Class XII Session 2023-24
Subject - Physics
Sample Question Paper - 6

Time Allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
3. All the sections are compulsory.
4. **Section A** contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, **Section B** contains five questions of two marks each, **Section C** contains seven questions of three marks each, **Section D** contains two case study based questions of four marks each and **Section E** contains three long answer questions of five marks each.
5. There is no overall choice. However, an internal choice has been provided in one question in Section B, one question in Section C, one question in each CBQ in Section D and all three questions in Section E. You have to attempt only one of the choices in such questions.
6. Use of calculators is not allowed.

Section A

1. The energy band gap is maximum in: **[1]**

a) Metals

b) Insulators

c) Superconductors

d) Semiconductors

2. Time taken by an 836 W water heater to heat one liter of water from 10°C to 40°C is: **[1]**

a) 100 s

b) 50 s

c) 150 s

d) 200 s

3. The magnifying power of telescope is high if **[1]**

a) the objective has a long focal length and the eye-piece has a short focal length

b) both objective and eye-piece have short focal lengths

c) the objective has a short focal length and the eye-piece has a long focal length

d) both objective and eye-piece have long focal length

4. Two similar magnets of magnetic moments M_1 and M_2 are taken and vibrate in a vibration magnetometer with their **[1]**

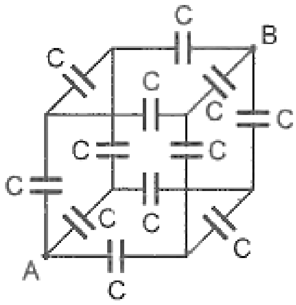
i. like poles together

ii. unlike poles together. If the ratio of the time periods is $\frac{1}{2}$, then the ratio of M_1 and M_2 $\left(\text{i.e., } \frac{M_1}{M_2}\right)$ is

a) 0.5 b) $\frac{5}{3}$

c) 2 d) $\frac{1}{3}$

5. The equivalent capacity between points A and B shown in the figure is: **[1]**



a) $(\frac{5}{6})C$ b) C

c) 30 C d) $(\frac{6}{5})C$

6. Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field B = $B_0\,\hat{k}$. **[1]**

a) The charge to mass ratio satisfy: $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$ b) They must have equal charges

c) They have equal z-components of momenta d) They necessarily represent a particle-antiparticle pair

7. Two concentric circular coils, one of small radius r_1 and the other of large radius r_2, such that $r_1 << r_2$, are placed co-axially with centres coinciding. Mutual inductance of the arrangement is **[1]**

a) $\frac{\mu_0 \pi r_1^2}{2r_2^3}$ b) $\frac{\mu_0 \pi r_1^3}{2r_2^2}$

c) $\frac{\mu_0 \pi r_1}{3r_2}$ d) $\frac{\mu_0 \pi r_1^2}{2r_2}$

8. Tesla is the unit of **[1]**

a) magnetic induction b) electric field

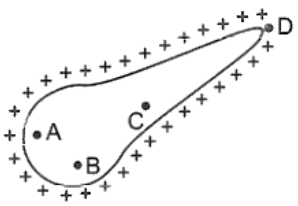
c) electric flux d) magnetic flux

9. For a parallel beam of monochromatic light of wavelength λ, diffraction is produced by a single slit whose width a is of the order of the wavelength of the light. If D is the distance of the screen from the slit, the width of the central maxima will be **[1]**

a) $\frac{2Da}{\lambda}$ b) $\frac{D\lambda}{a}$

c) $\frac{2D\lambda}{a}$ d) $\frac{Da}{\lambda}$

10. For the isolated charged conductor of given figure, the electric fields at points A, B, C and D are E_A, E_B, E_C and E_D respectively. Then: **[1]**

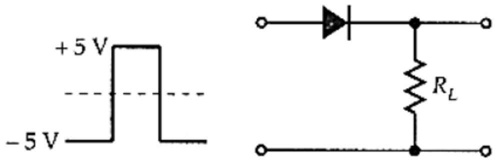


a) $E_D > E_A = E_B = E_C = 0$ b) $E_B = 0, E_A = E_C = E_D$

c) $E_A = E_B = E_C > E_D$

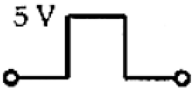
d) $E_A = E_B > E_C > E_D$

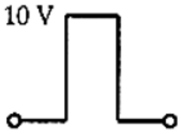
11. If in a p-n junction, a square input signal of 10 V is applied as shown, **[1]**

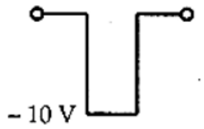


then the output across R_L will be

a) 

b) 

c) 

d) 

12. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will: **[1]**

a) Become infinite

b) Become zero

c) Reduce

d) Remain same as in air

13. **Assertion (A):** When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When the ultraviolet light is replaced by X-rays, both V_0 and K_{max}. increase. **[1]**

Reason (R): Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

14. **Assertion:** Circuits containing high capacity capacitors, charged to high voltage should be handled with caution, even when the current in the circuit is switched off. **[1]**

Reason: When an isolated capacitor is touched by hand or any other part of the human body, there is an easy path to the ground available for the discharge of the capacitor.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

c) Assertion is correct statement but reason is wrong statement.

d) Assertion is wrong statement but reason is correct statement.

15. **Assertion (A):** We cannot get a diffraction patterns from a wide slit illuminated by monochromatic light. **[1]**

Reason (R): In the diffraction pattern, all the bright bands are not of the same intensity.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

16. **Assertion (A):** Ac is more dangerous than dc. **[1]**

Reason (R): The frequency of ac is dangerous for the human body.

a) Both A and R are true and R is the correct explanation of A.

b) Both A and R are true but R is not the correct explanation of A.

c) A is true but R is false.

d) A is false but R is true.

