Class XII Session 2023-24
Subject - Physics
Sample Question Paper - 3

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. To provide the abundance of holes, the impurity added should be **[1]**

a) tetravalent b) pentavalent

c) trivalent d) monovalent

2. The ratio of voltage and electrical current in a closed circuit: **[1]**

a) Decreases b) Increases

c) Varies d) Remains constant

3. An astronomical telescope of ten fold angular magnification has a length of 44 cm. The focal length of the objective is **[1]**

a) 44 cm b) 440 cm

c) 4 cm d) 40 cm

4. A bar-magnet of the pole-strength 2 Amp-m is kept in a magnetic field of induction 4×10^{-5} Wb/m^2 such that the axis of the magnet makes an angle 30° with the direction of the field. If the couple acting on the magnet is found to be 80×10^{-7} Nm, then the distance between the poles of the magnet is: **[1]**

a) 20 cm b) 4 m

c) 2 m d) 8 m

5. The dimension of $\frac{1}{2}\varepsilon_0 E^2$ where ε_0 is the permittivity of free space and E is the electric field, is **[1]**

a) $ML^{-1}T^{-2}$

b) MLT^{-1}

c) ML^2T^{-2}

d) ML^2T^{-1}

6. The magnetic field of given length of wire for single turn coil at its centre is B, then its value for two turns coil for the same wire is **[1]**

a) 2B

b) $\frac{B}{4}$

c) 4B

d) $\frac{B}{2}$

7. The magnetic field between the Horizontal poles of an electromagnet is uniform at any time, but its magnitude is increasing at the rate of 0.020 T/s.The area of a horizontal conducting loop in the magnetic field is 120cm^2, and the total circuit resistance, including the meter, is 5Ω. Induced emf and the induced current in the circuit are **[1]**

a) 0.18 mV, 0.38 mA

b) 0.50 mV, 0.048 mA

c) 0.24 mV, 0.048 mA

d) 0.12 mV, 0.48 mA

8. The resistance of a circular coil of 50 turns and 10 cm diameter is 5Ω. What must be the potential difference across the ends of the coil so as to nullify the earth's magnetic field (B_H = 0.314 gauss) at the centre of the coil? How should the coil be placed to achieve this result? **[1]**

a) 0.25 V with the plane of the coil in the magnetic meridian

b) 0.5 V with the plane of coil normal to the magnetic meridian

c) 0.5 V with the plane of the coil in the magnetic meridian

d) 0.25 V with the plane of coil normal to the magnetic meridian

9. The refractive index of glass is 1.5. What is the speed of light in glass? (Speed of light in vacuum is 3.0 $\times 10^8 \text{ms}^{-1}$) **[1]**

a) 3.0 $\times 10^8 \text{ms}^{-1}$

b) 2.4 $\times 10^8 \text{ms}^{-1}$

c) 2.0 $\times 10^8 \text{ms}^{-1}$

d) 2.8 $\times 10^8 \text{ms}^{-1}$

10. Two insulated charged copper spheres A and B have their centres separated by a distance of 50 cm. What is the mutual force of electrostatic repulsion if the charge on each is $6.5 \times 10^{-7}\text{C}$? The radii of A and B are negligible compared to the distance of separation. **[1]**

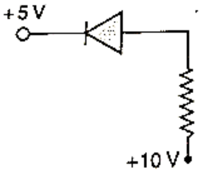
a) $3.5 \times 10^{-2}\text{N}$

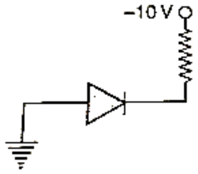
b) $4.5 \times 10^{-2}\text{N}$

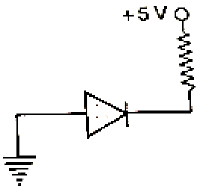
c) $1.5 \times 10^{-2}\text{N}$

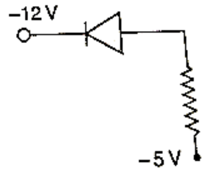
d) $2.5 \times 10^{-2}\text{N}$

11. In the following figures, which one of the diodes is reverse biased? **[1]**

a) 

b) 

c) 

d) 

