SECTION A

1. Define the term 'self-inductance' of a coil. Write its S.I. unit.

Ans: The property of a coil by virtue of which the coil opposes any change in the strength of current flowing through it by inducting an emf in itself is known as self-inductance. The S.I unit of self-inductance is Henry or Amperes per second.

2. Why does bluish colour predominates in a clear sky?

Ans: Light comes to the earth from sun across the intervening space with a full spectrum of seven colours. In clear sky, blue light scattered the most as it has shorter wavelength than others, so the bluish colour predominates in a clear sky.

3. I-V graph for a metallic wire at two different temperatures, T_1 and T_2 is as shown in the figure. Which of the two temperatures is lower and why?

Ans: Resistance depends on temperature as:

$$R = R_0 (1 + \alpha \Delta T) \qquad (1)$$

We can notice from the above equation that more the temperature more is the resistance.

Also according to Ohm's law,

$$R = V/I \qquad (2)$$

In the given figure, the I-V graph of wire at temperature T_1 is at lower voltage than that of wire at temperature T_2, so the resistance of the wire at temperature T_1 is less and hence the temperature is low.

From the above Eqs. (1) and (2), we conclude that T_1 is lower temperature.

4. Which basic mode of communication is used for telephonic communication?

Ans: We use wire communication or space wave communication through satellites.

5. Why do the electrostatic field lines not form closed loops?

Ans: Electrostatic field is conservative in nature so do not form closed loops.

SECTION B

6. When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron changes? Justify your answer.

Ans: The different states of hydrogen atom have different energies and so as the wavelengths associated with them represented by the relation:

$$E = hc/\lambda$$

As energy of state change wavelength associated with that level change so wavelength of electron at that level changes.

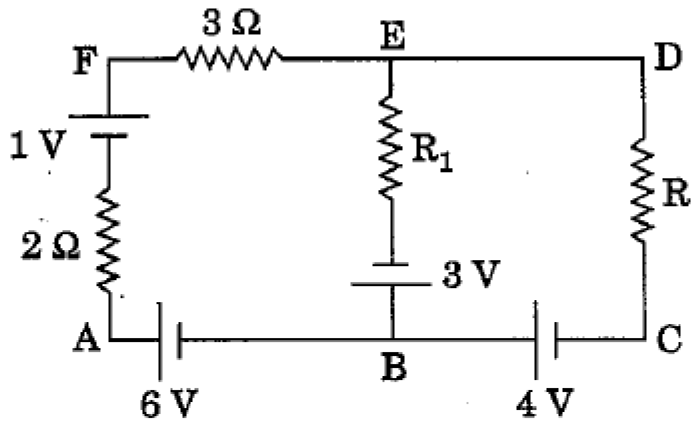
7. Write two factors which justify the need of modulating a low frequency signal into high frequency before transmission.

Ans: The two factors which justify the need of modulating a low frequency signal into high frequency before transmission:

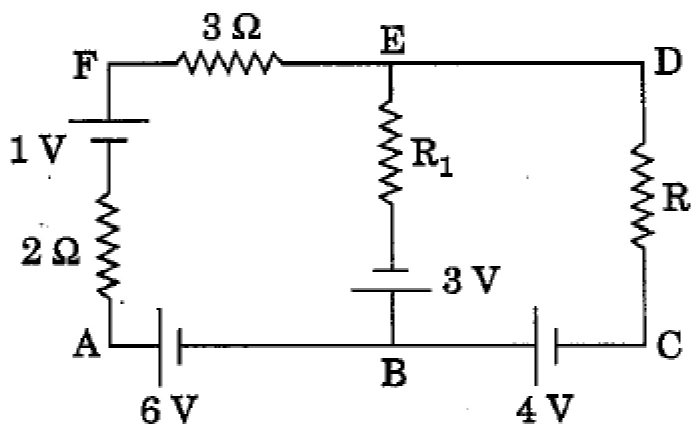
1. Size of the antenna or aerial.

2. Effective power radiated by an antenna.

8. Use Kirchhoff's rules to determine the potential difference between the points A and D when no current flows in the arm BE of the electric network shown in the figure.



Ans:



i_{B_E} along arm BE = 0 (given)

Now Apply KVL between A and D.

$$V_{AD} = V_A - V_D = i_B R_1 + 3 + 6$$
$$\because\ i_B = 0$$

Ans. $V_{AD} = 9\text{V}$

9. You are given two converging lenses of focal length 1.25 cm and 5 cm to design a compound microscope. If it is desired to have a magnification of 30, find out the separation between the objective and the eyepiece.

Ans: magnification of a compound microscope is given by:

$$M = (-LD/F_oF_e)$$

Where L is the distance between two lenses and D is the least distance of distinct vision, i.e. 25 cm.

$$30 = (25L/1.25\times5)$$

$$L = 30\times6.25/25$$

$$L = 30\times0.25 = 7.5 \text{ cm}$$

OR

9. A small telescope has an objective lens of focal length 150 cm and eyepiece of focal length 5 cm. What is the magnifying power of the telescope for viewing distant objects in normal adjustment?

If this telescope is used to view a 100 m tall tower 3 km away, what is the height of the image of the tower formed by the objective lens?

Ans: At normal adjustment magnifying power is given as:

$$M = -F_o/F_e$$

$$M = -150/5 = -30$$

The height of the image is given by:

$$I = H \times f_o/u$$

$$I = 1.0\times 10^5 \times 150/3.0 \times 10^6 \text{ cm}$$

$$I = 5 \text{ cm}$$

10. Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infra-red, visible, ultraviolet) of hydrogen spectrum does this wavelength lie?

Ans: Wavelength in the spectral series of hydrogen atom is given by:

$$\lambda = 1/(R_H(1/n_1^2 - 1/n_2^2))$$

For Balmer series $n_1 = 2$, for shortest wavelength $n_2 = \infty$

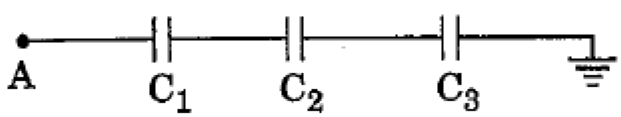
Therefore,

$$\lambda = 1/(1.09 \ x\ 10^7(1/2^2 - 1/\infty^2))$$

$$\lambda \approx 3.67 \text{ x } 10^{-7} = 3670 \text{ Angstrom}$$

SECTION C

11. Calculate the potential difference and the energy stored in the capacitor C_2 in the circuit shown in the figure. Given potential at A is 90 V, $C_1 = 20\ \mu F$, $C_2 = 30\ \mu F$ and $C_3 = 15\ \mu F$.



Ans: Total capacitance of the combination is:

$$C_T = 60/9$$

So, total charge in the circuit is:

$$Q = CV = 90 \times 60/9 = 600\ \mu C$$

Charge is constant in all capacitors in series, so energy stored in C_2 is:

$$E = (1/2)\ Q^2/C_2$$

$$E = (1/2)\ (600\times600)/30 = 6000\ \mu J = 6 \text{ mJ}$$

12. Find the relation between drift velocity and relaxation time of charge carriers in a conductor. A conductor of length L is connected to a d.c. source of emf 'E'. If the length of the conductor is tripled by stretching it, keeping 'E' constant, explain how its drift velocity would be affected.