Section B

17. A plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time, **E** = 6.3 $\hat{\mathbf{j}}$ V/m. What is **B** at this point? **[2]**

18. What is relative permeability of a magnetic material? How is it related to the magnetic susceptibility? **[2]**

19. Write the characteristics of a p-n junction which make it suitable for rectification. **[2]**

20. Determine the speed of the electron in n = 3 orbit of He^+ ion. **[2]**

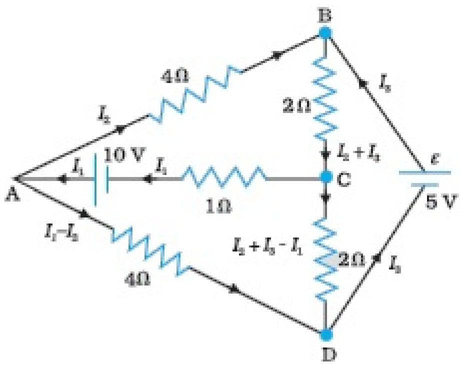
21. The magnetic field due to a current-carrying circular loop of radius 12 cm at its centre is 0.50×10^{-4} T. Find the magnetic field due to this loop at a point on the axis at a distance of 5.0 cm from the centre. **[2]**

OR

An electron enters with a velocity $v = v_0\hat{i}$ into a cubical region (faces parallel to coordinate planes) in which there are uniform electric and magnetic fields. The orbit of the electron is found to spiral down inside the cube in plane parallel to the x-y plane. Suggest a configuration of fields E and B that can lead to it.

Section C

22. Determine the current in each branch of the network shown in Fig. **[3]**



23. Draw V-I characteristics of a p-n junction diode. Answer the following giving reasons: **[3]**

a. Why is the reverse bias current almost independent of applied voltage up to breakdown voltage?
b. Why does the reverse current show a sudden increase at breakdown voltage?

24. Explain giving reasons for the following : **[3]**

i. Photoelectric current in a photocell increases with the increase in the intensity of the incident radiation.
ii. The stopping potential (V_0) varies linearly with the frequency (ν) of the incident radiation for a given photosensitive surface with the slope remaining the same for different surfaces.
iii. Maximum kinetic energy of the photoelectrons is independent of the intensity of incident radiation.

25. i. Draw a plot showing the variation of potential energy of a pair of nucleons as a function of their separation. Mark the regions where the nuclear force is **[3]**

a. attractive and
b. repulsive.

ii. In the nuclear reaction ${}_0n^1 + {}^{235}_{92}U \rightarrow {}^{a}_{54}Xe + {}^{94}_{b}Sr + 2{}_0n^1$ determine the values of a and b.

26. a. Using the Bohr's model, calculate the speed of the electron in a hydrogen atom in the n = 1, 2 and 3 levels. **[3]**

b. Calculate the orbital period in each of these levels.

27. A plane wavefront is incident on a surface separating two media of refractive indices n_1 and n_2 (> n_1). With the help of a suitable diagram, explain its propagation from the rarer to denser medium. Hence, verify Snell's law. **[3]**

28. A metallic rod of length l and resistance R is rotated with a frequency ν, with one end hinged at the centre and the other end at the circumference of a circular metallic ring of radius l, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. **[3]**

i. Derive the expression for the induced emf and the current in the rod.
ii. Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.
iii. Hence obtain the expression for the power required to rotate the rod.

OR

A magnetic field B is confined to a region $r \leq a$ and points out of the paper (the z-axis), r = 0 being the centre of the circular region. A charged ring (charge = Q) of radius b, b > a and mass m lies in the x-y plane with its centre at the origin. The ring is free to rotate and is at rest. The magnetic field is brought to zero in time Δt. Find the angular velocity ω of the ring after the field vanishes.

Section D

29. **Read the text carefully and answer the questions:** **[4]**

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) Which wavelength of the Sun is used finally as electric energy?
radio waves, infrared waves, visible light, microwaves

a) microwaves
b) visible light
c) radio waves
d) infrared waves

(ii) Which of the following electromagnetic radiations have the longest wavelength?
X-rays, γ-rays, microwaves, radiowaves

a) γ-rays
b) microwaves
c) radiowaves
d) X-rays

(iii) Which one of the following is not electromagnetic in nature?
X-rays, gamma rays, cathode rays, infrared rays

a) gamma rays
b) infrared rays
c) X-rays
d) cathode rays

OR

Which of the following has minimum wavelength?
X-rays, ultraviolet rays, γ-rays, cosmic rays

a) X-rays
b) cosmic rays
c) ultraviolet rays
d) γ-rays

(iv) The decreasing order of wavelength of infrared, microwave, ultraviolet and gamma rays is

a) gamma rays, ultraviolet, infrared, microwave

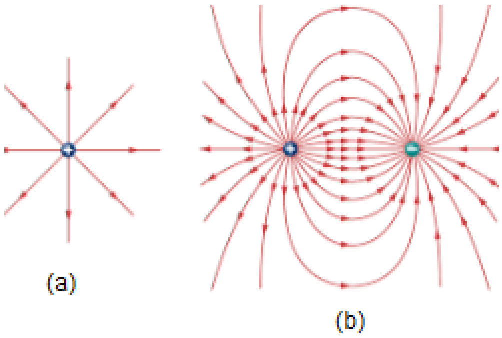
b) microwave, gamma rays, infrared, ultraviolet

c) microwave, infrared, ultraviolet, gamma rays

d) infrared, microwave, ultraviolet, gamma rays.

30. **Read the text carefully and answer the questions:** **[4]**

Electric field lines as a path, straight or curved in an electric field such that tangent to it at any point gives the direction of electric field intensity at the point. Electric field lines are continuous curves they start from a positive charged body and end at the negatively charged body. (Refer image)



(i) Electric field due to a single charge is:

a) cylindrically symmetric

b) none of these

c) asymmetric

d) spherically symmetric

(ii) The SI unit of electric field intensity is:

a) N/C

b) N

c) C/m^2

d) N/m^2

(iii) Pick the wrong statement.

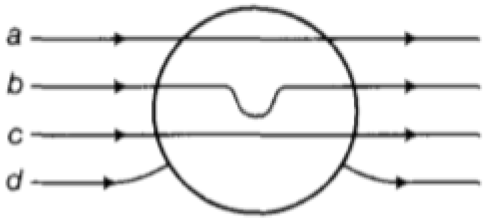
a) Electric field lines are continuous curves.

b) Electric field lines can intersect each other.

c) Electric field lines are always normal to the surface of a conductor.

d) The electrostatic field does not form a closed loop.

(iv) A metallic sphere is placed in a uniform electric field as shown in the figure. Which path is followed by electric field lines?



a) path 'd'

b) path 'c'

c) path 'a'

d) path 'b'

OR

Pick the true statements about electric field lines.

a) Electric field lines provide information

b) Electric field lines provide

about the field strength.

