is dispersed to form images corresponding to different colours at different points. The image viewed is blurred with coloured edges.

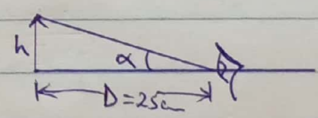
In spherical aberration a wide beam of light incident on the lens is refracted such that the marginal rays are focused closer to the lens and the central rays farther away. The image viewed is blurred without colours.

(ii)

Microscopes	Telescopes
- Have objective of short focal length and eye piece of long focal length.	- Have objective of long focal length and eye-piece of short focal length.
- used for viewing near objects.	- used for viewing distant objects.

(b)(i)





(ii) Angular magnification $M = \frac{\alpha'}{\alpha}$.

From above diagrams, for small angles α, α' measured in radians,

$$\alpha \simeq \tan\alpha = \frac{h}{D} \qquad \alpha' \simeq \tan\alpha' = \frac{h_2}{D}.$$

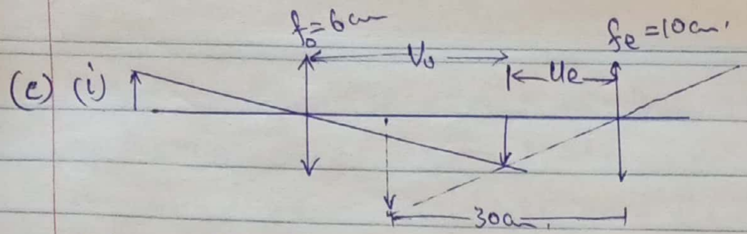
$$\therefore M = \frac{h_2}{D} \div \frac{h}{D} = \frac{h_2}{h} = \frac{h_2}{h_1} \times \frac{h_1}{h}.$$

But $\frac{h_2}{h_1} = \frac{v_e}{f_e} - 1 = -\frac{D}{f_e} - 1$ and $\frac{h_1}{h} = \frac{v_o}{f_o} - 1$

$$\therefore M = -\left(\frac{D}{f_e} + 1\right)\left(\frac{v_o}{f_o} - 1\right)$$

(iii)

(c) (i)



Action of the objective.

$u = 8cm$, $f = 6cm$

using $V_o = \frac{U_o f_o}{U_o - f_o} = \frac{8 \times 6}{8 - 6}$

$= 24cm$

Action of the eye piece.

$U_e = \frac{V_e f_e}{V_e - f_e} = \frac{-30 \times 10}{-30 - 10}$

$= 7.5cm$

$\therefore$ Separation of the lenses $= V_o + U_o = 24 + 7.5 = 31.5cm$

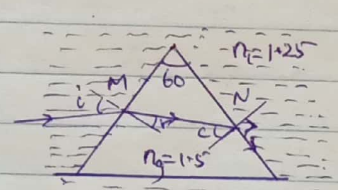
(ii) linear magnification

$M = m_1 \times m_2 = \frac{v_1}{u_1} \times \frac{v_2}{u_2} = \frac{24}{8} \times \frac{30}{7.5} = 12$.

3(a) - The incident ray the refracted ray and the normal at the point of incidence all lie in the same plane.

- The ratio of the sine of angle of incidence to the sine of angle of refraction is a constant for a ray of light moving from one medium into another.

(b)(i)



At N, $n_g \sin C = n_l \sin 90$

$\Rightarrow \sin C = \frac{n_l}{n_g} = \frac{1.25}{1.5}$

$\therefore C = 56.4°$

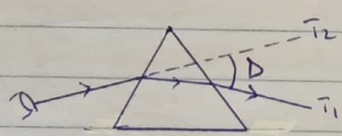
At M, $n_l \sin i = n_g \sin r$

but $r = 60 - 56.4 = 3.6°$

$\therefore \sin i = \frac{1.5 \sin 3.6}{1.25}$

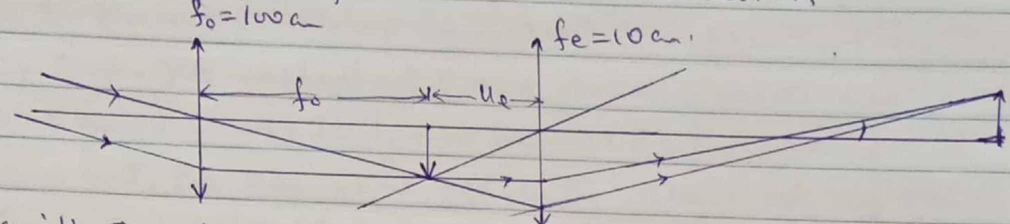
$\Leftrightarrow i = 4.3°$

(ii)



using a spectrometer. The telescope is adjusted to focus parallel light, the collimator is adjusted to produce parallel light, and the table is levelled. The prism is then placed on the table with its refracting edge facing away from the collimator. The telescope is turned to the opposite side of the prism to receive the refracted light. The table and telescope are now turned in one direction until light just begins to move in opposite direction. The angular position, T_1, of the telescope on the scale is noted. The prism is removed from the table and the telescope turned to receive light directly from the collimator. The angular position T_2 of the telescope is noted. The angle, D, between the two positions is measured, and is the angle of minimum deviation.

(c)



Magnification by the objective

$M_1 = \frac{v_o}{f_o} - 1 = \frac{100}{100} - 1 = 0$.

Magnification by the eyepiece.