Ans: In the presence of electric field charge carriers get electrostatic force:

$$F = eE$$

$$ma = eE$$

$$a = eE/m$$

From Newton's first equation of motion we get,

$$v_d = 0 + a\ \tau$$

$$v_d = eE\tau/m \qquad (1)$$

and

$$E = V/l \qquad (2)$$

Where V is the voltage applied and l is the length of the conductor in consideration.

So, using Eq. (2) in Eq. (1), we obtain

$$v_d = eV\tau/ml \qquad (3)$$

As we can notice from Eq. (3) that drift velocity and relaxation time are inversely related with each other, thus, if length of the conductor is tripled, then drift velocity would become one-third..

13. State clearly how an unpolarised light gets linearly polarised when passed through a Polaroid.

(i) Unpolarised light of intensity I_0 is incident on a Polaroid P_1 which is kept near another Polaroid P_2 whose pass axis is parallel to that of P_1. How will the intensities of light, I_1 and I_2, transmitted by the Polaroid P_1 and P_2 respectively, change or rotating P_1 without disturbing P_2?

(ii) Write the relation between the intensities I_1 and I_2.

Ans: Linearly polarized light can be produced from unpolarised light with the polaroid. Polaroid allow only the electric field along one direction to pass through, while absorbing the field component perpendicular to this direction.

(i) The unpolarised light of intensity I_0 passes through P_1, so the intensity I_1 is just half that of I_0 according to Malus' law:

$$I_1 = I_0/2$$

Now for I_2

$$I_2 = I_1 \cos \alpha^2$$

Where, α is the angle between P_1 and P_2.

Here P_1 and P_2 are parallel so $\alpha = 0$

So $$I_2 = I_0/2$$

(ii) According to Malus' law the intensities I_1 and I_2 are related as

$$I_2 = I_1 \cos\alpha^2$$

14. Define modulation index. Why is its value kept, in practice, less than one?

A carrier wave of frequency 1.5 MHz and amplitude 50 V is modulated by a sinusoidal wave of frequency 10 kHz producing 50% amplitude modulation. Calculate the amplitude of the AM wave and frequencies of the side bands produced.

Ans: the ratio of the maximum amplitude of the modulating signal to the maximum amplitude of carrier wave is known as the modulation index.

$$\mu = \frac{A_m}{A_c}$$

From above formula we can see that the value of modulation index kept less than 1, to avoid over-modulation and if the modulating signal is of greater amplitude, part of the information is lost in the process of modulation. Hence, to avoid distortion we kept it less than 1.

Given:

f_c = 1.5 MHz, f_m = 10 kHz, A_m = 50 V, $\mu = 50\%$

From above formula, we get the amplitude of carrier wave:

$$0.50 = \frac{A_m}{50}$$
$$A_m = 25\,\text{V}$$

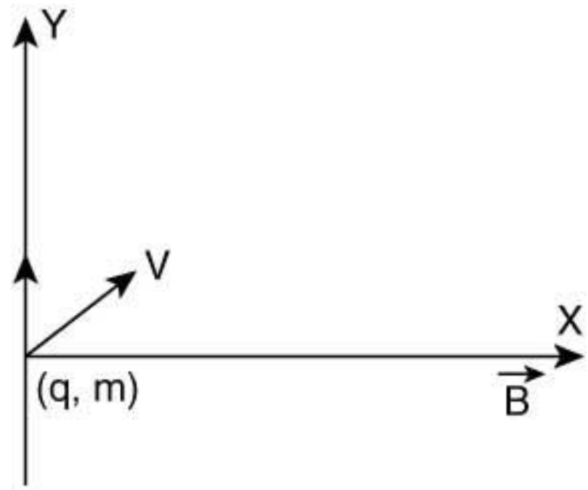
Frequencies of side bands are:

1.5 MHz – 10 kHz to 1.5 MHz + 10 kHz

1.49 MHZ to 1.51 MHz

15. A uniform magnetic field B is set up along the positive x-axis. A particle of charge 'q' and mass 'm' moving with a velocity $\vec{v}$ enters the field at the origin in X-Y plane such that it has velocity components both along and perpendicular to the magnetic field $\vec{B}$. Trace, giving reason, the trajectory followed by the particle. Find out the expression for the distance moved by the particle along the magnetic field in one rotation.

Ans: The perpendicular component of velocity $\vec{V}$ is responsible for magnetic force and along component of velocity $\vec{V}$ is responsible for straight line motion. ON combing both components take path of the change particle is "Helical".



Displacement of particle after 1 Revolution

= time period × component of velocity along $\vec{B}$

$= \dfrac{2\pi m}{B_q} \times (V\cos\theta)$

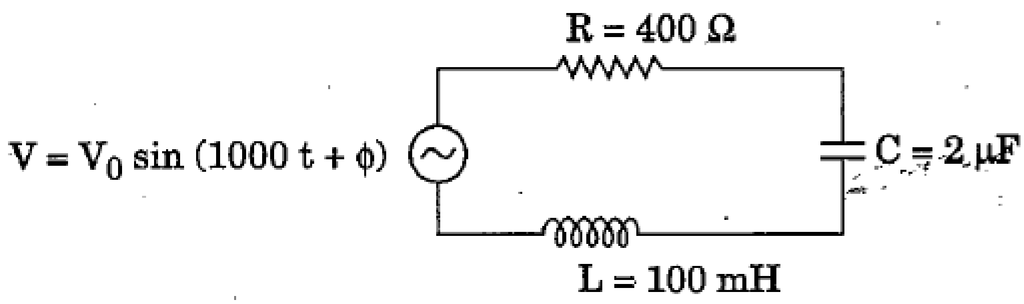
$\because\ V\cos\theta = \dfrac{\vec{V}.\vec{B}}{B}$

$\therefore$ Expression of displacement after

1 Revolution $= \dfrac{2\pi m}{Bq} \times \left(\dfrac{\vec{V}.\vec{B}}{B}\right)$

$$= \frac{2\pi m}{q}\left(\frac{\vec{V}.\vec{B}}{|B|^2}\right)$$

16. (a) Determine the value of phase difference between the current and the voltage in the given series LCR circuit.



(b) Calculate the value of the additional capacitor which may be joined suitably to the capacitor C that would make the power factor of the circuit unity.

Ans:

(a) Phase difference is given by:

$$\phi = \cos^{-1}\left(\frac{R}{Z}\right)$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$R = 400\Omega, L = 100\text{mH}, C = 2\mu\text{F}, \omega = 1000\text{Hz}$

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$= \sqrt{400^2 + \left(1000\times 100\times 10^{-3} - \frac{1}{1000\times 2\times 10^{-6}}\right)^2}$$

$$= 400\sqrt{2}$$

$$\phi = \cos^{-1}\left(\frac{400}{400\sqrt{2}}\right) = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right) = 60°$$

(b) Power factor:

$$\cos\phi = \left(\frac{R}{Z}\right)$$

For unity power factor cos ϕ = 1,

Or $$R = Z$$

That means,

$$(X_L - X_{C'}) = 0$$
$$X_L = X_{C'}$$

Where, $C' = 2\mu\text{F} + C$

$$\omega L = \frac{1}{\omega C'}$$

$$C' = \frac{1}{\omega^2 L} = \frac{1}{1000^2 \times 100 \times 10_{-3}} = 10^{-5}\text{F}$$

$$C = C' - 2\mu\text{F} = (10-2)\mu\text{F} = 8\mu\text{F}$$

So, a capacitor of 8 μF may be connected in parallel with 2 μF capacitor to make power factor unity.