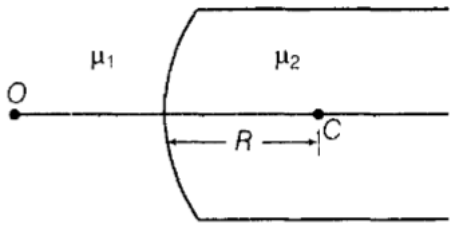
information about the type of charge.

c) All of these.

d) Electric field lines provide information about the direction of the electric field.

Section E

31. Figure shows a convex spherical surface with centre of curvature C separating the two media of refractive indices μ_1 and μ_2. Draw a ray diagram showing the formation of the image of a point object O lying on the principal axis. Derive the relationship between the object and image distance in terms of refractive indices of the media and the radius of curvature R of the surface. **[5]**

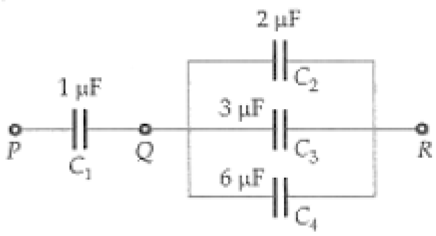


OR

i. What is the effect on the interference fringes to a Young's double slit experiment when
   a. the separation between the two slits is decreased?
   b. the width of the source slit is increased?
   c. the monochromatic source is replaced by a source of white light? Justify your answer in each case.

ii. The intensity at the central maxima in Young's double slit experimental set up is I_0. Show that the intensity at a point is $\frac{I_0}{4}$, where the path difference is $\frac{\lambda}{3}$.

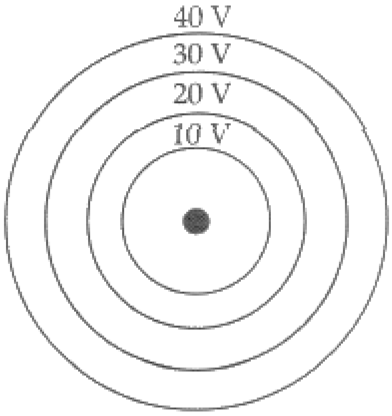
32. In Fig. the energy stored in C_4 is 27 J. Calculate the total energy stored in the system. **[5]**



OR

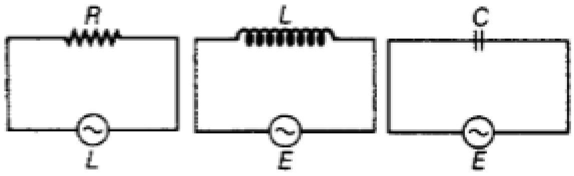
i. Two isolated metal spheres A and B have radii R and 2R respectively, and the same charge q. Find which of the two spheres have greater:
   a. capacitance and
   b. energy density just outside the surface of the spheres

ii. a. Show that the equipotential surfaces are closed together in the regions of a strong field and far apart in the regions of a weak field. Draw equipotential surfaces for an electric dipole,
   b. Concentric equipotential surfaces due to a charged body placed at the centre are shown. Identify the polarity of the charge and draw the electric field lines due to it.



33. i. What do you understand by the sharpness of resonance in a series L-C-R circuit? Derive an expression for Q-factor of the circuit. **[5]**

ii. Three electrical circuits having AC sources of variable frequency are shown in the figures. Initially, the current flowing in each of these is same. If the frequency of the applied AC source is increased, how will the current flowing in these circuits be affected? Give the reason for your answer.



OR

i. An ac source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L, C, and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when the current will be in phase with the voltage. What is the circuit in this condition called?

ii. In a series, LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate $\frac{P_1}{P_2}$.

Solution

Section A

1.

(b) Insulators

Explanation: Insulators

2.

(c) 150 s

Explanation: Heater gives energy at a rate of 836 joules per second.

$P = 836\ W$ and $T_1 = 10^0C$ and $T_2 = 40^0C$

Heat energy required to raise temperature of mass *m* of water from T_1 to T_2 is given as,

$Q = \ mS(T_2 - T_1)$

S is specific heat of water = 4.186 J/g℃

Let t be the time required to heat water, then

$Q = Pt$

From above equations,

$\Rightarrow 836 \times t = 1000 \times 4.186 \times (40 - 10)$

$\Rightarrow t = \frac{4186 \times 30}{836}$

$\Rightarrow t \approx 150\ seconds$

3. **(a)** the objective has a long focal length and the eye-piece has a short focal length

Explanation: Magnifying power of telescope is directly proportional to $\frac{f_o}{f_e}$.

Hence, f_o should be large and f_e should be small.

4.

(b) $\frac{5}{3}$

Explanation: $\frac{M_1}{M_2} = \frac{T_2^2 + T_1^2}{T_2^2 - T_1^2}$

$= \frac{1 + \left(\frac{T_1}{T_2}\right)^2}{1 - \left(\frac{T_1}{T_2}\right)^2} = \frac{1 + \frac{1}{4}}{1 - \frac{1}{4}} = \frac{5}{3}$

5.

(d) $(\frac{6}{5})C$

Explanation: $(\frac{6}{5})C$

6. **(a)** The charge to mass ratio satisfy: $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$

Explanation: For a given pitch, $P = \frac{2\pi mv\cos\theta}{Bq}$ by rearranging the equation we get,

$\frac{q}{m} = \frac{2\pi v\cos\theta}{BP}$ [θ is the angle of the velocity of a charged particle with X-axis]

If the motion is not helical then , θ = 0

As path both the particles are identical and helical but of opposite direction in the same magnetic field so by the law of conservation of momenta.

$\left(\frac{e}{m}\right)_1 + \left(\frac{c}{m}\right)_2 = 0$

7.

(d) $\frac{\mu_0 \pi r_1^2}{2r_2}$

Explanation: Let a time varying current I_2 flow through the outer circular coil.

$\therefore$ Magnetic field at the centre of this coil is

$B_2 = \frac{\mu_0 I_2}{2r_2}$

Since the inner coil placed co-axially has very small radius, B_2 may be considered constant over its cross-sectional area.