12. A fish looking up through the water sees the outside world, contained in a circular horizon. If the refractive index of water is 4/3 and the fish is 12 cm below the water surface, the radius of this circle (in cm) is: **[1]**

a) $36/\sqrt{7}$

b) $36\sqrt{5}$

c) $4\sqrt{5}$

d) $36\sqrt{7}$

13. **Assertion (A):** The threshold frequency of the photoelectric effect supports the particle nature of light. **[1]**
Reason (R): If the frequency of incident light is less than the threshold frequency, electrons are not emitted from the metal surface.

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:** A spherical equipotential surface is possible for a point charge. **[1]**
Reason: A spherical equipotential surface is not possible inside a spherical 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):** To observe diffraction of light, the size of the obstacle/aperture should be of the order of 10^{-7} m. **[1]**
Reason (R): 10^{-7} is the order of the wavelength of visible 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.

16. **Assertion (A):** Chock coil is preferred over a resistor to adjust current in an ac circuit. **[1]**
Reason (R): Power factor for inductance is zero.

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

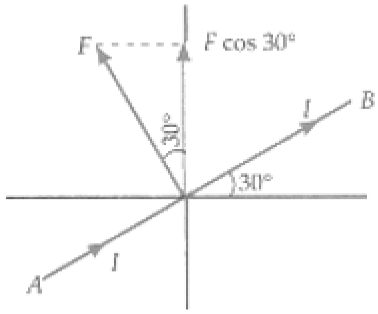
17. A capacitor made of two parallel plates, each of area **A** and separation **d** is charged by an external dc source. Show that during charging, the displacement current inside the capacitor is the same as the current charging the capacitor. **[2]**

18. Two magnetic poles, one of which is four times stronger than the other, exert a force of 5gf on each other when placed at a distance of 10 cm. Find the strength of each pole. **[2]**

19. Give two differences between a half-wave rectifier and a full-wave rectifier. **[2]**

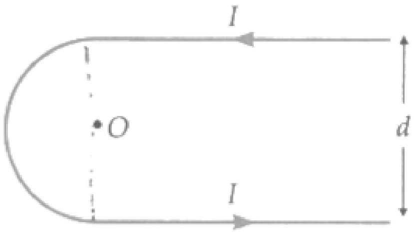
20. According to the classical electromagnetic theory, calculate the initial frequency of the light emitted by the electron revolving around a proton in hydrogen atom. **[2]**

21. A wire AB making an angle of 30° with a horizontal is supported by a magnetic field of 0.65 T, directed normally into the plane of paper. If the wire carries a current of 5 A. Determine its mass per unit length. **[2]**



OR

In the given figure, the curved portion is a semi-circle and the straight wires are long. Find the magnetic field at point O.



Section C

22. Prove that the current density of a metallic conductor is directly proportional to the drift speed of electrons. **[3]**

23. With the help of a suitable diagram, explain the formation of depletion region and potential barrier in a p-n junction. How does its width change when the junction is **[3]**

  i. forward biased and
  ii. reverse biased?

24. A photon of wavelength 3310 $\overset{o}{A}$ falls on a photo-cathode and an electron of energy 3×10^{-19} J is ejected. If the wavelength of the incident photon is changed to 5000 $\overset{o}{A}$ the energy of the ejected electron is 9.72×10^{-20} J. Calculate the value of Planck's constant and threshold wavelength of the photon. **[3]**

25. Are the nucleons fundamental particles, or do they consist of still smaller parts? One way to find out is to probe a nucleon just as Rutherford probed an atom. What should be the kinetic energy of an electron for it to be able to probe a nucleon? Assume the diameter of a nucleon to be approximately 10^{-15} m. **[3]**