17. Write the expression for the generalized form of Ampere's circuital law. Discuss its significance and describe briefly how the concept of displacement current is explained through charging/discharging of a capacitor in an electric circuit.

Ans: Ampere Circuital Law

$$\oint \vec{B}.\vec{dl} = \mu_0[i_{enc}]$$

$$= \mu_0[i_C + i_D]$$

$$= \mu_0\left[i_C + \frac{\varepsilon_0 d\phi_E}{dt}\right]$$

here i_C = conduction current

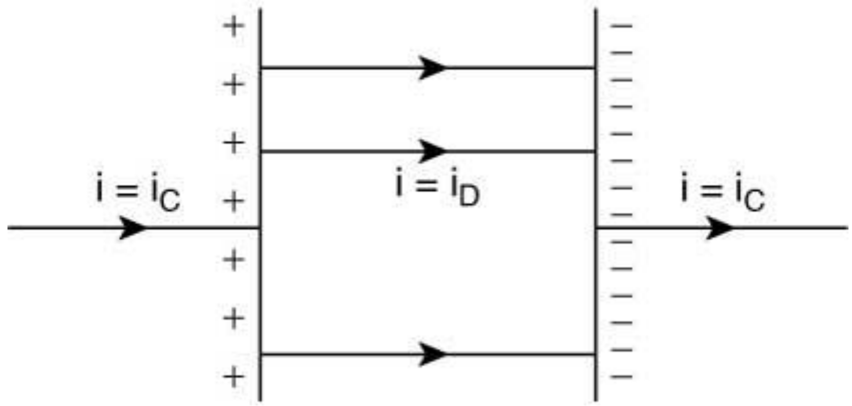
$i_D = \frac{\varepsilon_0 d\phi_E}{dt} =$ displacement current

Displacement current → is the current due to changing electric field between the plates of the capacitor. It is denoted by i_D.

Hence $i_{enc} = i_C + i_D$

$\therefore$ ACL $= \oint \vec{B}.\vec{dl} = \mu_0[i_C + i_D]$

When capacitor is allowed to change in electric circuit, the current flows through connecting wires. As capacitor charges, charge accumulates on the two plats of capacitor, as a result, a changing electric field is produced across the plats of the capacitor



Inside capacitor

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$$

$Q = \varepsilon_0$ (EA)

$Q = \varepsilon_0(\phi_E)$

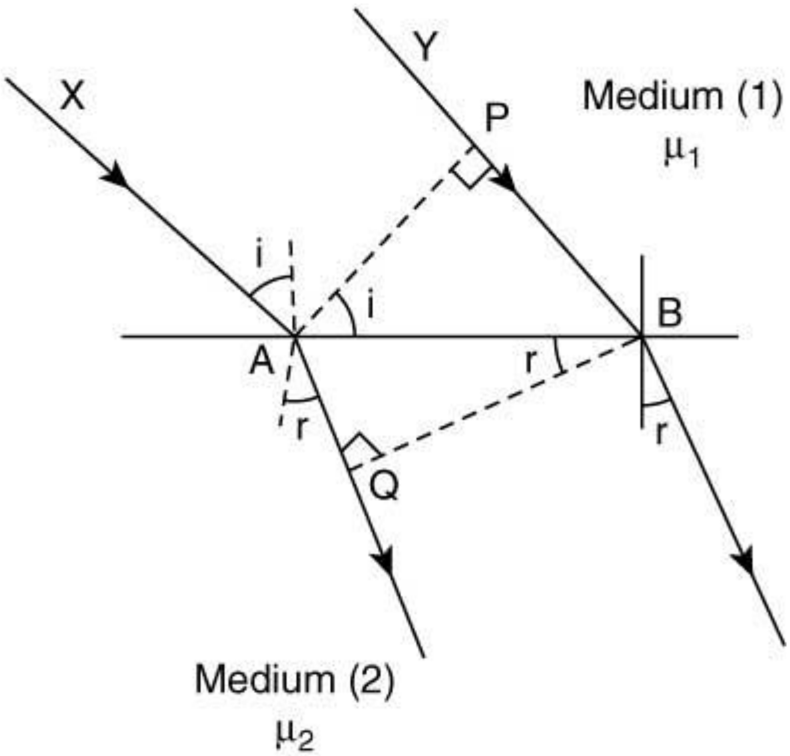
$\because$ Change is changing

$$\therefore \quad \boxed{i_D = \frac{d\theta}{dt} = \varepsilon_0\left(\frac{d\phi_E}{dt}\right)}$$

Hence displacement current comes in circuit.

18. Use Huygens' Principle to show how a plane wave front propagates from a denser to rare medium. Hence verify Snell's law of refraction.

Ans: Let the speed of light and refractive index of medium (1) V_1 and μ_1 and of medium (2) be V_2 and μ_2.



Consider Wave in Medium (1)

When it reaches A then another wave Y reach at P. When wave Y reaches from point P to B in the same time interval wave X reaches from A to Q.

Let the time to trave PB or AQ be t.

Then $PB = V_1 t$

$AQ = V_2 t$

$\because$ $PB = AB \sin i$ and $AQ = AB \sin r$

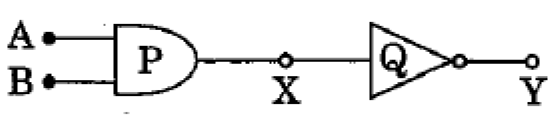
$$\therefore \quad \boxed{\frac{\sin i}{\sin r} = \frac{V_1}{V_2}}$$

$$\because \quad \frac{V_1}{V_2} = \frac{\mu_2}{\mu_1}$$

$$\therefore \quad \boxed{\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}}$$ snelle's law

Hence proved.

19. Identify the gates P and Q shown in the figure. Write the truth table for the combination of the gates shown.



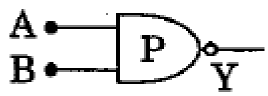
Name the equivalent gate representing this circuit and write its logic symbol.

Ans: The gate P is AND gate and gate Q is NOT gate.

The truth table is shown below for the combination of gates:

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Its logic symbol is:

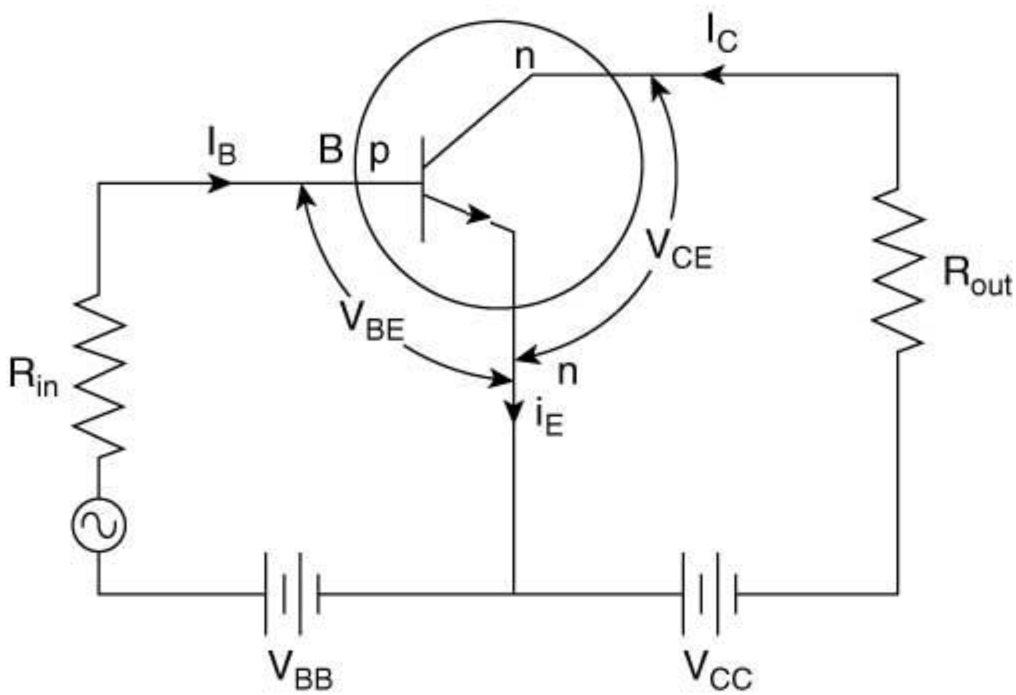


20. Draw a circuit diagram of a C.E. transistor amplifier. Briefly explain its working and write the expression for (i) current gain, (ii) voltage gain of the amplifier.