$\therefore$ Magnetic flux associated with inner coil is

$\phi_1 = B_2 \times \pi r_1^2 = \left(\frac{\mu_0 I_2}{2r_2}\right) \pi r_1^2 = \pi r_1^2 \frac{\mu_0 I_2}{2r_2}$

or $\phi_1 = \left(\frac{\mu_0 \pi r_1^2}{2r_2}\right) I_2 = M_{12} I_2$

$\therefore M_{12} = \frac{\mu_0 \pi r_1^2}{2r_2}$

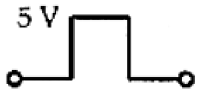
Now, $M_{12} = M_{21} = \frac{\mu_0 \pi r_1^2}{2r_2}$

8. **(a)** magnetic induction
Explanation: magnetic induction

9.
(c) $\frac{2D\lambda}{a}$
Explanation: Linear width of central maximum
= D × Angular width = D × $\frac{2\lambda}{a} = \frac{2D\lambda}{a}$

10. **(a)** $E_D > E_A = E_B = E_C = 0$
Explanation: $E_D > E_A = E_B = E_C = 0$

11.
(b)



Explanation: When the input level is -5 V, the diode gets reverse biased. No output is obtained across R_L. When the input level becomes +5 V, the diode gets forward biased and the current flows through R_L. The diode is ideal, the output across R_L will be exactly 5V.

12. **(a)** Become infinite
Explanation: $\frac{1}{f} = (\frac{\mu_2}{\mu_1} - 1)(\frac{1}{R_1} - \frac{1}{R_2})$
Since, $\mu_2 = \mu_1$,
$\frac{1}{f} = 0,\ hence\ f = \infty$

13.
(c) A is true but R is false.
Explanation: We know that
$eV_0 = K_{max} = h\nu - \phi$
where ϕ is the work function.
Hence, as ν increases (note that the frequency of X-rays is greater than that of U.V. rays), both V_0 and K_{max} increase.
So, A is true but R is false.

14. **(a)** Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation: Assertion and reason both are correct statements and reason is correct explanation for assertion.

15.
(b) Both A and R are true but R is not the correct explanation of A.
Explanation: Both A and R are true but R is not the correct explanation of A.

16. **(a)** Both A and R are true and R is the correct explanation of A.
Explanation: The effect of ac on the body depends largely on the frequency. Low-frequency currents of 50 to 60 Hz (cycles/sec), which are commonly used, are usually more dangerous than high-frequency currents and are 3 to 5 times more dangerous than dc of the same voltage and amperage (current). The usual frequency of 50 cps (or 60 cps) is extremely dangerous as it corresponds to the fibrillation frequency of the myocardium. This results in ventricular fibrillation and instant death.

Section B

17. $B = \frac{E}{c}$
$= \frac{6.3 \text{V/m}}{3 \times 10^8 \text{m/s}} = 2.1 \times 10^{-8} \text{T}$
To find the direction, we note that E is along y-direction and the wave propagates along x-axis. Therefore, B should be in a

direction perpendicular to both x- and y-axes. Using vector algebra, c = E $\times$ B should be along the x-direction.

Since, (+ $\hat{\mathbf{j}}$) $\times$ (+ $\hat{\mathbf{k}}$) = $\mathbf{i}$, B is along the z-direction.E is along y direction and c is along x direction

Thus, B = 2.1 $\times$ 10^{-8} $\hat{\mathbf{k}}$ T

18. **Relative permeability:** It is the ratio of the permeability of the material to the permeability of free space.

$\mu_r = \frac{\mu}{\mu_0}$

Magnetic susceptibility: It is the ratio of the intensity of magnetisation (M) incduced to the magnetising field intensity (H).

$\chi_m = \frac{M}{H}$

It can be shown that

$\mu = \mu_0 \left(1 + \chi_m\right)$

and $\mu_r = 1 + \chi_m$

19. p-n junction has an asymmetric voltage current relationship.

It allows the current to flow through it in the forward direction and block in the reverse direction.

20. Here n = 3 , Z = 2

$v = \frac{2\pi kZe^2}{nh}$

$= \frac{2\times3.14\times9\times10^9\times2\times\left(1.6\times10^{-19}\right)^2}{3\times6.6\times10^{-34}}$

= 1.46 $\times$ 10^6 ms^{-1}

21. B_{centre} = $\frac{\mu_0 I}{2a}$ and B_{axial} = $\frac{\mu_0 I a^2}{2\left(a^2+r^2\right)^{3/2}}$

$\therefore \frac{B_{\text{axial}}}{B_{\text{centre}}} = \frac{a^3}{\left(a^2+r^2\right)^{3/2}}$

or $B_{\text{axial}} = \frac{a^3}{\left(a^2+r^2\right)^{3/2}} \times B_{\text{centre}}$

Here a = 12 cm = 12 $\times$ 10^{-2} m, r = 5 cm = 5 $\times$ 10^{-2} m,

B_{centre} = 0.50 $\times$ 10^{-4} T

$\therefore$ B_{axial} = $\frac{\left(12\times10^{-2}\right)^3}{\left[144\times10^{-4}+25\times10^{-4}\right]^{3/2}}$ $\times$ 0.50 $\times$ 10^{-4} T

= $\frac{(12)^3\times0.50\times10^{-4}}{169\times13}$ = 3.9 $\times$ 10^{-5} T

OR

Due to magnetic force charge particle revolves in a uniform circular motion in x-y plane and due to electric field charge particle increases the speed along x-direction, which in turn increases the radius of a circular path and hence, particle traversed on spiral path.

Let us consider a magnetic field B = B_0 present in the region and an electron enters with a velocity into cubical region (faces parallel to coordinate planes). The force on electron, using magnetic Lorentz force, is given by

$\vec{F} = -e\left(v_0\hat{i} \times B_0\hat{k}\right) = ev_0 B_0\hat{j}$

which revolves the electron in x-y plane. and $E_0 = v_0B_0$

The electric force F = eE_0J accelerates e along z-axis which in turn increases the radius of the circular path and hence particle traversed on spiral orbit.