26. The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What are the radii of the n = 2 and n = 3 orbits? **[3]**

27. How is the spacing between fringes in a double slit experiment affected if: **[3]**

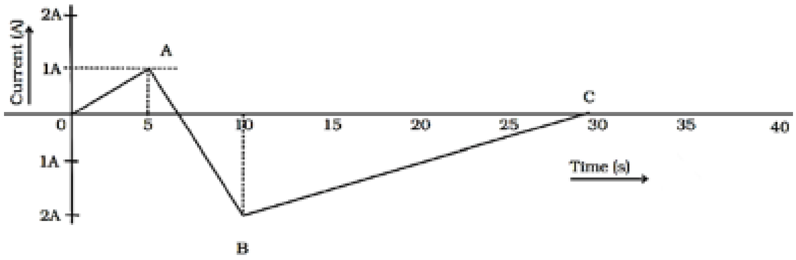
  a. the slits separation is increased,
  b. the colour of light used is changed from red to blue,
  c. the whole apparatus is submerged in a oil of refractive index 1.2?

Justify your anwer in each case.

28. **[3]**
  i. Define the term self-inductance and write its S.I. unit.
  ii. Obtain the expression for the mutual inductance of two long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.

OR

A (current vs time) graph of the current passing through a solenoid is shown in Figure. For which time is the back electromotive force (u) a maximum. If the back emf at t = 3s is e, find the back emf at t = 7 s, 15s, and 40s. OA, AB, and BC are straight line segments.



Section D

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

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) The electromagnetic waves propagated perpendicular to both $\vec{E}$ and $\vec{B}$. The electromagnetic waves travel in the direction of

a) $\vec{E} \cdot \vec{B}$ b) $\vec{B} \cdot \vec{E}$

c) $\vec{E} \times \vec{B}$ d) $\vec{B} \times \vec{E}$

(ii) Fundamental particle in an electromagnetic wave is

a) photon b) phonon

c) electron d) proton

(iii) Electromagnetic waves are transverse in nature is evident by

a) diffraction b) interference

c) polarisation d) reflection

OR

For a wave propagating in a medium, Name the property that is independent of the others.

a) frequency b) wavelength

c) velocity d) all these depend on each other

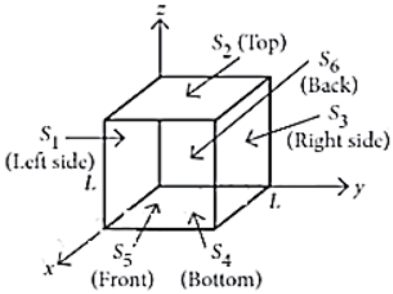
(iv) The electric and magnetic fields of an electromagnetic waves are

a) in opposite phase and parallel to each other b) in phase and parallel to each other.

c) in phase and perpendicular to each other d) in opposite phase and perpendicular to each other

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

Net electric flux through a cube is the sum of fluxes through its six faces. Consider a cube as shown in figure, having sides of length L = 10.0 cm. The electric field is uniform, has a magnitude E = $4.00 \times 10^3 NC^{-1}$ and is parallel to the xy plane at an angle of 37^o measured from the +x -axis towards the +y -axis.



(i) Electric flux passing through surface S_6 is

a) $-24\ Nm^2\ C^{-1}$ b) $32\ Nm^2\ C^{-1}$

c) $-32\ Nm^2\ C^{-1}$ d) $24\ Nm^2\ C^{-1}$

(ii) Electric flux passing through surface S_1 is

a) $-32\ Nm^2\ C^{-1}$ b) $-24\ Nm^2\ C^{-1}$

c) $32\ Nm^2\ C^{-1}$ d) $24\ Nm^2\ C^{-1}$

(iii) The surfaces that have zero flux are

a) S_2 and S_4 b) S_3 and S_6

c) S_1 and S_2 d) S_1 and S_3

(iv) The total net electric flux through all faces of the cube is

a) $24\ Nm^2\ C^{-1}$ b) $8\ Nm^2\ C^{-1}$

c) $-8\ Nm^2\ C^{-1}$ d) zero

OR

The dimensional formula of surface integral $\oint \vec{E} \cdot d\vec{S}$ of an electric field is