$M_2 = \frac{v_e}{f_e} - 1 = \frac{20}{10} - 1 = 1$

Total magnification $M = M_1 \times M_2 = 0 \times 1 = 0$

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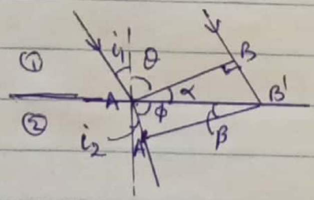
4 (a)(i) It is a section through an advancing wave on which all particles are vibrating in phase.

(ii) It states that every point on a wavefront acts as a source of secondary wavelets that move in the forward direction with the velocity of the wave and the new wavefront is the envelope which just touches the surfaces of the wavelets.

(iii)



Consider wave front AB, when side A has just reached the boundary with medium ②.

$i_1 + \theta = 90 \Rightarrow i_1 = 90 - \theta$. $\therefore \alpha = i_1$

& $\alpha + \theta = 90 \Rightarrow \alpha = 90 - \theta$

also $i_2 + \phi = 90 \Rightarrow i_2 = 90 - \phi$ and $\beta + \phi = 90 \Rightarrow \beta = 90 - \phi \therefore \beta = i_2$.

Now C_1 and C_2 are the velocities of light in media ① and ② respectively. Suppose B takes time t to move to B', ~~and~~ A takes time, t, to move to A', then $BB' = C_1 t$ and $AA' = C_2 t$. From the diagram $\sin\alpha = \frac{BB'}{AB'}$ and $\sin\beta = \frac{AA'}{AB'}$; therefore, $\frac{\sin i_1}{\sin i_2} = \frac{\sin\alpha}{\sin\beta} = \frac{BB'}{AB'} \times \frac{AB'}{AA'}$

$\Leftrightarrow \dfrac{\sin i_1}{\sin i_2} = \dfrac{BB'}{AA'} = \dfrac{C_1 t}{C_2 t} = \dfrac{C_1}{C_2}$,

(b) (i) Doppler effect is the apparent change in frequency of a wave due to relative motion between the source and the observer.

(ii) Microwaves from the speed gun are directed on to an approaching car, and is reflected by the car. The reflected wave mixes with the out going waves to form beats. As the wave goes out, the apparent velocity received by the car is $C+U_o$. When reflected the apparent wavelength is $\frac{C-U_o}{f}$. Therefore apparent frequency of the reflected wave $f' = \frac{C+U_o}{C-U_o}.f$. Beat frequency therefore is $\frac{C+U_o}{C-U_o}f - f = \frac{2U_o f}{C-U_o}$. Therefore Beat frequency $f_b \simeq \frac{2U_o f}{C} \Rightarrow U_o = \frac{C f_b}{2f}$. The speed gun counts the beats and calculates the velocity U_o of the vehicle.

(C) (i) Let the velocity of the car be U_o, then wavelength from the approaching car $\lambda' = \frac{V-U_o}{f}$

apparent frequency $f' = \frac{V}{V-U_o}.f = 600$

$\therefore f = \frac{600(320-U_o)}{320}$.

apparent wavelength from the receding car $\lambda'' = \frac{V+U_o}{f}$, and apparent frequency $f'' = \frac{V}{V+U_o}.f = 560$

$\Rightarrow f = \left(\frac{320+U_o}{320}\right) \times 560$.

$\therefore \left(\frac{320+U_o}{320}\right) \times 560 = \left(\frac{320-U_o}{320}\right) \times 600$

$= 320+U_o = (320-U_o) \times \frac{600}{560} = 320 \times 1.07 - 1.07 U_o$.

$\Leftrightarrow (1+1.07)U_o = 320(1.07-1)$

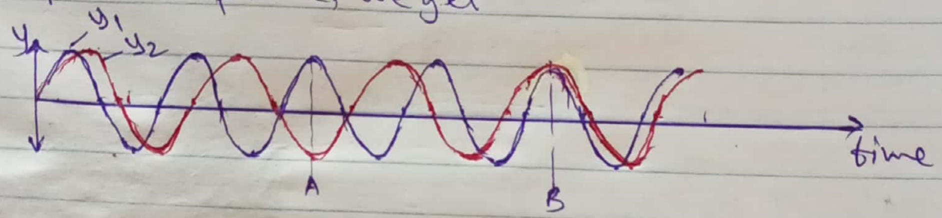
$\Leftrightarrow \quad U_o = \frac{320 \times 0.07}{2.07} = 10.8\,m/s$.

(ii) $U_o = \frac{C f_b}{2f} = \frac{3 \times 10^8 \times 0.6}{2 \times 10 \times 10^6} = 9\,m/s$.

5(a) (i) When two waves superpose, the resultant displacement at any point is the sum of the displacements due to the individual waves at that point.

(ii) Beats is a note whose intensity rises and falls periodically, formed by superposition of two notes of slightly different frequencies but similar amplitudes sounded together.

(b) (i) Let the progressive waves be $y_1 = a\sin 2\pi\left(f_1 t - \frac{x}{\lambda_1}\right)$ and $y_2 = a\sin 2\pi\left(f_2 t - \frac{x}{\lambda_2}\right)$. If $f_1 > f_2$ then $T_2 > T_1$. When plotted as function of time, we get



When the waves are sounded together they superpose. At instants like A, the waves meet completely out of phase, cancellation takes place and no sound is heard. At instants like B, the waves arrive in phase and reinforcement takes place. A loud sound is heard. Since the waves are not coherent, the positions of reinforcement and cancellation keep changing. Hence a periodic rise and fall in intensity.