Section C

22. Each branch of the network is assigned an unknown current to be determined by the application of Kirchhoff's rules. To reduce the number of unknowns at the outset, the first rule of Kirchhoff is used at every junction to assign the unknown current in each branch. (current entering into the junction is equal to current leaving the junction) We then have three unknowns I_1, I_2 and I_3 which can be found by applying the second rule of Kirchhoff to three different closed loops. Kirchhoff's second rule for the closed-loop ADCA gives,

$10 – 4(I_1 – I_2) + 2(I_2 + I_3 – I_1) – I_1 = 0$ ...(i)

that is, $7I_1 – 6I_2 – 2I_3 = 10$

For the closed-loop ABCA, we get

$10 – 4I_2 – 2 (I_2 + I_3) – I_1 = 0$

that is, $I_1 + 6I_2 + 2I_3 = 10$ ...(ii)

For the closed-loop BCDEB, we get

$5 – 2 (I_2 + I_3) – 2 (I_2 + I_3 – I_1) = 0$

that is, $2I_1 - 4I_2 - 4I_3 = -5$ ...(iii)

Equations (i, ii, iii) are three simultaneous equations in three unknowns. These can be solved by the usual method to give

$I_1 = 2.5A$, $I_2 = \frac{5}{8}$ A, $I_3 = 1\frac{7}{8}$ A

The currents in the various branches of the network are

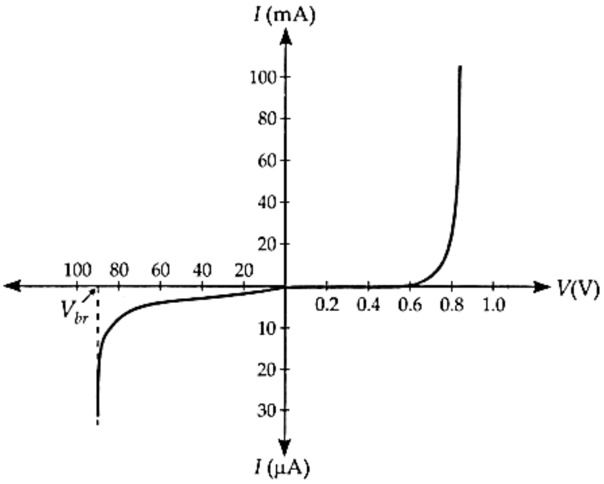
AB : $\frac{5}{8}$ A, CA : $2\frac{1}{2}$ A, DEB : $1\frac{7}{8}$ A

AD : $1\frac{7}{8}$ A, CD : 0 A, BC : $2\frac{1}{2}$ A

It is easily verified that Kirchhoff's second rule applied to the remaining closed loops does not provide any additional independent equation, that is, the above values of currents satisfy the second rule for every closed loop of the network. For example, the total voltage drop over the closed-loop BADEB

$5V + \left(\frac{5}{8} \times 4\right) V - \left(\frac{15}{8} \times 4\right) V$ equal to zero, as required by Kirchhoff's second rule.

23. For V - I characteristic of a p-n junction diode, see figure.

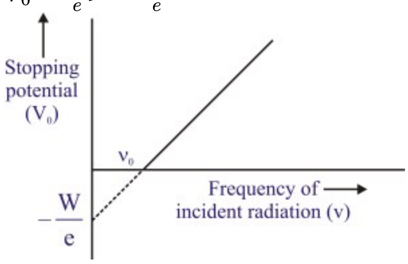


a. A very small current of order of few μA flows, when the diode is reverse biased. It is due to the drift of minority charge carriers whose number density remains constant, so the current under reverse bias is almost independent of the applied potential upto a critical voltage.
b. When the reverse voltage across the p-n junction reaches a critical voltage, the reverse current abruptly increases to a large value. It is due to the large increase in the number of minority charge carriers because of the breakdown of the diode. The avalanche breakdown occurs in lightly doped diodes due to ionisation by collision. Zener breakdown occurs at low voltages in heavily doped diodes by field emission.

24. i. The collision of a photon can cause emission of a photoelectron (if the frequency is above the threshold frequency). As intensity, if the frequency increases, number of photons increases. Hence, the current increases.

ii. We have, $eV_0 = h(\nu - \nu_0)$

$V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$

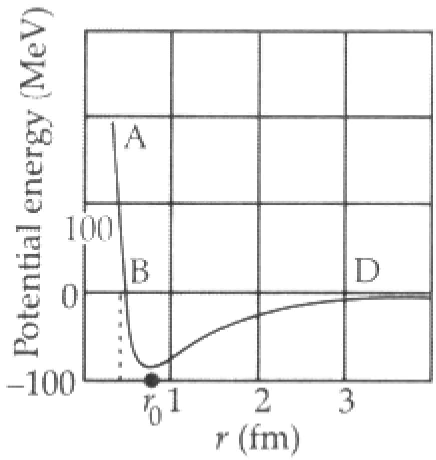


Graph of V_0 vs. ν is a straight line and slope is a constant.

iii. Maximum K.E. for different surfaces is given by $= h(\nu - \nu_0)$

Hence, kinetic energy depends on the frequency and not on the intensity of the incident radiation.

25. i.



For r > r_0, the force is attractive

For r < r_0, the force is repulsive

ii. We have, In nuclear reactions , mass no .is conserved Hence ,

1 + 235 =a + 94 + 2 × 1

∴ a = 2 3 6 - 9 6 = 140

In nuclear reactions , charge no. is conserved .so 0 + 92 = 54 + b + 2 × 0

∴ b = 92 - 54 = 38

26. a. Now, $v = \frac{c}{n}\alpha$,

where $\alpha = \frac{2\pi Ke^2}{ch}$ = 0.0073

$v_1 = \frac{3\times10^8}{1} \times 0.0073 = 2.19 \times 10^6 m/s$

$v_2 = \frac{3\times10^8}{3} \times 0.0073 = 1.095 \times 10^6 m/s$

$v_3 = \frac{3\times10^8}{3} \times 0.0073 = 7.3 \times 10^5 m/s$

b. Orbital period, $T = \frac{2\pi r}{v}$

As $r_1 = 0.53 \times 10^{-10} m$

$T_1 = \frac{2\pi\times0.53\times10^{-10}}{2.19\times10^6} = 1.52 \times 10^{-16} s$

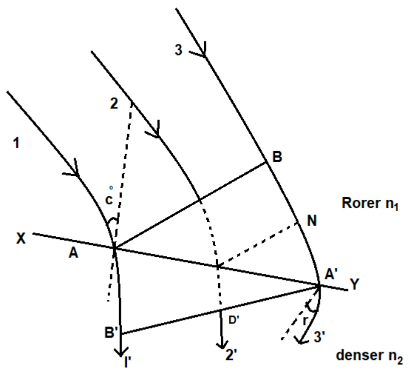
As r_2 = 4 r_1 and $v_2 = \frac{1}{2}v_1$

$T_2 = 8\ T_1 = 8 \times 1.52 \times 10^{-16} s = 1.216 \times 10^{-15} s$

As r_3 = 9r_1 and $v_3 = \frac{1}{3}v_1$

$\therefore T_3 = 27\ T_1 = 27 \times 1.52 \times 10^{-16} s = 4.1 \times 10^{-15} s$

27.