a) $[M^{-1}\ L^3\ T^{-3}\ A]$ b) $[M\ L^2\ T^{-2}\ A^{-1}]$

c) $[M\ L^3\ T^{-3}\ A^{-1}]$ d) $[M\ L^{-3}\ T^{-3}\ A^{-1}]$

Section E

31. i. Obtain lens maker's formula using the expression **[5]**

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$

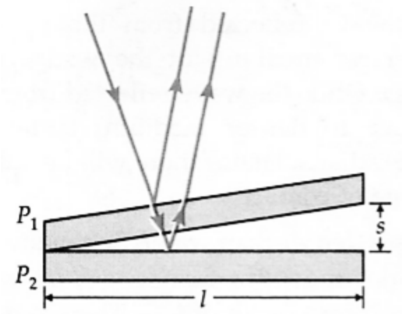
Here, the ray of light propagating from a rarer medium of refractive index (μ_1) to a denser medium of refractive index (μ_2) is incident on the convex side of spherical refracting surface of radius of curvature R.

ii. Draw a ray diagram to show that image formation by a concave mirror when the object is kept between its focus and the pole. Using this diagram, derive the magnification formula for the image formed.

OR

Figure shows two flat glass plates P_1 and P_2 placed nearly (but not exactly) parallel forming an air wedge. The plates are illuminated normally by monochromatic light and viewed from above. Light waves reflected from the upper and lower surfaces of the air wedge give rise to an interference pattern:

a. Show that the separation between two successive bright (or dark) fringes is given by $\frac{\lambda l}{2s}$, where l is the length of each plate and s is the separation between the plates at the open end of the wedge.



b. In the experiment, a dark fringe is observed along the line joining the two plates. Why?

c. If the space between the glass plates is filled with water, what changes in the fringe pattern do you expect to see, if at all?

d. Suggest a way of obtaining a bright fringe along the line of contact of the two plates in this experiment.

32. a. Derive the expression for the capacitance of a parallel plate capacitor having plate area A and plate separation d. **[5]**

b. Two charged spherical conductors of radii R_1 and R_2 when connected by a conducting wire acquire charges q_1 and q_2 respectively. Find the ratio of their surface charge densities in terms of their radii.

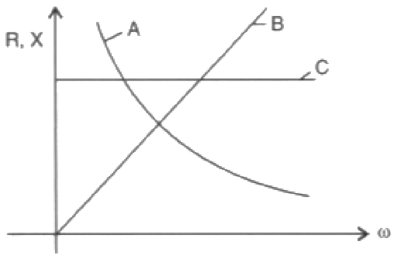
OR

i. Find the expression for the potential energy of a system of two point charges q_1 and q_2 located at $\vec{r}_1$ and $\vec{r}_2$, respectively in an external electric field $\vec{E}$.

ii. Draw equipotential surfaces due to an isolated point charge (- q) and depict the electric field lines.

iii. Three point charges + 1 μC, - 1 μC and + 2 μC are initially infinite distance apart. Calculate the work done in assembling these charges at the vertices of an equilateral triangle of side 10 cm.4

33. i. The figure shows the variation of resistance and reactance versus angular frequency. Identify the curve which corresponds to inductive reactance and resistance. **[5]**



ii. Show that series LCR circuit at resonance behaves as a purely resistive circuit. Compare the phase relation between current and voltage in series LCR circuit for (i) $X_L > X_C$, (ii) $X_L = X_C$ using phasor diagrams.

iii. What is an acceptor circuit and where it is used?

OR

i. Prove that an ideal capacitor in an ac circuit does not dissipate power.

ii. An inductor of 200 mH, a capacitor of 400 μf, and a resistor of 10 Ω are connected in series to ac source of 50 V of variable frequency. Calculate the

a. the angular frequency at which maximum power dissipation occurs in the circuit and the corresponding value of the effective current and

b. value of Q-factor in the circuit.