Ans: In common Emitter Arrangement emitter-base junction is forward biased and collector emitter junction is Reverse Biased.

A small change in i_B in the base circuit controls the larger current i_C in the collector circuit. This is the Basis of amplification with the help of a transistor.

The input signal to be amplified, is connected in series with the biasing battery V_{BB} in the base circuit. A load resistor R_L is connected in the collector circuit to take output voltage across it. As potential difference V_{BE} changes with time due to input signal, the base current i_B changes due to which collector current i_C changes.



Hence common emitter works.

<u>Current Gain</u> → It is ratio of change in collector current ($\Delta\ i_C$), to the change in base current (Δi_B)*il*

$$\beta = \frac{\Delta i_C}{\Delta i_B}$$

<u>Voltage Gain</u> → It is ratio of change in output voltage to change in input voltage.

$$\text{Voltage gain } = \frac{\Delta i_C \times R_L}{\Delta i_B \times R_{in}}$$

$$= \beta \times \frac{R_L}{R_{in}}$$

21. (a) Write three characteristic of nuclear force.

(b) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusion that can be drawn from the graph.

Ans: Characteristic properties of nuclear forces-

(1) Nuclear force is short range. It acts only, when interacting particles are very close i.e. separation is of order 10^{-15}m.

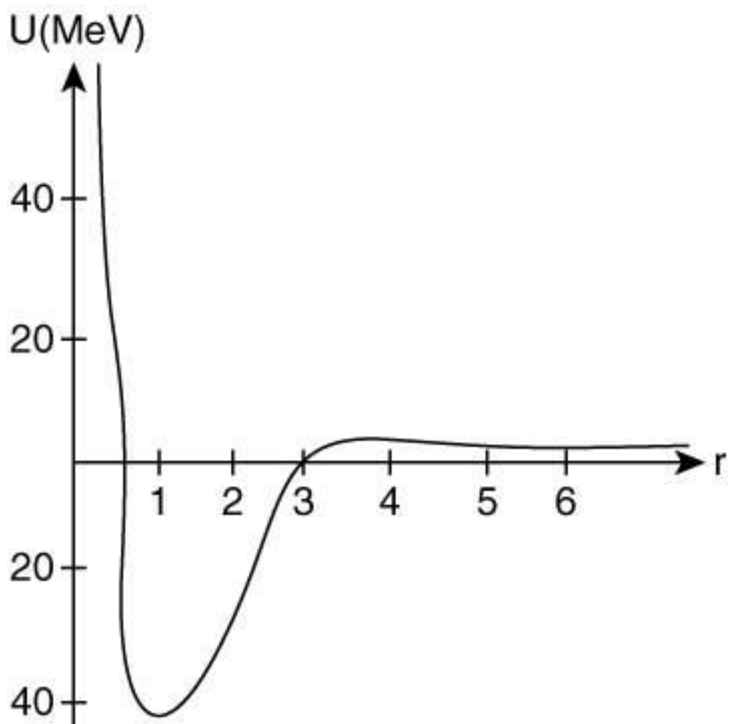
(2) Nuclear force is independent of charge

(3) It depends on the relative orientation of spins of the interacting nucleus. This fact has been confirmed from the nuclear energy levels.

<u>Conclusions from Graph</u>

(1) Beyond certain distance potential energy is constant and force is zero.

(2) At very short distances a repulsive core exists.



Nuclear energy v/s seperation graph

22. (a) Describe briefly three experimentally observed features in the phenomenon of photoelectric effect.

(b) Discuss briefly how wave theory of light cannot explain these features.

Ans: **(a)** Features deserved in photoelectric effect:-

(1) Above threshold frequency, the maximum velocity with which electrons emerge is dependent solely on the frequency and not on the intensity of incident light.

(2) No emission of electrons take place if incident frequency is less than threshold frequency.

(3) The emission of photoelectron is an instantaneous process.

Wave theory of light cann't explains those features.

(b) (1) If intensity of light falling on metal is increased, then acc to wave theory ($\vec{E}$) electric field also increases hence oscillating force acts on emitting electron and kinetic energy has to increase. But experimentally kinetic energy is constant in changing intensity.

(2) Acc to wave theory, the photoelectric effect should occur for any frequency of light however observation shows that photo-electric effect doesn't occur if the frequency of incident radiation is less than threshold frequency.

(3) Acc to wave theory, when light falls on metal, the energy of incident light will have be distributed uniformly on all electron's not on one electron. So, electron will take some time to accumulate enough energy to escape from metal surface. However experimentally there is no time lag.

OR

21. (a) Write the important properties of photons which are used to establish Einstein's photoelectric equation.

(b) Use this equation to explain the concept of (i) threshold frequency and (ii) stopping potential.

Ans: (a) Properties of photon

(1) Energy of photon depends on its frequency and it doesn't change with change in medium.

(2) Photons are electrically Neutral

(3) Its Rest mass is zero

Equivalent mass of photon = $E = mc^2$

$$m = \frac{E}{C^2} = \frac{hv}{C^2}$$

$$\boxed{m = \frac{hv}{C^2} = \frac{h}{\lambda C}}$$

(4) Photons have momentum $\boxed{P = \frac{h}{\lambda}}$

(5) Intensity α number of photons present

(b) Einsteins photoelectric equation $hv = W_0 + KE$

Where v is frequency of incident photon.

When photon is incident, on metal surface with frequency v having energy hv, then it is used to get the electron free from the atom and away from metal surface.

This energy is known as work function (W_0) and min frequency required to eject electron from metal surface without gaining any kinetic energy is known as threshold frequency (v_0)

Hence

$\boxed{W_0 = hv_0}$

W_0 = Work junction

v_0 = Threshold frequency

If frequency (v) is greater than (v_0) then remaining energy $\boxed{h(v - v_0)}$ is gained by electron in the form of KE.

Due to which electron moves from cathode to anode now M_{in} potential R_{eq} to in opposite direction so that e' having maximum KE cann't be able to reach anode. Hence stopping potential → is defined as the M_{in} potential required by anode so that electron having maximum KE cann't be able to reach anode.

SECTION D

23. One morning an old man walked bare-foot to replace the fuse wire in kit Kat fitted with the power supply mains for his house. Suddenly he screamed and collapsed on the floor. His wife dried loudly for help. His neighbor's son Anil heard the cries and rushed to the place with shoes on. He took a wooden baton and used it to switch off the main supply.

Answer the following questions:

(i) What is the voltage and frequency of mains supply in India?