Let XY be interface of two mediums and c_1 and c_2 are velocity of light is rarer and denser medium respectively.

Then, refractive index of denser medium relative to rarer medium $\mu = \frac{c_1}{c_2}$

Also, according to Huygens principle, every point of plane wavefront AB acts as a source of secondary wavelet. Let the secondary wavelets takes time t from B to strike at XY surface at A'

BA' = c_1 × t

in same time t wavelet from A travels with speed c_2 and strikes B'

AB' = $c_2 \times t$

In △AA'B

sin i = $\frac{BA'}{AA'} = \frac{C_1 t}{AA'}$

In △AA'B'

sin r = $\frac{AB'}{AA'} = \frac{C_2 \times t}{AA'}$

$\frac{\sin i}{\sin r} = \frac{c_1}{c_2} = \mu = \frac{n_2}{n_1}$ This verifies the snell's law of refraction.

28. i. In the one revolution, change of area,

$dA = \pi l^2$

∴ Change of magnetic flux in one revolution of the rod,

$d\phi_B = \vec{B} \cdot d\vec{A} = BdA\cos 0^\circ = B\pi l^2$

(Given, magnetic field intensity, $\vec{B}$ is parallel to change in area, $d\vec{A}$)

If period of revolution is T,

a. Induced emf (e) = $\frac{d\phi}{dt} = \frac{B\pi l^2}{T} = B\pi l^2 \nu$ $(\because \nu = \frac{1}{T}$)

b. Induced current in the rod,

$I = \frac{e}{R} = \frac{\pi \nu B l^2}{R}$

(Given R = resistance of the rod)

ii. Magnitude of force acting on the rod,

$|\vec{F}| = |I(\vec{l} \times \vec{B})| = BIlsin90^0 = \frac{\pi \nu B^2 l^3}{R}$

The external force required to rotate the rod opposes the Lorentz force acting on the rod, i.e external force acts in the direction opposite to the Lorentz force.

iii. Power required to rotate the rod,

$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi \nu B^2 l^3 v}{R}$

OR

By the relation between electric field and potential we get,

The induced emf = Electric field E × ($2\pi b$) (Because V = E × d) ..... (i)

If E is the electric field generated around the charged ring of radius b, then as e By Faraday's law:

$|\varepsilon| = \frac{d\phi}{dt} = A\frac{dB}{dt}$

$|\varepsilon| = \frac{B\pi a^2}{\Delta t}$ ...... (ii)

From Eqs. (i) and (ii), we have

$2\pi bE = \varepsilon = \frac{B\pi a^2}{\Delta t}$

As we know the electric force experienced by the charged ring, F_e = QE

his force try to rotate the coil, and the torque is given by

Torque = b × Force

$\tau = QEb = Q\left[\frac{B\pi a^2}{2\pi b\Delta t}\right]b$

$\Rightarrow \quad \tau = Q\frac{Ba^2}{2\Delta t}$

If ΔL is the change in angular momentum of the charged ring then,

$\Delta L = \text{ Torque } \times \Delta t = Q\frac{Ba^2}{2}$

since, initial angular momentum = 0

And Torque $\times \Delta t$ = Change in angular momentum

Final angular momentum $= mb^2\omega = \frac{QBa^2}{2}$

Where, mb^2 = I (moment of inertia of ring)

$\omega = \frac{QBa^2}{2mb^2}$

On rearranging the term, we have the required expression of angular speed.

Section D

29. **Read the text carefully and answer the questions:**

All the known radiations from a big family of electromagnetic waves which stretch over a large range of wavelengths. Electromagnetic wave include radio waves, microwaves, visible light waves, infrared rays, UV rays, X-rays and gamma rays. The orderly distribution of the electromagnetic waves in accordance with their wavelength or frequency into distinct groups having widely differing properties is electromagnetic spectrum.

(i) **(d)** infrared waves

Explanation: Infrared rays can be converted into electric energy as in solar cell.

(ii) **(c)** radiowaves

Explanation: Radiowaves have longest wavelength.

(iii) **(d)** cathode rays

Explanation: Cathode rays are invisible fast moving streams of electrons emitted by the cathode of a discharge tube which is maintained at a pressure of about 0.01 mm of mercury.

OR

(d) γ-rays

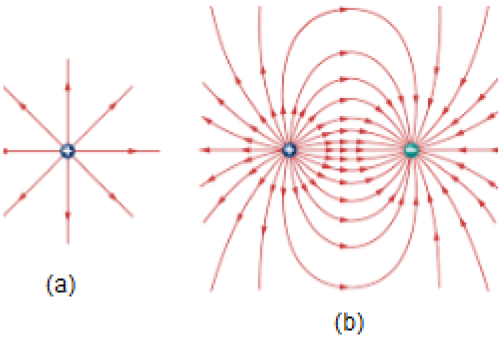
Explanation: γ-rays have minimum wavelength.

(iv) **(c)** microwave, infrared, ultraviolet, gamma rays

Explanation: $\lambda_{\text{micro}} > \lambda_{\text{infra}} > \lambda_{\text{ultra}} > \lambda_{\text{gamma}}$

30. **Read the text carefully and answer the questions:**

Electric field lines as a path, straight or curved in an electric field such that tangent to it at any point gives the direction of electric field intensity at the point. Electric field lines are continuous curves they start from a positive charged body and end at the negatively charged body. (Refer image)



(i) **(d)** spherically symmetric

Explanation: spherically symmetric

(ii) **(a)** N/C

Explanation: N/C

(iii) **(b)** Electric field lines can intersect each other.

Explanation: Electric field lines can intersect each other.