Solution

Section A

1.

(c) trivalent

Explanation: If we introduce a "Trivalent" (3-electron) impurity into the crystalline structure, such as Aluminium, Boron or Indium, which have only three valence electrons available in their outermost orbital, the fourth closed bond cannot be formed. Therefore, a complete connection is not possible, giving the semiconductor material an abundance of positively charged carriers known as "holes" in the structure of the crystal where electrons are effectively missing.

2.

(d) Remains constant

Explanation: The ratio of voltage and electrical current in a closed circuit Remains constant.

3.

(d) 40 cm

Explanation: $L = f_o + f_e = 44 \text{ and } |m| = \frac{f_o}{f_e} = 10$

$\text{This gives } f_o = 40\text{cm}$

4. **(a)** 20 cm

Explanation: $\tau = q_m \times 2l \times B\sin\theta$

$\therefore$ 2l = $\frac{\tau}{q_m \times B\sin\theta}$

= $\frac{80\times10^{-7}}{2\times4\times10^{-5}\times\sin30^\circ}$ = 0.20 m = 20 cm

5. **(a)** $ML^{-1}T^{-2}$

Explanation: $\left[\frac{1}{2}\varepsilon_0 E^2\right]$ = energy density

$= \frac{\mathrm{ML^2\,T^{-2}}}{\mathrm{L^3}} = \left[\mathrm{ML^{-1}}\mathbf{T}^{-2}\right]$

6.

(c) 4B

Explanation: Magnetic field due to coil is directly proportional to no. of turns and inversely proportional to radius. As radius become half and no. of turns gets doubled, so magnetic field gets 4 times.

7.

(c) 0.24 mV, 0.048 mA

Explanation: e = Rate of change of magnetic field $\times$ area

$= 0.02 \times 120 \times 10^{-4} = 0.24\text{mV}$

$i = \frac{e}{R} = \frac{0.24}{5} = 0.48\text{mA}$

8.

(d) 0.25 V with the plane of coil normal to the magnetic meridian

Explanation: $B_H = \frac{\mu_0 NI}{2r}$

$0.314 \times 10^{-4} = \frac{4\pi\times10^{-7}\times50\times V}{10\times10^{-2}\times5}$

V = $\frac{0.314\times10^{-6}}{4\times3.14\times10^{-7}}$ V

= $\frac{1}{4}V$ = 0.25 V

The field of the coil acts normal to its plane. So the plane of the coil should be normal to the magnetic meridian to nullify the earth's field.

9.

(c) 2.0 $\times 10^8 \text{ms}^{-1}$

Explanation:

Using, $\mu = \frac{c}{v}$

$1.5 = \frac{3\times10^{-8}}{v} \Rightarrow v = 2.0 \times 10^8 \text{ms}^{-1}$

10.

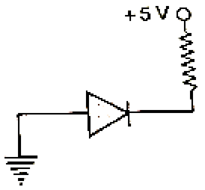
(c) 1.5×10^{-2}N

Explanation: in the given question ; r= 50 cm = 50 x 10^{-2} cm

$F = \frac{1}{4\pi\varepsilon_0} \frac{|q_1||q_2|}{r^2} = \frac{9\times10^9\times(6.5\times10^{-7})^2}{(50\times10^{-2})^2}$

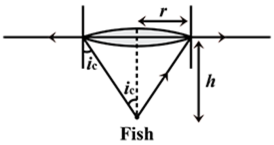
$= 1.5 \times 10^{-2} N$

11.

(c) 

Explanation: The p-n junction is said to be reverse biased, when the positive terminal of the external battery in the circuit is connected to n-section and the negative terminal to p-section of the junction diode.

12. **(a)** $36/\sqrt{7}$

Explanation: 

From the figure it is clear that:

$\tan C = \frac{r}{h}$

Therefore, the radius of the circle is given by

r = h tan C,

where C is critical angle at the water-air interface and h, the depth of the fish below the water surface.