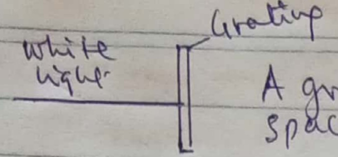
(ii) $y = 4\sin 2\pi\left(\frac{t}{0.1} - \frac{x}{2}\right)$ $\Rightarrow f = \frac{1}{0.1} = 10\,Hz$

c.f. $y = a\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$ $\lambda = 2\,m$.

$\therefore v = f\lambda = 2 \times 10 = 20\,m/s$.

(c) (i) In division of wavefront, wave energy from the same wave front is divided to take different paths and then meet again as if from different sources, while in division of amplitude, the wave energy is divided by partial reflection and partial refraction to travel different paths and meet again.

(ii)



A grating consists of many clear spaces close to each other. When white light is incident on the grating, it diffracts through the spaces and get dispersed. The diffraction patterns due to different wave lengths from the same slit superpose, and also superpose with those from other slits. The resultant pattern has sharp and brightly coloured bands. The colours range from violet near the point of incidence of the white light, to red farther out side.

(iii) using $y_m = \frac{m\lambda D}{a}$ $\Rightarrow \lambda = \frac{a\, y_m}{mD}$

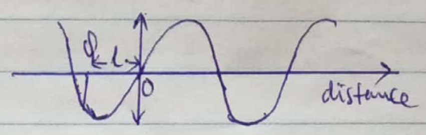
$\therefore \lambda = \frac{0.18\times10^{-6}\times 8.1\times10^{-3}}{3\times0.5} = \underline{\underline{9.72\times10^{-7}\,m}}$

(d) As white light from the sun travels through the sky and air in the atmosphere, it is scattered by the water droplets. Short wavelength light is scattered more than long wavelength light. At sun set, the light travels a very long path to reach the earth. It therefore reaches the earth when nearly all the short wavelength light has been scattered. The light received is therefore predominantly red, making the sun appear red.

6(a)(i) Frequency is the number of cycles made by a wave per second or number of waves produced by the source per second.

(ii) A phase is a stage in a cycle of vibration that a particle in a wave undergoes.

(b)



Consider a wave travelling from left to right.

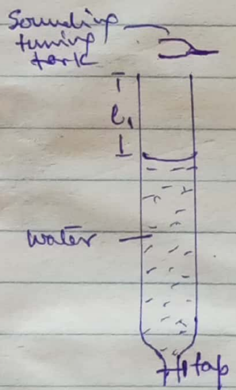
Suppose the displacement function for a particle at O is $y = a\sin 2\pi ft$.

The vibration of the particle at Q, distance l to the left of O lags on that at O by a time $\left(-\frac{l}{\lambda}T\right)$. Its time of vibration therefore is $t-\left(-\frac{l}{\lambda}T\right)$ and its displacement function is $y = a\sin 2\pi f\left(t-\left(-\frac{l}{\lambda}T\right)\right) = a\sin\left(2\pi ft + 2\pi f\frac{l}{\lambda}.T\right)$

$$y = a\sin\frac{2\pi}{\lambda}(f\lambda t + l) = a\sin\frac{2\pi}{\lambda}(vt + l)$$

(ii) When the wave is reflected, they superpose to form stationary waves, whose characteristics are :-
- They have nodes and antinodes.
- amplitude of the wave varies with position along the profile.
- The energy of the wave does not flow along the profile.
- All particles between adjacent nodes in the wave vibrate in phase.

(c)



A long glass tube is filled with water and a sounding tuning fork held above its open end. The tap is opened and water is allowed out until a loud sound is heard. The tap is closed and the length l_1 of the air column in the tube is measured. The tuning fork is again sounded and held above the glass. Water is allowed out until a loud sound is heard again. The tap is closed and the length l_2 of the air column is measured, and recorded together with the frequency f of the tuning fork. Velocity, v, of sound is then calculated from $v = 2f(l_2 - l_1)$.

(d) (i) using $f_n = \frac{nv}{4l}$, $1564 = \frac{n \times 340}{4 \times 0.29}$

$$\Rightarrow n = \frac{1564 \times 4 \times 0.29}{340} = 5.3$$

$\therefore n = 7$

(ii) When $n=7$,

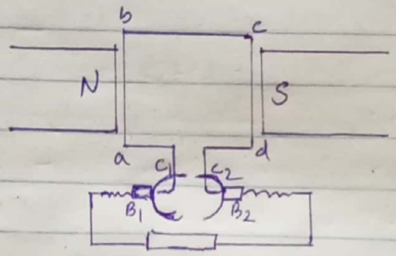
$$1564 = \frac{7 \times 340}{4 \times (0.29+e)}$$

$$\Leftrightarrow 0.29+e = \frac{7\times 340}{4 \times 1564} = 0.38$$

$$\therefore e = 0.38 - 0.29 = 0.09\,m.$$

7 (a) Electromagnetic induction is the production of emf in a circuit (or conductor) due to change in magnetic flux linkage with the circuit (or conductor).

(b)



abcd – coil
NS – pole pieces of permanent magnet.
C_1C_2 – Commutators
B_1B_2 – Carbon brushes.

The set up is as above. The coil is rotated with uniform angular velocity, and the resulting current tapped out through the carbon brushes $B_1 B_2$.
When side ab is moving up and cd down, emf is induced in the coil in the direction abcd. In the vertical position, the induced emf is zero. As ab begins to move down and cd up, current reverses in the coil, but at this same time, the commutator halves change contacts with carbon brushes C_1 to B_2 and C_2 to B_1. Current supplied to the load therefore continues to flow in the same direction.