(ii) These days most of the electrical devices we use require a.c. voltage. Why?

(iii) Can a transformer be used to step up d.c. voltage?

(iv) Write two qualities displayed by Anil by his action.

Ans: **(i)** In India voltage supply = 220 V

frequency supply = 50 Hz

(ii) because

(a) In AC we can easily regulate voltage.

(b) AC is cheaper then DC

(c) Transmission in AC is very less as compared to DC

(iii) No because transformer works on the principle of mutual induction is it when current changes, emf induces but in DC current is constant.

(iv)(a) Shoe and Wood are bad conductors of electricity so they can't complete the circuit so Anil will get protected from shock.

(b) Human body is good conductor of electricity.

SECTION E

24. (a) Define electric flux. Write its S.I. unit.

"Gauss's law in electrostatics is true for any closed surface, no matter what its or size is." Justify this statement with the help of a suitable example.

(b) Use Gauss's law to prove that the electric field inside a uniformly charged spherical shell is zero.

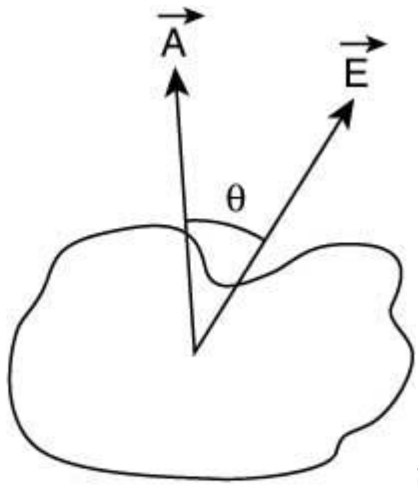
Ans: (a) Electric flux → It is defined as the number of electric field lines passing through given surface area.

It is defined as the dot product of electric field $(\vec{E})$ and area $(\vec{A})$

Elective flux

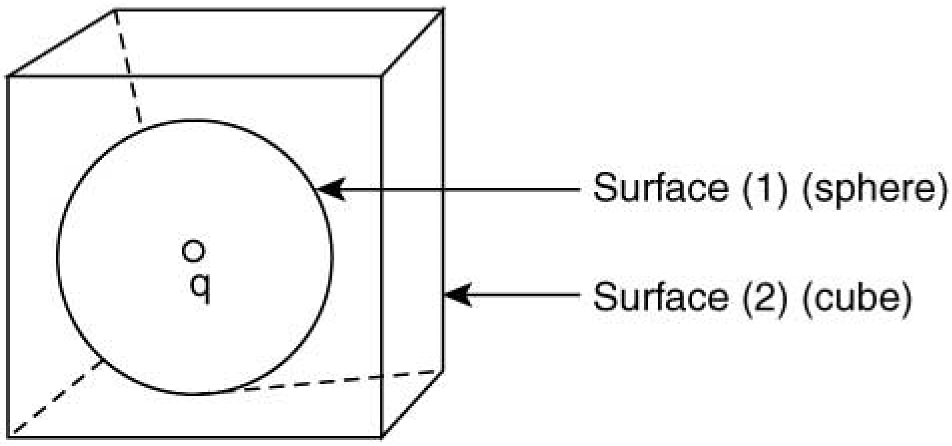
$\phi = \vec{E}.\vec{A}$

$= EA \cos \theta$



S.I. Unit $\rightarrow \frac{Nm^2}{C}$

Consider the given diagram for showing that gauss law doesn't depend on shape and size.



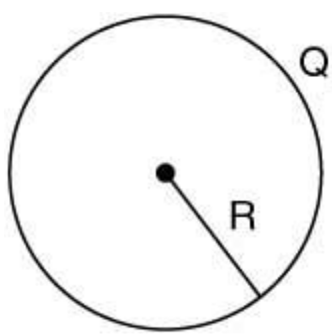
for surface (1)

Electric flux $\phi = \frac{q_{enc}}{\varepsilon_0} = \frac{q}{\varepsilon_0}$

for surface (2)

Electric flux $\phi = \frac{q_{enc}}{\varepsilon_0} = \frac{q}{\varepsilon_0}$

(b) Consider spherical should of change Q and Radius R



Now Acc to gauss law

$\phi = \frac{q_{enc}}{\varepsilon_0}$

and $\phi = \oint \vec{E}.\overrightarrow{ds}$

$\because$ E = constant

$\therefore$ $\boxed{E\oint ds = \frac{q_{enc}}{\varepsilon_0}}$

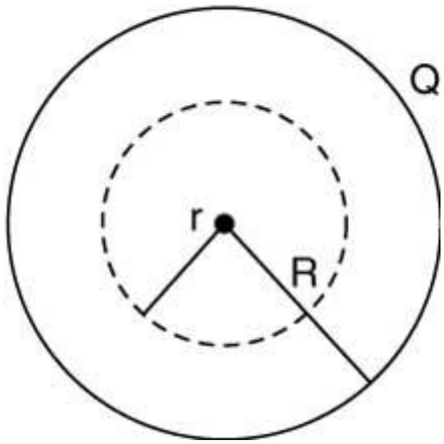
for sphere at r distance from centre

$\oint ds = 4\pi r^2$

$q_{enc} = 0$

$E \times 4\pi r^2 = \frac{0}{\varepsilon_0}$

$\boxed{E = 0 \text{ Ans}}$

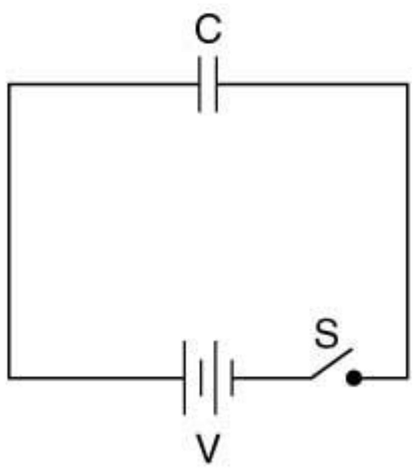


OR

24. (a) Drive the expression for the energy stored in a parallel p[late capacitor. Hence obtain the expression for the energy density of the electric filed.

(b) A fully charged parallel plate capacitor is connected across an uncharged identical capacitor. Show that the energy stored in the combination is less than that stored initially in the single capacitor.

Ans: (a) Consider a capacitor (C) connected to battery of emf (V) when switch (S) is closed current starts flowing and charge on capacitor any instant is q now small change dq will add to it and charge will increase to (q + dq).



$\because$ Energy = Vdq and $q = CV$

$\therefore$ Energy $= \int_0^Q \frac{q\,dq}{C}$

$$\text{Energy} = \frac{Q}{2C}$$

$\because\ Q = CV$

$$\therefore \quad \text{Energy} = \frac{Q^2}{2C} = \frac{1}{2}CV^2$$

Now energy density

$$\text{Energy Density} = \frac{\text{Energy}}{\text{Volume}} = \frac{Q^2}{2C(Ad)}$$ where A = Area , l = width of plates

Now

$$\text{Energy Density} = \frac{Q^2}{2CAd}$$

$$\because \ C = \frac{\varepsilon_0 A}{d}$$

$$\therefore \quad \text{Energy Density} = \frac{Q^2 \cancel{d}}{2A\cancel{d}\,\varepsilon_0 A}$$

$$= \frac{Q^2}{A^2 2\varepsilon_0} = \frac{\sigma^2}{2\varepsilon_0}$$

$$\boxed{\text{Energy density} = \frac{\sigma^2}{2\varepsilon_0}}$$

(b) Initially capacitor of capacitance is charged to potential V

It is now connected to identical capacitor.