Now, sin C = $\frac{1}{\mu} = \frac{1}{4/3} = 0 \cdot 75$

or C = $48 \cdot 6^{\circ}$

Thus, r = 12 tan 48.6^{o} = $13 \cdot 6$ = $36/\sqrt{7}$ cm

13.

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

Explanation: There is no emission of photoelectrons till the frequency of incident light is less than a minimum frequency, however intense light it may be. In the photoelectric effect, it is a single particle collision. Intensity is h$\nu \times N$, where hv is the individual energy of the photon and N is the total number of protons. In the wave theory, the intensity is proportional, not only ti v^2 but also to the amplitude squared. For the same frequency, an increase in intensity only increase the number of photons (in the quantum theory of Einstein).

14.

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

Explanation: Assertion is correct statement but reason is wrong statement.

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

Explanation: Both A and R are true and R is the correct explanation of A.

Diffraction is prominent when the size of the obstacle or the aperture is comparable to the wavelength of light used.

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

Explanation: If the resistor is used in controlling ac supply, electrical energy will be wasted in the form of heat energy across the resistance wire. However, ac supply can be controlled with choke without any wastage of energy. This is because the power factor (cos θ) for resistance is unity and is zero for an inductance. [P = EI cos θ].

Section B

17. The charge on the plates is because of the conduction current flowing in the wires,

$i_C = \frac{dq}{dt}$

According to Maxwell equation, displacement current between the plates of the capacitor is,

$i_d = \varepsilon_o \frac{d\phi_E}{dt}$

where ϕ_E = electric flux

Now, using Gauss theorem,

$\phi_E = \frac{q}{\varepsilon_o}$

Thus,

$i_d = \varepsilon_o \frac{d}{dt}\left(\frac{q}{\varepsilon_o}\right) = \frac{dq}{dt} = i_c$

Thus during charging, the displacement current inside the capacitor is the same as the current charging the capacitor.

18. Let the pole strengths of the two dipoles be q_m and $4q_m$.

Here F = 5 gf = 5×10^{-3} kgf = $5 \times 10^{-3} \times 9.8$ N, r = 10 cm = 0.1 m

Using Coulomb's law of magnetism,

$F = \frac{\mu_0}{4\pi} \cdot \frac{q_{m_1} q_{m_2}}{r^2}$

$\therefore 5 \times 10^{-3} \times 9.8 = \frac{10^{-7} \times q_m \times 4q_m}{(0.1)^2}$

or $q_m^2 = \frac{5 \times 9.8 \times (0.1)^2 \times 10^4}{4} = 25 \times 49$

or $q_m = 5 \times 7 = 35$ Am and $4q_m = 4 \times 35 = 140$ Am

19. i. Full wave rectifier rectifies the negative component of voltage and converts it into DC whereas half wave rectifier rectifies the negative component of voltage only.
    ii. Efficiency of the full wave rectifier is greater than the half-wave rectifier.

20. We know that the velocity of an electron moving around a proton in a hydrogen atom in an orbit of radius is 5.3×10^{-11} m is 2.2 $\times 10^6$ m/s. Thus, the frequency of the electron moving around the proton is given by ;

$v = \frac{v}{2\pi r} = \frac{2.2 \times 10^6 \text{ms}^{-1}}{2\pi(5.3 \times 10^{-11}\text{m})}$

$\approx 6.6 \times 10^{15}$ Hz

According to the classical electromagnetic theory, we know that the frequency of the electromagnetic waves emitted by the revolving electrons is equal to the frequency of its revolution around the nucleus. Thus the initial frequency of the light emitted is given by 6.6×10^{15} Hz.