(c) (i) $E_b = V - Ir$ also $E_b = \omega NBA$.

$$\therefore \omega NBA = V - Ir$$

$$\Leftrightarrow \omega = \frac{V-Ir}{NBA} = \frac{240-(0.8\times 50)}{600 \times 2\times 10^{-4} \times 0.4}$$

$$= 416.7 \text{ rad s}^{-1}$$

(ii) Efficiency $\eta = \frac{E_b}{V} \times 100 = \frac{(240-(0.8\times 50))}{240}\times 100$

$= 83.3\%$

(d) When magnetic flux linking the coil changes, emf is induced in it. Induced emf
$E = -\frac{d\phi}{dt}$. Induced current $I = \frac{E}{R} = -\frac{1}{R}\frac{d\phi}{dt}$.
But $I = \frac{dQ}{dt}$ $\therefore \frac{dQ}{dt} = -\frac{1}{R}\frac{d\phi}{dt}$.
$\Leftrightarrow dQ = -\frac{1}{R}d\phi$
If the magnetic flux linkage changes from ϕ_0 to ϕ_f then total charge induced

$$Q = \int_{\phi_0}^{\phi_f} -\frac{1}{R}d\phi = -\frac{1}{R}[\phi]_{\phi_0}^{\phi_f} = -\left(\frac{\phi_f-\phi_0}{R}\right)$$

$$= \frac{\phi_0-\phi_f}{R}.$$

8(a)(i) Mutual induction is the production of emf in a circuit due to change of current in a nearby circuit while self induction is the production of emf in a circuit due to change of current in the same circuit.
- Mutual induction requires two circuits while self induction requires only one circuit.

(ii) Self inductance is the ratio of back emf induced to the rate of change of current in the same circuit.

(b) (i) A transformer consists of a primary and secondary coils wound on a soft iron ring. The primary is connected to an alternating voltage supply, while the secondary is connected to an external load.
When a.c. flows in the primary coil, it establishes changing magnetic field

which links the primary coil. A back emf is thus induced in the primary. For finite current in the primary, the back emf equals the supply voltage $V_p = -N_p A \frac{dB}{dt}$ —①.

The changing magnetic field in the primary also links the secondary coil, inducing emf in it. The induced emf,

$$V_s = -N_s A \frac{dB}{dt} \quad —②$$

②/① $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

When $N_s > N_p$, $V_s > V_p$ it is a step up transformer

When $N_s < N_p$, $V_s < V_p$ it is a step down transformer.

(ii) When increases, the magnetic flux due to it also increases. Since this flux acts in opposition to that due to primary current, the flux linkage, and rate of change of flux linkage with the primary reduces leading to a reduction in back emf in the primary. When the back emf reduces, the primary current increases.

(c) $V_p = \frac{N_p V_s}{N_s} = \frac{3000}{150} \times 12 = 20V$.

Now $\frac{I_s V_s}{I_p V_p} = 0.9 \Leftrightarrow \frac{30}{I_p \times 20} = 0.9$.

$\therefore I_p = \frac{30}{20 \times 0.9} = 1.67 A$.

$\therefore I_0 = \sqrt{2} \times I_{rms} = \sqrt{2} \times 1.67 = 2.36 A$.

(d) — It is cheaper to produce a.c. in large amounts compared to d.c.

— a.c. can be transmitted long distances with minimum loss of power compared to d.c.

— It is easier to produce a.c. than d.c. even on small scale.

9 (a) (i) Impedance is the total opposition to flow of alternating current in a circuit containing both resistive and reactive components.

(ii) Reactance is the non-resistive opposition to flow of alternating current in a circuit containing a capacitor or inductor or both.

(b) (i) Back emf induced

$$E = -L\frac{dI}{dt} = -0.04 \times \frac{d}{dt}(5\sin 120\pi t).$$

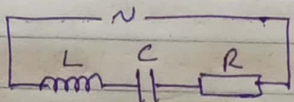
$$= -0.04 \times 120\pi \times 5 \cos 120\pi t.$$

$$= -75.36 \cos 120\pi t.$$

(ii) $E_0 = 75.36.$

$$\therefore E_{rms} = \frac{75.36}{\sqrt{2}} = 53.3\,A.$$

(c) (i)



Consider the circuit above connected across a voltage source of $V = V_0 \sin wt. = V_0 \sin 2\pi f t.$

$X_L = 2\pi f L$ while $X_c = \frac{1}{2\pi f c}.$

Resonance in the circuit occurs when $X_L = X_c.$

$$\Rightarrow 2\pi f L = \frac{1}{2\pi f c} \quad \Leftrightarrow 4\pi^2 f^2 LC = 1$$

$$\Rightarrow f^2 = \frac{1}{4\pi^2 Lc} \quad \therefore f = \frac{1}{2\pi\sqrt{LC}}$$

(ii) When current flows in the solenoid, magnetic flux density at the centre of the coil

$$B = \mu_0 \frac{N}{x} I$$

Magnetic flux linkage with the coil

$$\Phi = NBA. = N.\mu_0 \frac{N}{x} I.A.$$

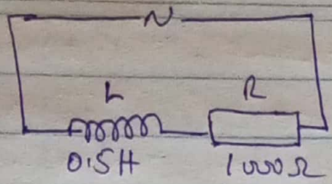
Back emf induced in the coil

$$E = -\frac{d\Phi}{dt} = -\frac{d}{dt}\left(\mu_0 \frac{N^2}{x} A I\right) = -\mu_0 \frac{N^2}{x} A \frac{dI}{dt}.$$

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

400 V, 63.7 Hz.

(d) (i)



$X_L = 2\pi f L = 2\pi \times 63.7 \times 0.5 = 200\ \Omega$

$Z = \sqrt{X_L^2 + R^2} = \sqrt{200^2 + 1000^2} = 1019.8\ \Omega.$

Current supplied $I = \frac{V}{Z} = \frac{400}{1019.8} = 0.3922\ A.$

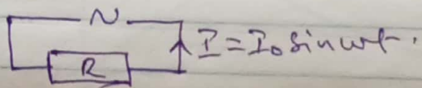
$I_{rms} = 0.3922 A.$

(ii) P.d. across the coil $V_L = I X_L$.

