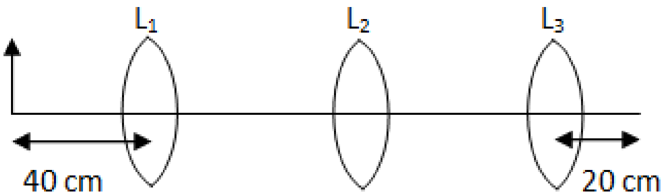
Q21. You are given three lenses L_1, L_2 and L_3, each of focal length 20 cm. An object is kept at 40 cm in front of L_1, as shown. The final real image is formed at the focus 'I' of L_3. Find the separations between L_1, L_2 and L_3.

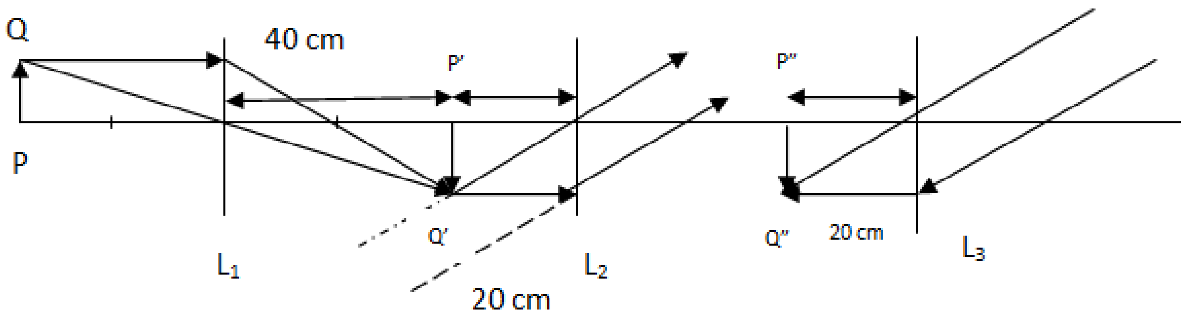


Answer: Considering the first lens L_1 , focal length=20 cm, u=40 cm, it means object PQ is kept at 2f from convex lens L_1 hence image P'Q' will be formed at 2f i.e 40 cm on the other side of L1.

Now let us take it in reverse way, final image P"Q" is formed by at focus of L_3 (at a distance 20 cm), this is possible if object distance for L_3 is at infinity (object of L_3 not shown in ray diagram as it is at infinite distance and rays falling on L_3 is parallel to each other).

L_2 produced image is actually object for L_3, so L_2 must produce image at infinity then only L_3 can form final image at its focus. This is possible if object (P'Q') distance for L_2 is equal to its focal length.

Case I: If the distance of separation is more than 40 then one possibility is object distance for L_2 is equal to its focal length 20 cm therefore separation between L_1 and L_2 is 40+20=60 cm.



Case II: if separation is not more than 40 cm then P'Q' will lie on the other side of L_2, above ray diagram cannot be justified.

Thus separation between lenses cannot be concluded with certainty.

Q22. Define the terms (I) cut-off voltage and (II) threshold frequency in relation to phenomenon of photoelectric effect.

Using Einstein's photo electric equation show how the cut-off voltage and threshold frequency for a given photosensitive material can be determined with the help of suitable photograph.

Answer: (I) Cut-off voltage: When the collector is kept at negative potential with respect to the emitter current (i) decrease rapidly as Potential (V) become more and more negative and current (i) becomes zero at a particular value of negative potential. This negative potential at which photo electric current becomes zero is known as stopping potential (V_s) or Cut-off voltage.

(II) Threshold frequency: For every emitting electrode there is a minimum value of frequency of the incident light below which no photoelectric current is emitted and that frequency is known as threshold frequency.

Einstein's Photo electric equation:

Let ν = frequency of incident light

E = Energy of the incident light $= h\nu$

h = Plank's constant $= 6.625\times10^{-34}$ Joule Sec

E_0 = Work function of the emitting electrode

For emission of electron the necessary condition $E >> E_0$

$E_0 = h\nu_0$

$\therefore h\nu \geq h\nu_0$

$\nu \geq \nu_0$

Thus for emission of photo electron the frequency of incident light ν must be greater than or equal to ν_0 hence ν_0 is the thereshold frequency.