$\because$ Battery is disconnected

$\therefore$ Charge is constant

$Q_{initial} = Q_{final}$

$CV = 2C\ V'$ (V' = final potential of combination)

$$V' = \frac{V}{2}$$

Now

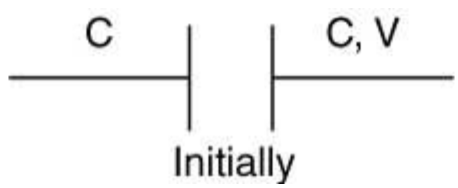
Energy initial = $\frac{1}{2}CV^2$

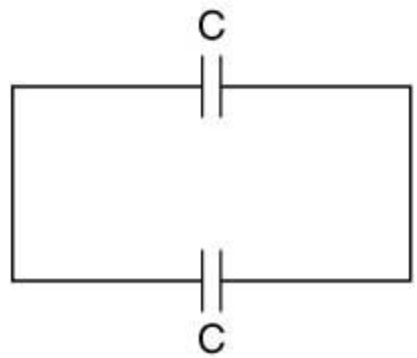
Energy final = $\frac{1}{2}C(V')^2 + \frac{1}{2}C(V')^2$

$$= \frac{1}{2}\frac{CV^2}{4} + \frac{1}{2}\frac{CV^2}{4}$$

$$= \frac{CV^2}{4}$$

Hence energy decreases





25. Explain, using a labeled diagram, the principle and working of a moving coil galvanometer. What is the function of (i) uniform radial magnetic field, (ii) soft iron core?

Define the term (i) current sensitivity and (ii) voltage sensitivity of a galvanometer. Why does increasing the current sensitivity not necessarily voltage sensitivity?

Ans: Moving coil galvanometer

It is used to measure small amount of current

Principle → When current carrying coil is placed in magnetic field it experiences Torque.

Working → When current passes through the coil it produces torque in the coil is

$C_{deflecting} = BiNA \sin\theta$

$\because$ $(\theta = 90°)$ due to Radial magnetic field.

$C_{deflecting} = BiNA$

It is blanced by Restoring torque due to elasticity of spring supporting the coil

$C_{restoring} = C\theta$ (where θ is twist angle)

Now

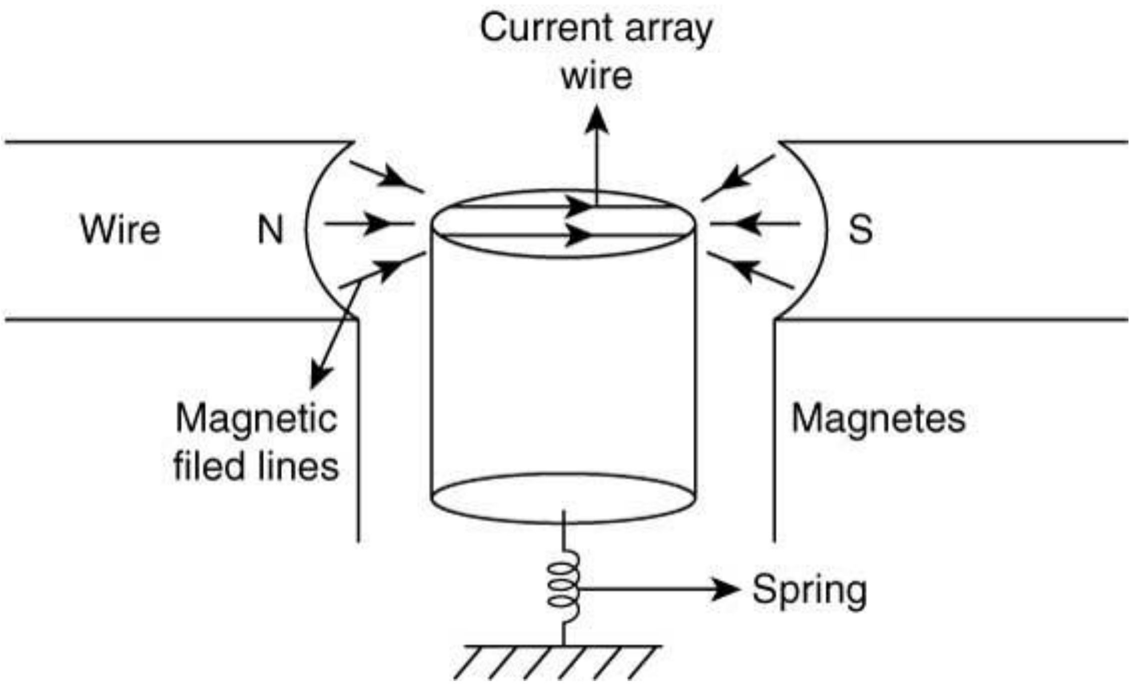
$T_{deflecting} = \tau_{restoring}$

$BiNA = C\theta$

$$i = \left(\frac{C}{NBA)}\right)\theta$$

$i = K\theta$ where $K = \frac{C}{NBA} =$ galvanometer constant

$\Rightarrow \boxed{i \propto \theta}$



Function of

(1) Radial Magnetic Field → because angle between magnetic field and magnetic moment of coil remains 90° for making torque constant.

(2) Soft Iron Core →

(a) To increase the magnetic field by reducing the length of air gap across which magnetic flux has to pass.

(b) To give radial magnetic field of uniform density.

Current sensitivity → It is defined as the deflection produced in the galvanometer when unit current flows through it.

$CS = \frac{\theta}{i} = \frac{NBA}{C}$ Unit $\rightarrow \frac{\text{Radian}}{\text{Ampere}}$

Voltage sensitivity → It is defined as the deflection per unit voltage across voltmeter.

$V.S. = \frac{\theta}{V} = \frac{\theta}{iR}$

$VS = \frac{NBA}{CR}$ unit $= \frac{\text{Radian}}{\text{Volt}}$

Increase in (C.S) not necessarily leads to (V.S) because if we increase No. of turns of coil (CS) increases but due to increase in resistance $\frac{\theta}{V} \propto \frac{N}{R}$ Remains same therefore (V.S) remains same

OR

25. (a) Write, using Biot – Savart law, the expression for the magnetic field $\vec{B}$ due to an element $\vec{dl}$ carrying current I at a distance $\vec{r}$ from it in a vector form.

Hence derive the expression for the magnetic field due to a current carrying loop of radius R at a point P distance x from its centre along the axis of the loop.

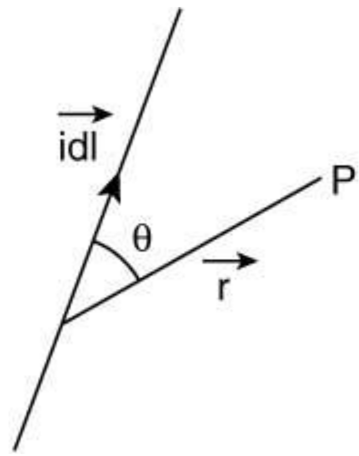
(b) Explain how Biot – Savart law enables one to express the Ampere's circuital law in the integral form, viz.,

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 I$$

where I is the total current passing through the surface.