$= 0.3922 \times 200 = 78.44 V$

10 (a) (i) Root mean square value of an alternating current is the value of steady current which dissipates heat in a given resistor at the same rate as the alternating current.

(ii)



Consider current of $I = I_0 \sin\omega t$ flowing through the resistor of R. Instantaneous power dissipated

$P_{inst} = I^2 R = (I_0 \sin\omega t)^2 R.$

$\langle P \rangle = \langle (I_0 \sin\omega t)^2 R \rangle = I_0^2 R \langle \sin^2 \omega t \rangle.$

But $\langle \sin^2 \omega t \rangle = \frac{1}{2}$.

$\therefore \langle P \rangle = \frac{I_0^2 R}{2}$.

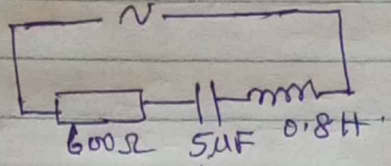
If I_{rms} is the value of steady current which dissipates heat in the resistor as the alternating current then

$I_{rms}^2 R = \frac{I_0^2 R}{2} \Leftrightarrow I_{rms}^2 = \frac{I_0^2}{2}$

$\therefore I_{rms} = \frac{I_0}{\sqrt{2}}$

$V = 340 \sin 50\pi t$

(b) (i)



$2\pi f = 50\pi$
$\Rightarrow f = 25\,Hz$.

$X_C = \frac{1}{2\pi f C} = \frac{10^6}{2\pi \times 25 \times 5} = 1273.9\,\Omega$.

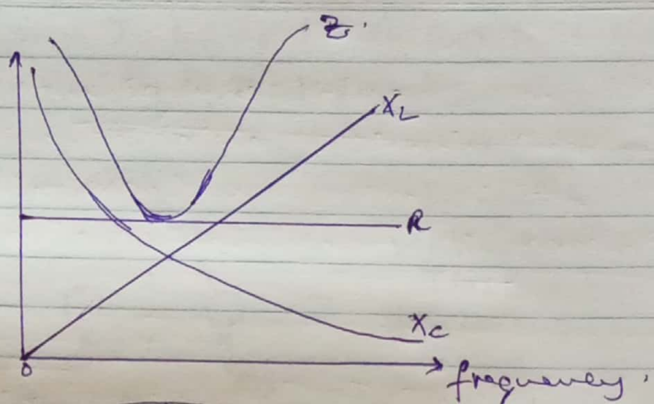
$X_L = 2\pi f L = 2\pi \times 25 \times 0.8 = 125.6\,\Omega$.

$Z = \sqrt{(1273.9 - 125.6)^2 + 600^2} = 1295.6\,\Omega$.

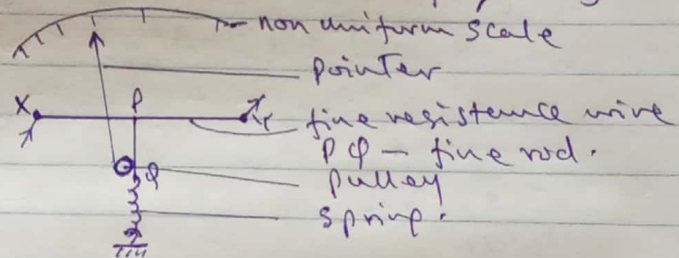
$I_{rms} = \frac{V_0}{\sqrt{2} Z} = \frac{340}{\sqrt{2} \times 1295.6}$

$= 0.186\,A$

(ii)



(c) (i)



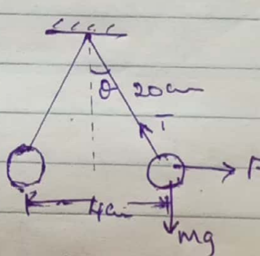
Current to be measured is passed through the fine resistance wire XY. The wire heats up, expands and sags. The sag is taken up by the fine rod PQ which is pulled down by the spring. As PQ moves down it rotates the pulley which turns the pointer over the scale. The deflection of the pointer is proportional to the sag, which is proportional to the rate at which heat is dissipated in XY. Hence the deflection θ is proportional to the square of the average current.

$\theta \propto I_{rms}^2$.

(ii) - The Hot wire ammeter can measure both a.c. and d.c. while moving coil ammeter cannot measure a.c.
- Moving coil ammeter is more prone to getting blown by high currents compared to hot wire ammeter.

11 (a) (i) Electric field intensity at a point in an electric field is the force experienced by 1C of positive charge placed at the point.
(ii) Electric field potential at a point is the work done to bring 1C of positive charge from infinity to that point.