Let $E > E_0$

$E - E_0$ = The maximum kinetic energy of the phto electron $= \frac{1}{2}mv_{max}^2$

or $h\nu - h\nu_0 = \frac{1}{2}mv_{max}^2$

$h\nu - h\nu_0 = eV_s$

$\nu - \nu_0 = \frac{e}{h}V_s$

$\nu = \nu_0 + \frac{e}{h}V_s$

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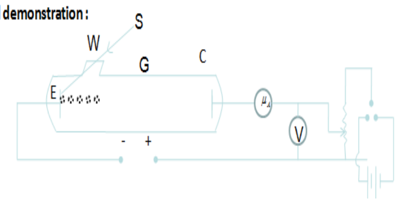
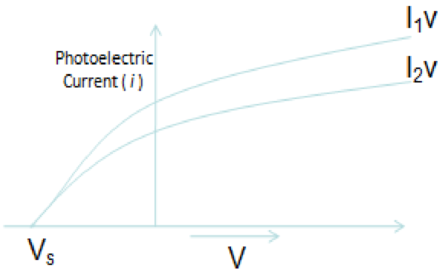
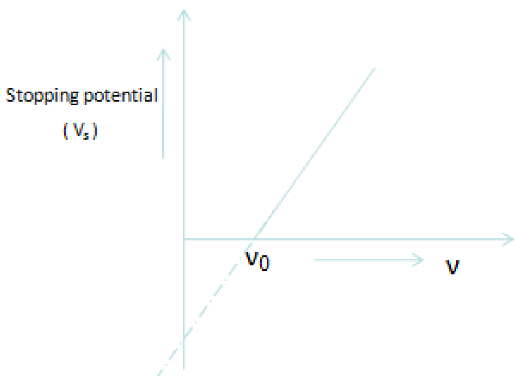
Experimental demonstration:



Graph for finding Stopping Potential:



Graph of finding Threshold frequency



G is a glass discharge tube having a window W of quartz which allow the ultraviolet light to pass through. E is the emitting surface and C is the collecting electrode. A potential difference known as accelerating potential difference is applied between the two electrodes by using a potential divider arrangement and commutator and he applied potential difference is measured by a voltmeter. The photo electric current flowing in the circuit is measured by micro ammeter.

Photo electric equation is $\nu = \nu_0 + \frac{e}{h}V_s$

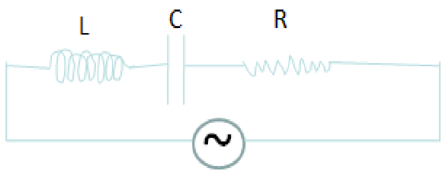
1. Different voltages applied plotted along X-axis and photo electric current found plotted along Y axis. Voltage for which no current found in circuit is cut-off voltage (Graph shows Vs data point)

2. Now keeping intensity of incident light same only Frequency is varied from the plotted data point graph shown threshold frequency can be found.

Q23. A series LCR circuit is connected to an ac source. Using the phasor diagram, derive the expression for the impedance of the circuit. Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation.

Answer:

L-C-R circuit :



We know that in capacitor (C) current leads emf by π/2 , in inductance current lags emf by π/2 (L) and in resistance (R) current is in phase with emf.

If V_L, V_c, V_R and V represents the voltage across the inductor, capacitor, resistance and source.

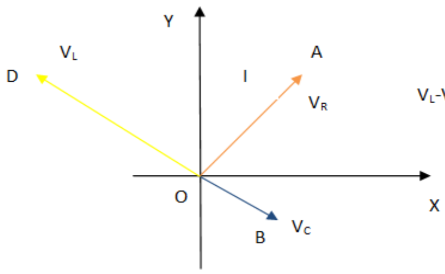


Fig-1

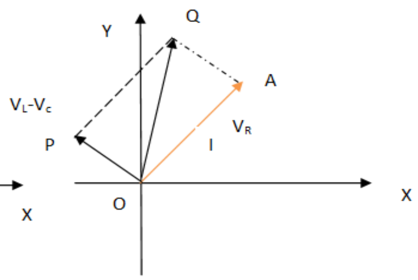


Fig-2

For the above vector diagram, Let the direction of current be along $\overrightarrow{OA}$, therefore

V_R= IR can be represented along $\overrightarrow{OA}$.

V_L=IX_L=IωL , since it lags current by π/2 , represented along $\overrightarrow{OD}$.

V_c=IXc=I/ωC, since current leads by π/2, represented along$\overrightarrow{OB}$.