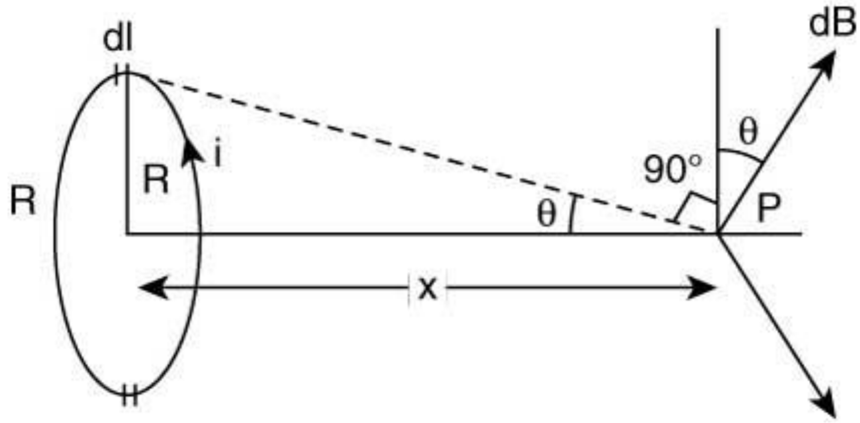
Ans: (a) $\overrightarrow{dB} = \frac{\mu_0 (i\overrightarrow{dl} \times \vec{r})}{4\pi r^3}$

$$\overrightarrow{dB} = \frac{\mu_0 (i\overrightarrow{dl} \times \hat{r})}{4\pi r^2}$$



Magnetic field along axis

Consider small element all of ring of radius R having current i



$\therefore$ Acc to BSL magnetic field at point P is

$$dB = \frac{\mu_0 idl \sin 90}{4\pi\left(\sqrt{R^2 + x^2}\right)^2} \qquad (\theta = 90°)$$

$$dB = \frac{\mu_0 idl}{4\pi(R^2 + x^2)}$$

Now

$$B_{Net} = \int_{2\pi R}^{2\pi R} dB \sin\theta$$

$$= \int_0^{2\pi R} \frac{\mu_0 idl \sin\theta}{4\pi(R^2 + x^2)}$$

$$\because \ \sin\theta = \frac{R}{\sqrt{R^2 + x^2}}$$

$$\therefore \ B_{Net} = \frac{\mu_0 iR}{4\pi(R^2 + x^2)^{3/2}} \int_0^{2\pi R} dl$$

$$B_{Net} = \frac{\mu_0 iR}{4\pi(R^2+x^2)^{3/2}} 2\pi R$$

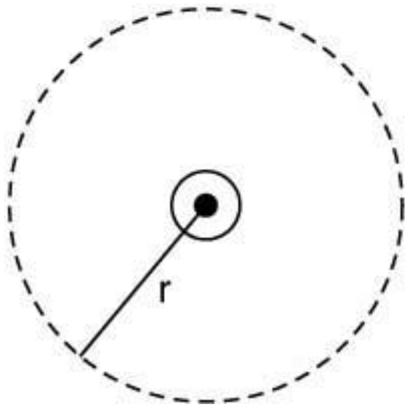
$$\boxed{B_{Net} = \frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}}$$

(b) Consider a straight wire of infinite length having current i. We know that magnetic field due to it is circular in nature.

Now we know

B for wire at separation

r is



$$B = \frac{\mu_0 i}{2\pi r}$$

B $2\pi r = \mu_0 i$

Now consider a circular loop of radius r from wire whose $\oint \vec{dl} = 2\pi r$

$\therefore\ \vec{B}\oint \vec{dl} = B\, 2\pi r$

$\oint \vec{B}.\vec{dl} = B\,(2\pi r)\ \ (\theta = 0°)$

$\boxed{\oint \vec{B}.\vec{dl} = \mu_0 i}$ Hence proved

26. (a) Consider two coherent sources S_1 and S_2 producing monochromatic waves to produce interference pattern. Let the displacement of the wave produced by S_1 be given by

$$Y_1 = a \cos \omega t$$

And the displacement by S_2 be

$$Y_2 = a \cos(\omega t + \phi)$$

Find out the expression for the amplitude of the resultant displacement at a point and show that the intensity at that point will be

$$I = 4a^2 \cos^2 \phi/2$$

Hence establish the conditions for constructive and destructive interference.

(b) What is the effect on the interference fringes in Young's double slit experiment when (i) the width of the slit is increased; (ii) the monochromatic source is replaced by a source of white light?

Ans: (a) Phazor representation of 2 coherent sources is given by

Hence from player phazor difference = ϕ

Now

$\because \; I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$ and $I \; \alpha$ (amplitude)^2.

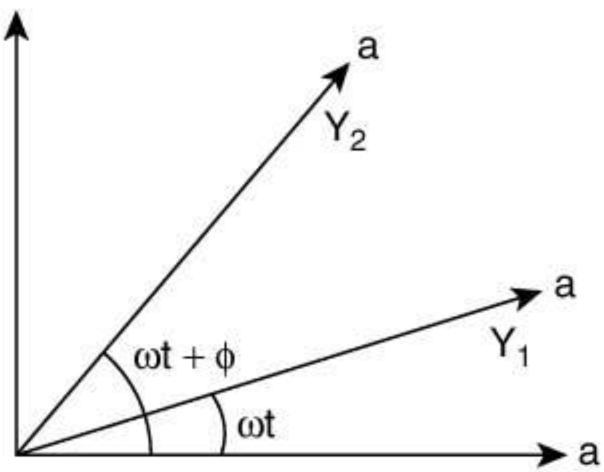
$\therefore \; I = a^2 + a^2 + 2\sqrt{a^2 \times a^2}\cos\phi$

$= 2a^2 + 2a^2\cos\phi$

$= 2a^2[1+\cos\phi]$

$= 2a^2 2\cos\left(\frac{\phi}{2}\right)$ $\qquad\qquad \left(1+\cos\theta = 2\cos^2\frac{\theta}{2}\right)$

$$\boxed{I = 4a^2\cos^2\left(\frac{\phi}{2}\right)}$$



for constructive interference

$\cos\left(\frac{\phi}{2}\right) = 1 \Rightarrow \cos\left(\frac{\phi}{2}\right) = \pm 1$

$\Rightarrow \; \frac{\phi}{2} = r\pi$

$\therefore \; \phi = 2\pi r$ (where n $\geq$ 0 and n $\in$ integers)

for destructive interference

$\cos^2\left(\frac{\phi}{2}\right) = 0 \qquad \cos\left(\frac{\phi}{2}\right) = 0$

$\Rightarrow \; \frac{\phi}{2} = (2n+1)\frac{\pi}{2}$

$\phi = (2n+1)\pi$ (where $n \geq 0$ and n $\in$ integers)

(b) $\because \; \boxed{\beta = \frac{\lambda D}{d}}$

(1) As slit width increases, gets less sharp when the source slit is so vide the condition

$\frac{s}{s} \leq \frac{\lambda}{d}$ is not satisfied, interference pattern disappears.

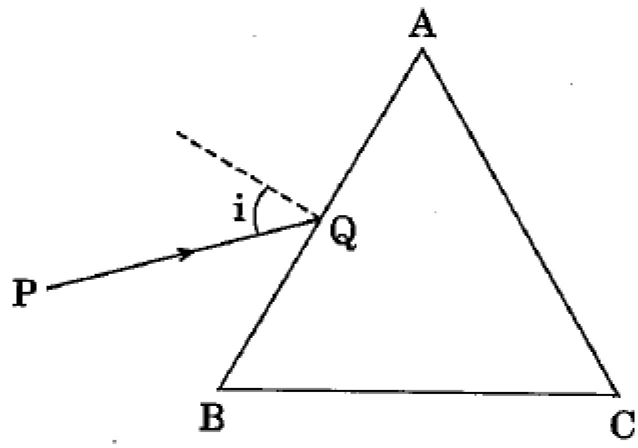
(2) It monochromatic light is replaced by white light then control fringe will remain white but on either side red is closest and blue will appear farthest after few fringes, no clear fringe pattern will be seen.