(iv) **(a)** path 'd'

Explanation: path 'd'

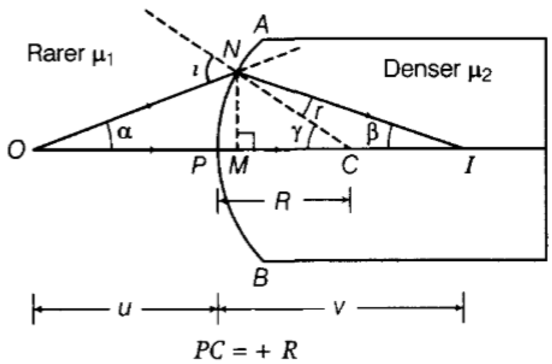
OR

(c) All of these.

Explanation: All of these.

Section E

31. The ray diagram is shown in the figure.



Let, NM = h

The convex spherical refracting surface forms the image of object O at I. The radius of curvature is R

Here $PI = +v \ and \ PO = -u$

In $\triangle NCO, \ i = \gamma + \alpha$ ...(i)

In $\triangle NCI, \ \gamma = r + \beta$

$\Rightarrow \quad r = \gamma - \beta$ ...(ii)

For small angles $\alpha, \ \beta$ and γ and assuming M is very close to P, we have

$\alpha \approx \tan\alpha = \frac{MN}{MO} = \frac{MN}{PO} = \frac{+h}{-u}$

$\beta \approx \tan\beta = \frac{MN}{MI} = \frac{MN}{PI} = \frac{h}{v}$

$\gamma \approx \tan\gamma = \frac{MN}{MC} = \frac{MN}{PC} = \frac{h}{+R}$

By Snell's law,

$\frac{\mu_2}{\mu_1} = \mu = \frac{\sin i}{\sin r}$

For small i and r,

$\frac{\mu_2}{\mu_1} = \frac{i}{r}$ or $r\mu_2 = i\mu_1$

$\mu_2(\gamma - \beta) = (\alpha + \gamma)\mu_1$ [From Eqs. (i) and (ii)]

$(\mu_2 - \mu_1)\gamma = \mu_1\alpha + \mu_2\beta$

$(\mu_2 - \mu_1)\left(\frac{h}{R}\right) = \mu_1\left(\frac{h}{-u}\right) + \mu_2\left(\frac{h}{v}\right)$

$\Rightarrow \quad \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

This is the required relation.

OR

i. a. From the fringe width expression, we have
   $\beta = \frac{\lambda D}{d}$, therefore with the decrease in separation between two slits, ‘d’ the fringe width increases.
   b. For interference fringes to be seen, $\frac{s}{S} < \frac{\lambda}{d}$, condition should be satisfied otherwise, the interference patterns produced by different parts of the source slit will overlap.
   As, the source slit width increases, the fringe pattern gets less and less sharp. When the source slit is so wide, the above condition does not satisfy and the interference pattern disappears. However, as long as the fringes are visible, the fringe width remains constant.
   c. When monochromatic light is replaced by white light, then coloured fringe pattern is obtained on the screen.
   The interference pattern due to different colour component of white light overlap. The central bright fringes for different colours are at the same position. Therefore, central fringes are white. And on the either side of the central fringe white coloured bands will appear.

ii. Intensity at a point is given by
   $I = 4I' \cos^2 \phi/2$
   where I' = intensity produced by each one of the individual sources.
   At central maxima, $\phi = 0$,
   The intensity at the central maxima,
   $I_0 = 4I'$
   $I' = \frac{I_0}{4}$ ..... (i)
   As, path difference $= \frac{\lambda}{3}$
   Phase difference, $\phi' = \frac{2\pi}{\lambda} \times$ path difference
   $= \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$
   Now, intensity at this point
   $I'' = 4I' \cos^2 \frac{1}{2}\left(\frac{2\pi}{3}\right)$
   $= 4I' \cos^2 \frac{\pi}{3}$
   $= 4I' \times \frac{1}{4}$
   $= I'$
   $= \frac{I_0}{4}$ [from Eq. (i)]
   Hence proved.

32. Energy stored in C_4 is
   $U_4 = \frac{1}{2}C_4V^2 = 27J$

or $\frac{1}{2} \times 6 \times 10^{-6} \times V^2 = 27$

or $V^2 = \frac{27 \times 2}{6 \times 10^{-6}} = 9 \times 10^6$

Energy stored in C_2

$U_2 = \frac{1}{2} \times 2 \times 10^{-6} \times 9 \times 10^6 = 9J$

Energy stored in C_3,

$U_3 = \frac{1}{2} \times 3 \times 10^{-6} \times 9 \times 10^6 = 13.5$ J

Energy stored in C_2, C_3 and C_4

$= U_2 + U_3 + U_4 = 9 + 13.5 + 27 = 49.5$ J

Equivalent capacitance of C_2, C_3 and C_4 connected in parallel

$= 2 + 3 + 5 = 11\ \mu F$

$\therefore \frac{q^2}{2 \times 11 \times 10^{-6}} = 49.5 \text{ J} \ \left[u = \frac{q^2}{2C}\right]$

Energy stored in C_1

$U_1 = \frac{q^2}{2C_1} = \frac{49.5 \times 2 \times 11 \times 10^{-6}}{2 \times 1 \times 10^{-6}}$ = 544.5 J

Total energy stored in the arrangement

= 544.5 + 49.5 = 594.0 J

OR

i. $C_A = 4\pi\varepsilon_0 R$, $C_B = 4\pi\varepsilon_0$ (2R) (in general form $C = 4\pi \in 0r$

a. $\therefore C_B > C_A$

b. $U = \frac{1}{2}\varepsilon_0 E^2$

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

$\therefore U \propto \frac{1}{A^2}$

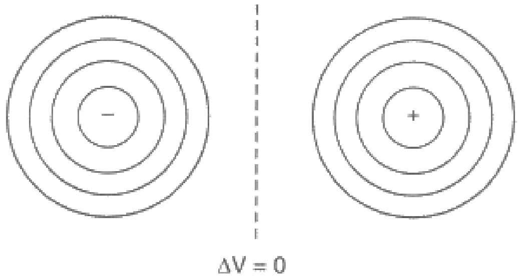
$\therefore U_A > U_B$

ii. a. $E = -\frac{dV}{dr}$

For the same change in dV, $E \propto \frac{1}{dr}$

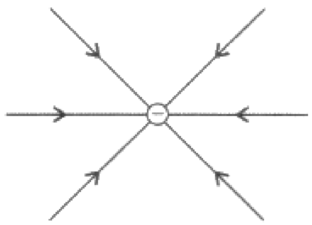
where, ‘dr' represents the distance between equipotential surfaces.