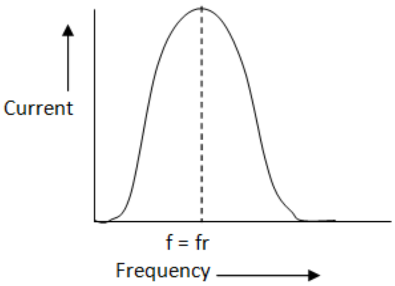
Therefore V_c and V_L are 180^0 apart, resultant obtained by subtraction= V_L- V_C=$\overrightarrow{OP}$ (shown in fig-2)

Now from ΔOQP: $OQ^2 = OP^2 + PQ^2$, $V^2= V_R^2+(V_L - V_c)^2= I^2[R^2 + (\omega L - 1/\omega C)^2]$ Or $\frac{V}{I} = Impedance(Z)$

The impedance of the circuit

$$z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega c}\right)^2}$$

The given graph showing variation of current with the frequency of the applied voltage.



As the frequency increased initially current increases, for a particular value of frequency current reaches to its peak value (maximum value) in this instance Impedance offered by LCR is minimum, this frequency is known as Resonant Frequency ω_r. When frequency of AC in increased further current decreases. The rapidity by which current increases or decreases with frequency is referred as sharpness, more is the sharpness less will be the inverted bell graph shown width. It is called acceptor circuit.

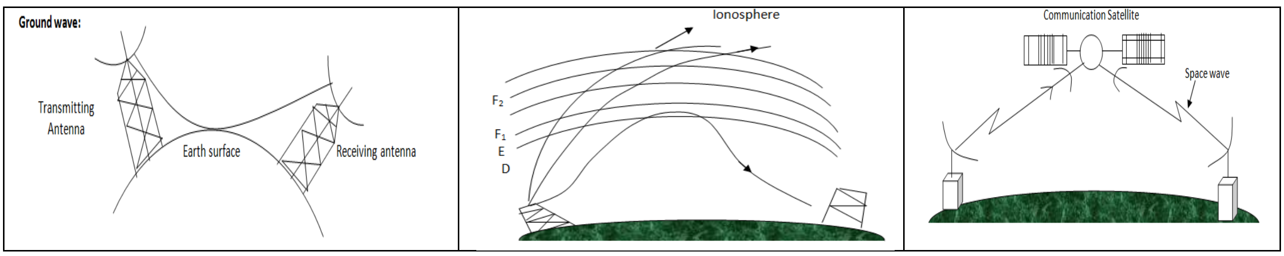
The impedance of the circuit

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

Z will be minimum where when $\omega L = \frac{1}{\omega C}$ $or\ \omega^2 = \frac{1}{LC}$ $this\ \omega\ say\ \omega_r\ therefore\ \omega_r = \frac{1}{\sqrt{LC}}$

Q24. Mention three different modes of propagation used in communication system. Explain with the help of diagram how long distance communication can be achieved by ionospheric reflection of radio waves.

Answer: schematic diagram showing the (I) ground wave (II) sky wave and (III) space wave



The ionosphere is a region of the upper atmosphere where there are large concentrations of free ions and electrons. Ionosphere contains ions, the free electrons that affect the radio waves and radio communications. The ionosphere affects signals on the short wave radio bands where it "reflects" signals, which helps these radio communications signals to be heard over vast distances. Radio stations have long used the properties of the ionosphere to enable them to provide worldwide radio communications coverage. Although today, satellites are widely used, HF radio communications using the ionosphere still plays a major role in providing worldwide radio coverage.

The different layers of ionosphere contributing to the wave propagation are

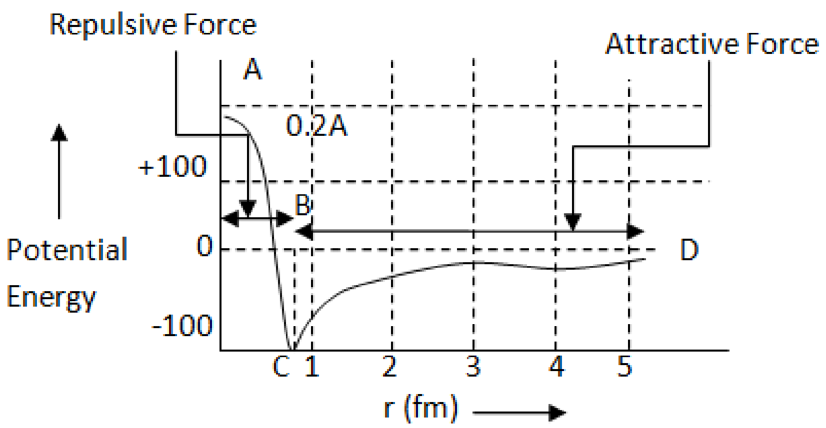
D- Region:60-90 KM, It mainly has the affect of absorbing or attenuating radio communications signals particularly in the LF and MF portions of the radio spectrum.