(b)



In equilibrium
vertically
$T\cos\theta = mg$ — (1)
Horizontally
$T\sin\theta = F$ — (2)

$\Rightarrow$ (2)/(1) $\tan\theta = \frac{F}{mg}$. But $F = \frac{Kq^2}{x^2}$

$\therefore \tan\theta = \frac{Kq^2}{mgx^2} \Rightarrow q^2 = \frac{mgx^2\tan\theta}{K}$

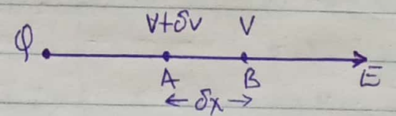
$q^2 = 8\times10^{-3}\times9.81\times(4\times10^{-2})^2\times\frac{2}{\sqrt{20^2-2^2}}$

$= 8\times9.81\times16\times0.1\times10^{-7}$

$q = \sqrt{1.256\times10^{-5}} = \sqrt{12.56\times10^{-6}}$

$= 3.54\times10^{-3}\,C$

(c) (i)



Consider two points A and B, a small distance δx apart in ~~and~~ any electric field such that the potential at B is V and, $V+\delta V$ at A. If the electric field intensity is almost constant at the two points, The work done to transfer 1C of charge from B to A is $= F\times-\delta x = E\times-\delta x$.

But the work done $= V+\delta V - V = \delta V$

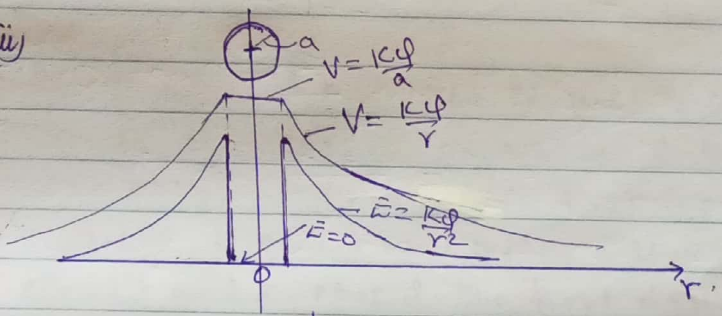
$\therefore \delta V = -E\,\delta x$

$\therefore E = -\dfrac{\delta V}{\delta x}$ The electric field intensity is equal to potential gradient.

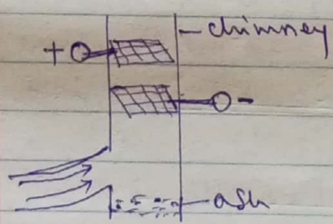
(ii) An equipotential surface is one on which the electric potential at all points is the same. This means the potential difference between any two points is zero. Work done to transfer charge of q from one point to another on the surface $W = Vq = 0 \times q = 0$.

Work done to transfer charge from one point to another $W = F \times \delta x = E\cos\theta \times \delta x$, where $E\cos\theta$ is the component of electric field intensity along the surface. From above $W = 0 \Rightarrow E\cos\theta = 0$. This implies that $\theta = 90°$. Hence electric field intensity is perpendicular to the surface.

(iii)



(d)

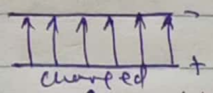


The chimney is fitted with layers of wire mesh, one is maintained at negative potential, and the other positive. Smoke from combustion passes through the negatively charged mesh picking negative charge from it. They are attracted and get attached to the positively charged mesh. The wire mesh is periodically shaken to remove ash particles that fall to the bottom of the chimney.

12(a) (i) Capacitance of a Capacitor is the ratio of the magnitude of charge on either plate of the Capacitor to the p.d. between the plates.

(ii) A dielectric is an electrical insulator while dielectric constant is the ratio of Capacitance of a Capacitor with a dielectric between the plates to Capacitance of the same capacitor with vacuum between the plates.

(b)



Consider a Capacitor of plate separation d and area A. The electric field intensity between the plates $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon A}$.

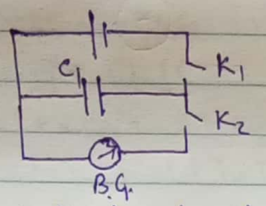
But electric field intensity $E = \frac{V}{d}$.

$\therefore \frac{V}{d} = \frac{Q}{\varepsilon A}$. $\Rightarrow \frac{\varepsilon A}{d} = \frac{Q}{V}$

Also $\frac{Q}{V} = C$ Capacitance of the Capacitor

$\therefore \quad C = \frac{\varepsilon A}{d}$.

(c)

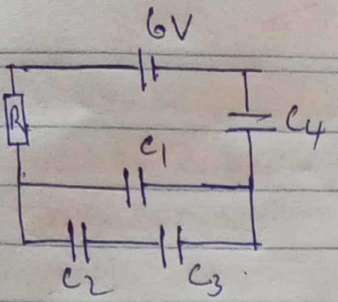


The circuit is connected as above. Let C_1 be capacitance of the first Capacitor connected. Switch K_1 is closed and after a short time K_1 is opened and K_2 closed. The first deflection θ_1 of the B.G. is noted. K_2 is opened and the Capacitor is replaced by another, let its Capacitance be C_2. K_1 is closed and after a short time it is opened and K_2 is closed. The first deflection θ_2 of the B.G. The ratio of Capacitances

$$\frac{C_1}{C_2} = \frac{\theta_1}{\theta_2}$$

(d) (i) When the circuit is connected current flows for a short time then it stops when the Capacitor are full. $\Rightarrow I = 0$. P.d. across the resistor $V = IR = 0$.

(ii)



Capacitance in series

$C_A = \frac{800 \times 800}{1600} = 400 \mu F$

Capacitance in parallel

$C_B = 800 + 400 = 1200 \mu F$.

Total capacitance

$C_E = \frac{800 \times 1200}{2000}$

$= 480 \mu F$

Charge stored in the network

$Q = 480 \times 6 = 2880 \mu C$

p.d. across C_B

$= \frac{2880 \times 10^{-6}}{1200 \times 10^{-6}} = 2.4 V$

Charge in ~~the~~ ~~ca~~ C_A

$= 400 \times 2.4$

$= 960 \mu C$.