OR

26. (a) A ray 'PQ' of light is incident on the face AB of a glass prism ABC (as shown in figure) and emerges out of the face AC. Trace the path of the ray. Show that

$$\angle i + \angle e = \angle A + \angle \delta$$

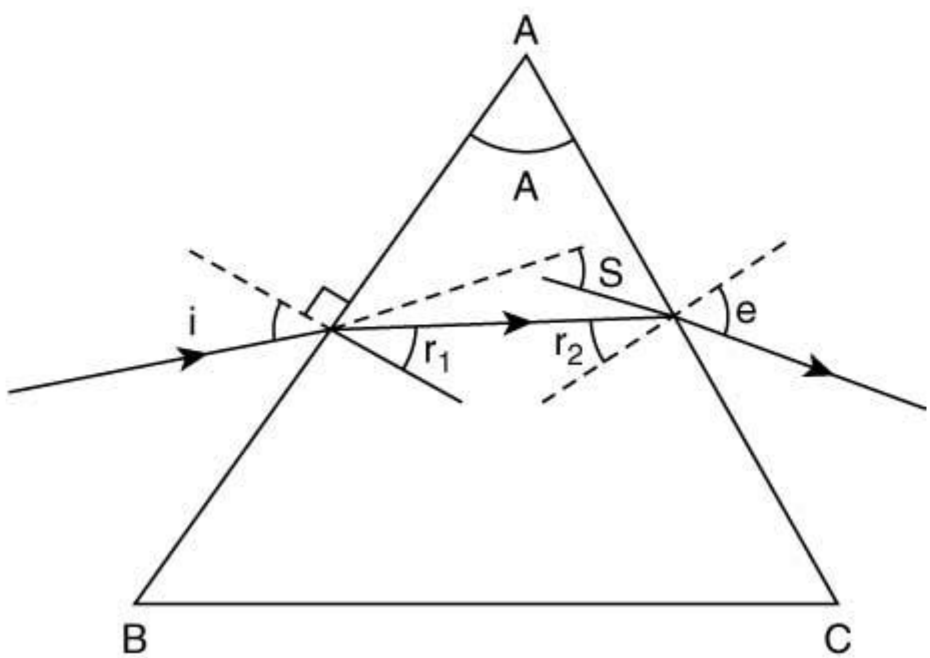
where δ and e denote the angle of deviation and angle of emergence respectively.



Plot a graph showing the variation of the angle of deviation as a function of angle of incidence. State the condition under which is $\angle \delta$ minimum.

(b) Find out the relation between the refractive index (μ) of the glass prism and $\angle A$ for the case when the angle of prism (A) is equal to the angle of minimum deviation (δ_m). Hence obtain the value of the refractive index for angle of prism $A = 60°$.

Ans: (a)



Let Refracting angle from surface *AB* and *AC* be *r*, and r_2.

Now,

Deviation from surface AB

$\angle \delta_1 = \angle i - \angle r_1$

Deviation from surface AC

$\angle\delta_2 = \angle e - \angle r_2$

Net deviation

$\angle\delta = \angle\delta_1 + \angle\delta_2$

$\angle\delta = (\angle i - \angle r_1) + (\angle e - \angle r_2)$

$\angle\delta = (\angle i - \angle e) + (\angle r_1 - \angle r_2)$ ……….(1)

Now in triangle

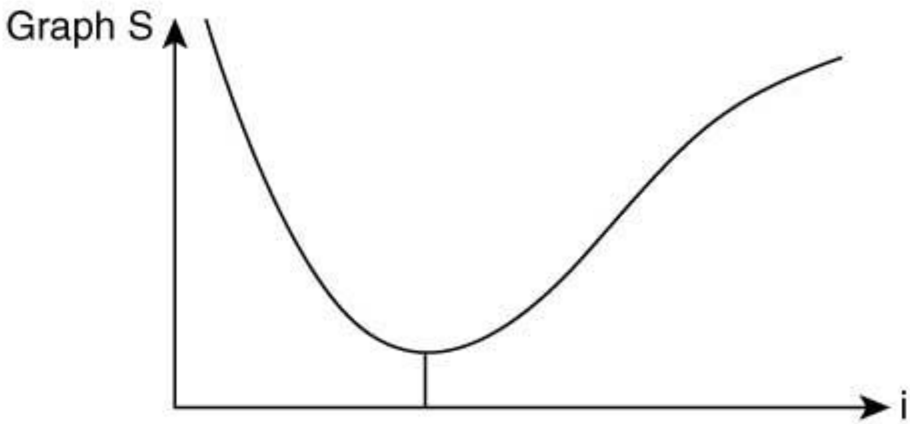
$\angle A + (90 - \angle r_1) + (90 - \angle r_2) = 180°$

$\boxed{\angle A = \angle r_1 + \angle r_2}$ ……………(2)

from (1) and (2)

$\angle\delta = (\angle i + \angle e) - \angle A$

$(\angle i + \angle e) = \angle A + \angle\delta$



for minimum deviation

$(r_1 = r_2) = r$ say

$\therefore\ r + r = A$

$r = \left(\frac{A}{2}\right)$

$i = e =$ Also

(b)

From previous part

For min deviation

$r_1 = r_2 = r = \frac{A}{2}$

and $(i = e)$

$i + e = A + \delta_{\min}$

$\because\ \delta_{\min} = A$ (given)

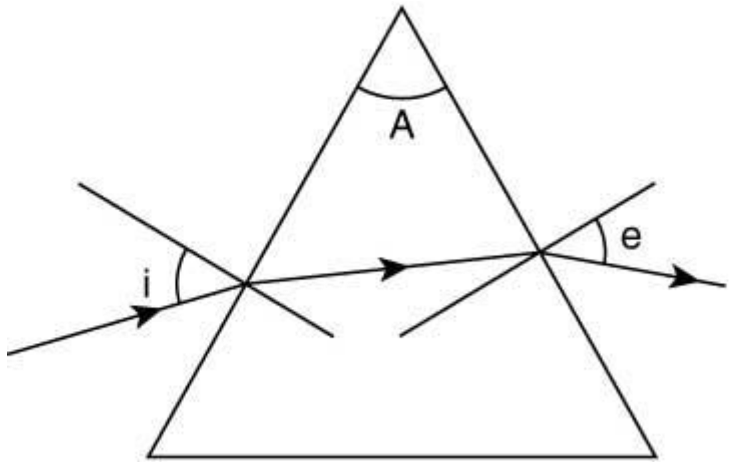
$\therefore\ 2i = 2A$

$i = A$

Now acc to snells law

$\mu = \frac{\sin i}{\sin r} = \frac{\sin A}{\sin\left(\frac{A}{2}\right)}$

$$\boxed{\mu = 2\cos\left(\frac{A}{2}\right)}$$



$\because\ A = 60°$

$\therefore\ \mu = 2\cos\left(\frac{60}{2}\right)$

$\mu = 2\left(\frac{\sqrt{3}}{2}\right)$

$$\boxed{\mu = \sqrt{3} = 1.732}$$