E-Region: Above D-Region, 100 and 125 kilometres. Instead of attenuating radio communications signals this layer chiefly refracts them, often to a degree where they are returned to earth.

F-Region: It is subdivided into F1 and F2, F1 at height 300 KM & F2 layer above it at around 400 kilometres. The combined F layer acts as a "reflector" of signals in the HF portion of the radio spectrum enabling worldwide radio communications to be established. It is the main region associated with HF signal propagation.

Q25. Draw a plot of potential energy of a pair of nucleons as a function of their separations. Mark the regions where the nuclear force is (I) attractive and (II) repulsive. Write any two characteristic features of nuclear forces.

Answer:



Potential energy is plotted along Y –axis, distance of separation between nucleons r(fm) plotted along X-axis, in the above graph segment AB represents repulsive force and BCD segment represents attractive force.
Two characteristic features of Nuclear Forces

i. Nuclear forces are stronger but short ranged.
ii. Nuclear forces are charge-independent.

Q26. In a Geiger – Marsden experiment, calculate the distance of closet approach to the nucleus of Z = 80, when an $\alpha -$ particle of 8 MeV energy impinges on it before it comes momentarily to rest and reverses its direction.

How will the distance of closet approach be affected when the kinetic energy of the $\alpha -$ particle is doubled?

Answer: At the closest distance the Kinetic Energy = Electric Potential Energy

Given Kinetic Energy (KE) = 8 MeV =$8 \times 1.6 \times 10^{-13}$J.

Potential energy $= \frac{1}{4\pi\epsilon_0}\frac{(Ze)e}{r} = 9 \times 10^9 \times \frac{80\times(1.6\times10^{-19})^2}{r}$

Therefore $8 \times 1.6 \times 10^{-13} = 9 \times 10^9 \times \frac{80\times(1.6\times10^{-19})^2}{r}$

At closest approach: $9 \times 10^9 \times \frac{80\times(1.6\times10^{-19})^2}{r} = 8 \times 1.6 \times 10^{-13}$

$$r = 9 \times 10^9 \times \frac{80 \times (1.6 \times 10^{-19})^2}{8 \times 1.6 \times 10^{-13}} = \frac{9 \times 1.6 \times\ 10^{9-38+13+1}}{1} = 14.4 \times 10^{-15}\text{m}$$

When KE is doubled it becomes = 16 MeV, then Kinetic Energy = Electric Potential Energy

$16 \times 1.6 \times 10^{-13}$=$9 \times 10^9 \times \frac{80\times(1.6\times10^{-19})^2}{r_1}$ here distance of closest approach $\frac{14.4\times10^{-15}}{2}$

Thus the distance of closed approach becomes half.

Q27. Define relaxation time of the free electrons drifting in conductor. How is it related to the drift velocity of free electrons? Use this relation to deduce the expression for the electrical resistivity of the material.

Answer: Relaxation time **-** The time of free travel of electrons between successive collisions is called the relaxation time. It is denoted by τ.

Relation between relaxation time (τ) and drift velocity(v_d):

Let v_d= drift velocity is the average velocity that a particle, such as an electron, attains due to an electric field.

m= mass of electron, e= charge of electron, E = Electric field then

$$\tau = \frac{v_d m}{eE} \rightarrow (1)$$

When temperature increases, the thermal speed of electrons increases; so collisions of electrons occur more frequently. As a result the relaxation time of electrons decreases.

Expression for electrical Resistivity:

The formula for evaluating the drift velocity of charge carriers in a material of constant cross-sectional area is given by

$$\overrightarrow{v_d} = \frac{I}{neA} \; or \; I = \overrightarrow{v_d} neA \rightarrow (2)$$

Where I = current flowing through the material,

n = charge-carrier density

A = area of cross-section of the material

Multiplying both sides of equation (2) by Δt, we get

$$I\Delta t = \overrightarrow{v_d} neA\Delta t$$

$\frac{I\Delta t}{A\Delta t} = \overrightarrow{v_d} ne$ Putting the value of $\overrightarrow{v_d}$ from equation (1)

$$\vec{J} = \frac{\tau e\vec{E}}{m} ne$$

$\vec{J} = \frac{n\tau e^2\vec{E}}{m} \rightarrow (3)$

Because current is proportional to drift velocity, which in a resistive material is, in turn, proportional to the magnitude of an external electric field.

We know that resistivity (ρ) is defined as $\rho = \frac{E}{J}$ $from$ (3)

$\rho = \frac{m}{n\tau e^2} \rightarrow (4)$

Equation (4) gives the relation between resistivity and relaxation time.