21. Force on wire AB, $F = IlB \sin 90^\circ = IlB$

Component of the force in the vertically upward direction = $F \cos 30^\circ = IlB \cdot \frac{\sqrt{3}}{2}$

If m is the mass per unit length of wire, then its weight = mlg

$\therefore mlg = IlB \cdot \frac{\sqrt{3}}{2}$

or $m = \frac{IB \cdot \sqrt{3}}{2g} = \frac{5 \times 0.65 \times \sqrt{3}}{2 \times 9.8}$

= 0.2872 kg m^{-1}

OR

Magnetic field at point O due to any current element is perpendicular to and points out of the plane of paper.

Magnetic field at O due to the upper straight wire is

$B_1 = \frac{1}{2} \times \frac{\mu_0 I}{2\pi\left(\frac{d}{2}\right)} = \frac{\mu_0 I}{2\pi d}$

Similarly, field at O due to lower straight wire is

$B_2 = \frac{\mu_0 I}{2\pi d}$

Field at O due to the semicircle of radius $\frac{d}{2}$ is

$B_3 = \frac{1}{2} \times \frac{\mu_0 I}{2\left(\frac{d}{2}\right)} = \frac{\mu_0 I}{2d}$

Resultant field at O,

$B = B_1 + B_2 + B_3 = \frac{\mu_0 I}{2d}\left[1 + \frac{2}{\pi}\right]$

Section C

22. Consider a conductor of length l and area of cross section A having n electrons per unit length, as shown in the figure.

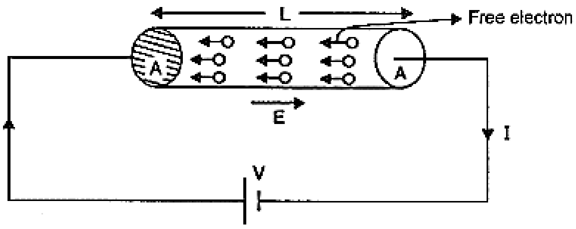
Volume of the conductor = Al

Total number of electrons in the Conductor = Volume $\times$ electron density = Aln

If C is the charge of an electron, then total charge contained in the conductor, Q = en Al

Let the potential difference V is applied across the conductor. The resulting electric field in the conductor is given by

$E = \frac{V}{l}$



Under the influence this field E, free electrons begin to drift in a direction opposite to that of the field. Time taken by electrons to cross over the conductor is

$t = \frac{l}{v_d}$

Where v_d is the drift velocity of electrons. Therefore, current through the conductor is given by

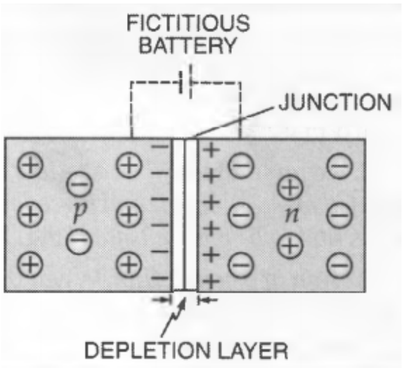
$I = \frac{Q}{t} = \frac{enAl}{l/v_d}$

or $I = neAv_d \Rightarrow \frac{I}{A} = n_e v_d$ or J = $n_e v_d$

$\Rightarrow J \propto v_d$ [$\because$ n, e, A are all constant]

Thus, current density is proportional to drift velocity.

23. A p-n juntion is a basic semiconductor device.



When a p-type crystal is placed in contact with n-type crystal so as to form one piece, the assembly so obtained is called p-n junction or junction diode or crystal diode. The surface of contact of p and n-type crystals is called junction. In the p-section, holes are the majority carriers; while in n-section, the majority carriers are electrons. Due to the high concentration of different types of charge carriers in the two sections, holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. In both cases, when an electron meets a hole, the two cancel the effect of each other and as a result, a thin layer at the junction becomes devoid of charge carriers. This is called the depletion layer as shown in Fig.

i. When a p-n junction is forward biased, the width of the depletion layer decreases. As a result, it offers low resistance during forward bias.
ii. When a p-n junction is reverse biased, the width of the depletion layer increases. As a result, it offers high resistance during reverse bias.