Diagram of the equipotential surface due to a dipole

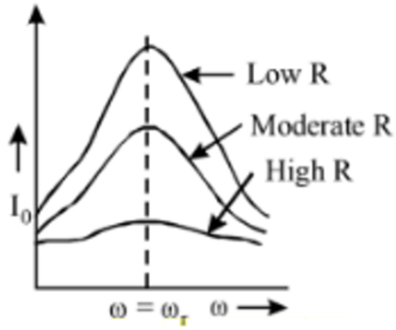


b. The polarity of charge: negative

The direction of the electric field is radially inward,(for a negative charge electric field lines are radially inward)



33. i. The sharpness of resonance in series L-C-R circuit refers how quick fall of alternating current in circuit takes place when the frequency of alternating voltage shifts away from the resonant frequency. It is measured by the quality factor (Q-factor) of circuit.



The Q -factor of the series resonant circuit is defined as the ratio of the voltage developed across the capacitance or inductance at resonance to the impressed voltage which is the voltage applied.

i.e., quality factor (Q) = $\frac{\text{voltage across L or } C}{\text{applied voltage}}$

Q = $\frac{(\omega_r L)I}{RI}$

[∵ applied voltage = voltage across R]

or Q = $\frac{\omega_r L}{R}$ or Q = $\frac{(1/\omega_r C)I}{RI} = \frac{1}{RC\omega_r}$

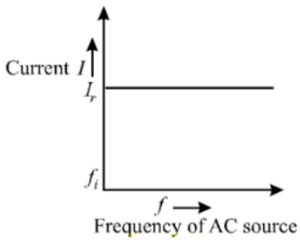
∴ Q = $\frac{L}{RC \cdot \frac{1}{\sqrt{LC}}}$ [using $\omega_r = \frac{1}{\sqrt{LC}}$]

Thus, Q = $\frac{1}{R}\sqrt{\frac{L}{C}}$

This is required expression.

ii. Let initially I_r current is flowing in all the three circuits. If the frequency of applied AC source is increased then, the change in current will occur in the following manner:

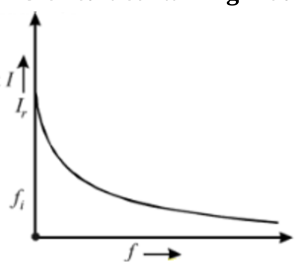
Circuit containing resistance R only:



where, f_i = initial frequency of AC source.

There is no effect on current with the increase in frequency.

AC circuit containing inductance only:



With the increase of frequency of AC source, inductive reactance increase as

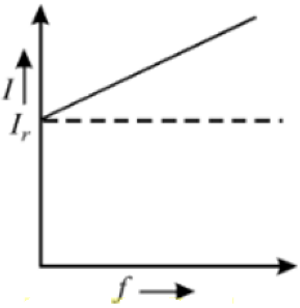
I = $\frac{V_{\text{rms}}}{X_L} = \frac{V_{\text{rms}}}{2\pi f L}$

For given circuit,

I ∝ $\frac{1}{f}$

Current decreases with the increase of frequency.

AC circuits containing capacitor only:



$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$

Current, I = $\frac{V_{\text{rms}}}{X_{\text{C}}} = \frac{V_{\text{rms}}}{\left(\frac{1}{2\pi fC}\right)}$

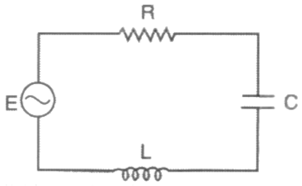
I = $2\pi fCV_{\text{rms}}$

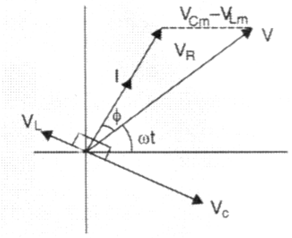
For given circuit, I $\propto$ f

Current increases with the increase of frequency.

OR

i. In a series LCR circuit shown,





From the phasor relation, voltages $V_L + V_R + V_C = V$, as V_C and V_L are along the same line and in opposite directions, so they will combine in single phasor ($V_C + V_L$) having magnitude $|V_{Cm}$ - VLm|. Since voltage V is shown as the hypotenuse of right-angled triangle with sides as V_R and ($V_C + V_L$), so the Pythagoras Theorem results as :

$V_m^2 = V_R^2 + (V_{Cm} - V_{Lm})^2$

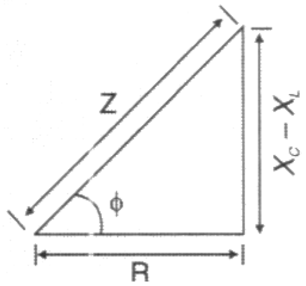
V_m^2 = $(I_m R)^2 + (I_m X_C - I_m X_L)^2$

V_m^2 = $I_m{}^2(R^2 + (X_C - X_L)^2)$

Now current in tire circuit :

$I_m = \frac{V_m}{\sqrt{\left(R^2 + (X_C - X_L\right)^2}}$

$I_m = \frac{V_m}{Z}$ as $Z = \sqrt{\left[R^2 + (X_C - X_L)^2\right]}$



As phasor 1 is always parallel to phasor V_R, the phase angle ϕ is the angle between V_R and V and can be determined from the figure.

$\tan\phi = \frac{V_{Cm} - V_{Lm}}{V_{Rm}}$

$\tan\phi = \frac{X_C - X_L}{R}$ andϕ= $\frac{\tan^{-1}(X_C - X_L)}{R}$ condition for current and voltage are in phase V_L=V_C and X_L=$X_C$and the circuit is said resonant circuit.

ii. Power factor

$P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + R^2}}$ (as X_L = R)

$= \frac{1}{\sqrt{2}}$

Power factor when capacitor C of Reactance $X_C = X_L$ is put in series in the circuit as Z = R (at resonance)

$P_2 = \frac{R}{Z} = \frac{R}{R}$ = 1

$\therefore \frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1} = \frac{1}{\sqrt{2}}$