$\therefore$ p.d. across C_3

$= \frac{960 \times 10^{-6}}{800 \times 10^{-6}}$

$= 1.2 V$

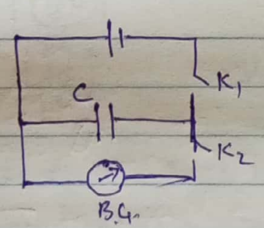
(iii) Energy stored in C_4

$E = \frac{Q^2}{2C} = \frac{(2880 \times 10^{-6})^2}{2 \times 800 \times 10^{-6}} = 1.8 \times 10^{-6} J$

13 (a)(i) One farad is the capacitance of a capacitor across which is a p.d. of 1V when it carries charge of 1C.

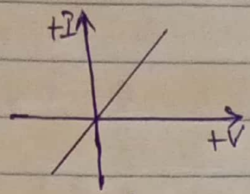
(ii) Dielectric strength is the minimum electric field intensity required to cause dielectric break down in a material.

(b)

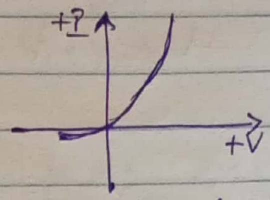


The circuit is connected as above. C is a capacitor with air between the plates, switch K_1 is closed and after a short time it is opened and K_2 is closed. The first deflection, θ_1 is noted, and K_2 is opened. The test dielectric is now inserted in the capacitor and the experiment is repeated. The first deflection, θ_2 is noted. The dielectric constant ε_r is now calculated from $\varepsilon_r = \frac{\theta_2}{\theta_1}$.

(iii) Metals are examples of ohmic conductors while a semi-conductor or junction diode is a non ohmic conductor.



metal

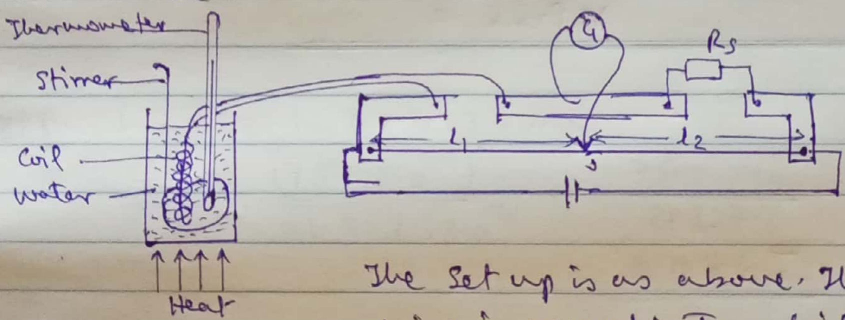


Semi Conductor diode.

(b) (i) When current flows through a wire, the conduction electrons collide with the metal atoms losing some of their kinetic energy to the atoms. The atoms thus vibrate with increased amplitude, which manifests as increase in temperature.

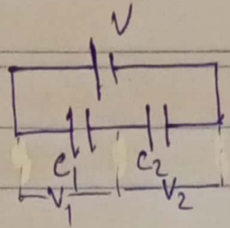
(ii) When the temperature of a conductor increases, the atoms of the conductor vibrate with larger amplitudes, thus reducing the mean free path for conduction electrons. Fewer electrons are thus able to flow per second implying increase in resistance.

(c)



The set up is as above. The test wire is wound into a coil and connected on the left hand gap of the bridge, while R_s is standard resistance.

The water bath is heated gently while stiring continuously. At some thermometer reading θ, the balance point is determined, where G, shows no deflection. The balance lengths l_1 and l_2 are measured and recorded together with θ. The experiment is repeated for other values of θ and the results recorded in a table including

(c) 

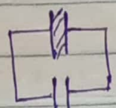
The circuit is connected as above. charge on the two capacitors are equal let it be Q. The p.ds $V_1 + V_2 = V$.

But $V_1 = \frac{Q}{C_1}$ and $V_2 = \frac{Q}{C_2}$

$\therefore V = \frac{Q}{C_1} + \frac{Q}{C_2} \Leftrightarrow \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$ But $\frac{V}{Q} = \frac{1}{C}$

where C is the effective capacitance

$\therefore \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

(d) (i) 

$C_0 = 600\,\mu F$

$\varepsilon_r C_0 = 1.2 \times 600\,\mu F$.

Total capacitance initially $C_1 = \frac{(600 \times 10^{-6})^2}{2 \times 600 \times 10^{-6}}$

$= 300\,\mu F$

Charge stored $Q = CV = 300 \times 25 = 7500\,\mu C$.

When the dielectric is inserted; total capacitance $C_T = \frac{1.2 \times (600 \times 10^{-6})^2}{2.2 \times 600 \times 10^{-6}} = 327.3\,\mu F$.

P.d. across the network $= \frac{Q}{C_T}$ $\frac{7500 \times 10^{-6}}{327.3 \times 10^{-6}}$

$= 22.9\,V$

(ii) Final energy in the network

$E = \frac{Q^2}{2C} = \frac{(7500 \times 10^{-6})^2}{2 \times 327.3 \times 10^{-6}} = \frac{7500^2 \times 10^{-6}}{2 \times 327.3}$

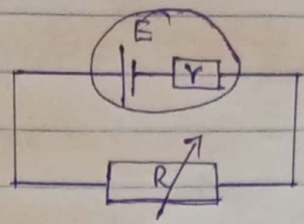
$= 0.086\,J$

14 (a) (i) The current through a homogeneous conductor is directly proportional to the p.d. between its ends provided the temperature and other conditions remain constant.

(ii) ohmic conductors are those in which the current flowing through is directly proportional to the p.d. across its ends, while non ohmic ones current is not directly proportional to the p.d. across its ends.

the external load and the internal resistance. Hence emf is always greater than terminal p.d.

(b)



Consider the circuit above. Current supplied to the circuit $I = \frac{E}{(R+r)}$

$\therefore$ Power delivered to the load

$$P = I^2R = \left(\frac{E}{R+r}\right)^2 R = \frac{E^2 R}{(R+r)^2}$$

$$\frac{dP}{dR} = E^2\left[\frac{(R+r)^2 - R\cdot 2(R+r)}{(R+r)^4}\right] = E^2\left[\frac{(R+r-2R)(R+r)}{(R+r)^4}\right]$$

$$= E^2\left(\frac{r-R}{(R+r)^3}\right) \quad \text{when } \frac{dP}{dR} = 0, \ R = r.$$

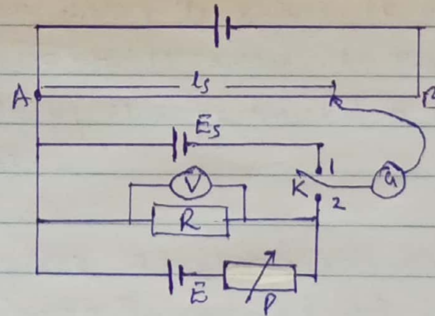
$$\frac{d^2P}{dR^2} = E^2\left(\frac{-1(R+r)^3 - (r-R)\cdot 3(R+r)^2}{(R+r)^6}\right)$$

$$= E^2\frac{(-R-r-3r+3R)(R+r)^2}{(R+r)^6} = \frac{E^2(2R-4r)}{(R+r)^4}$$

When $R = r$, $\frac{d^2P}{dR^2} = E^2\frac{(2r-4r)}{(2r)^4}$ which is $-$ve

Hence P is max. when $R = r$.

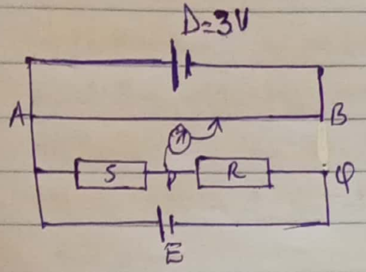
(c)



V is voltmeter to be calibrated.

The circuit is connected as above. E_s is standard emf. Switch K is connected to position 1 and the balance point determined where the galvanometer values of $R_\theta = \frac{l_1}{l_2} \times R_s$. A graph of R_θ against θ is plotted, and the slope, S, determined and recorded together with the intercept R_0 on the R_θ axis. The temperature coefficient of resistance α is calculated from $\alpha = \frac{S}{R_0}$.

(d)



$R_{AB} = 20\,\Omega$
$S = 5\,\Omega$
$E = 2.5V$

(i) $\frac{R_2}{R_1} = \frac{l_2}{l_1} \iff \frac{R}{5} = \frac{60}{20}$

$\Rightarrow R = 15\,\Omega$

(ii) $I_d = \frac{3}{20}$

∴ with the G connected at P

$I_t \times 5 = \frac{3}{\cancel{20}} \times \frac{\cancel{20}}{10\cancel{0}} \times 2\cancel{0}$

$\frac{2.5}{(5+15+r)} \times 5 = 0.6$

$\Rightarrow 20 + r = \frac{2.5 \times 5}{0.6}$

$\therefore r = \frac{2.5 \times 5}{0.6} - 20$

$= 0.83\,\Omega$

15(a)(i) potential difference between ~~across~~ a conductor is the work done to move 1C of charge across the conductor while e.m.f. is the work done to convey 1C of charge round a circuit containing the source.

(ii) In practice, electric cells have internal resistance. Terminal p.d. is the work done to pass charge of 1C through the external load connected to the cell while emf includes includes work done to pass 1C of charge through shows no deflection. The balance length l_s is determined. Switch K is now connected to position 2 and the rheostat P adjusted to give a large value. The balance point is determined and the balance length l, measured and recorded together with the ammeter reading V_r. The experiment is repeated for other settings of P and the results recorded in a table including values of $V_a = \frac{E_s}{l_s} \times l$. A graph of V_a against V_r is plotted, and it constitutes the calibration graph.

(d) (i) $r = R\left(\frac{l_0}{l} - 1\right) = 5\left(\frac{20}{15} - 1\right)$

$= 1.67\ \Omega$

(ii) At balance when K_1 is open;

$I_d = \frac{E_D}{20+10} = \frac{E_D}{30}$

At balance with K_2 open:

$1.5 = \frac{E_D}{30} \times \frac{20}{100} \times 20$

$\Rightarrow E_D = \frac{1.5 \times 30}{4} = 11.25\,V$

When both K_1 and K_2 are closed,

$I_d' = \frac{E_D}{20} = \frac{11.25}{20} = 0.5625\,A.$

$I_t = \frac{1.5}{5+1.67} = 0.225\,A.$

$\therefore$ At balance:

$I_t \times 5 = I_d' \times \frac{20}{100} \times l.$

$0.225 \times 5 = 0.5625 \times \frac{\cancel{20}^{1}}{\cancel{100}_{5}} \times l$

$l = \frac{0.225 \times 5 \times 5}{0.5625} = 10\,cm$