24. When a photon of wavelength λ is incident on a photocathode, the energy of the rejected electron is given by

$E = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$

$\therefore \quad 3 \times 10^{-19} = \frac{hc}{3310 \times 10^{-10}} - \frac{hc}{\lambda_0}$ ...(i)

and $9.72 \times 10^{-20} = \frac{hc}{5000 \times 10^{-10}} - \frac{hc}{\lambda_0}$ ...(ii)

Subtracting (ii) from (i), we get

$(3 - 0.972) \times 10^{-19} = \frac{hc}{10^{-10}} \left(\frac{1}{3310} - \frac{1}{5000} \right)$

or $2.028 \times 10^{-19} = \frac{h \times 3 \times 10^8}{10^{-10}} \times \frac{1690}{3310 \times 5000}$

$\therefore \quad h = \frac{2.028 \times 10^{-19} \times 10^{-10} \times 3310 \times 5000}{3 \times 10^8 \times 1690}$

= 6.62×10^{-34} Js.

Now $W_0 = \frac{hc}{\lambda} - E$

$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{3310 \times 10^{-10}} - 3 \times 10^{-19}$

= (6 - 3) $\times$ 10^{-19} = 3 $\times$ 10^{-19} J

Threshold wavelength,

$\lambda_0 = \frac{hc}{W_0} = \frac{6.62\times10^{-34}\times3\times10^8}{3\times10^{-19}}$

= 6.62 $\times$ 10^{-7} m = 6620 Å.

25. Each particle (neutron and proton) present inside the nucleus is called a nucleon.

Let λ be the wavelength $\lambda=10^{-15}$m.

To detect separate parts inside a nucleon the electron must have wavelength less than 10^{-15}m.

λ = 10^{-15} m

$\lambda = \frac{h}{p}$

$\because E = hv = \frac{hc}{\lambda}$ [$\because$ c = vλ]

K.E. = P.E. of (electron) = $\frac{6.6\times10^{-34}\times3\times10^8}{10^{-15}}$J

K.E. = $\frac{6.6\times3\times10^{-34+8+15}}{1.6\times10^{-19}}$ eV = $\frac{99\times10^{-34+23+19}}{8}$

= 12.4 $\times$ 10^{-34+42} = 1.24 $\times$ 10^1 $\times$ 10^{+8}

K.E. = 1.24 $\times$ 10^9 eV

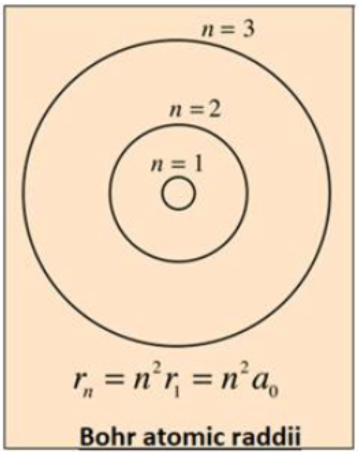
So the K.E. of particle which may detect nucleon inside the nucleus must be of 1.24 $\times$ 10^9 eV per particle.

26. Given, the radius of the innermost orbit, r_1 = 5.3 $\times$ 10^{-11} m

Then, let r_2 be the radius of an orbit at n = 2.

Then, $r_2 = (n)^2 r_1$

As shown in the diagram:



$\Rightarrow$ $r_2 = 2^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow$ $r_2 = 2.12 \times 10^{-10}$ m

For n = 3, we can write the corresponding electron radius as:

$\Rightarrow$ $r_3 = (n)^2\, r_1$

$\Rightarrow$ $r_3 = 3^2 \times 5.3 \times 10^{-11}$ m

$\Rightarrow$ $r_3 = 4.77 \times 10^{-10}$ m

Hence, the radii of an electron for n = 2 and n = 3 orbits are 2.12 $\times$ 10^{-10} m and 4.77 $\times$ 10^{-10} m

27. $\beta = n\frac{\lambda D}{d}$

a. As d increases, β decreases so spacing between fringes also decreases.

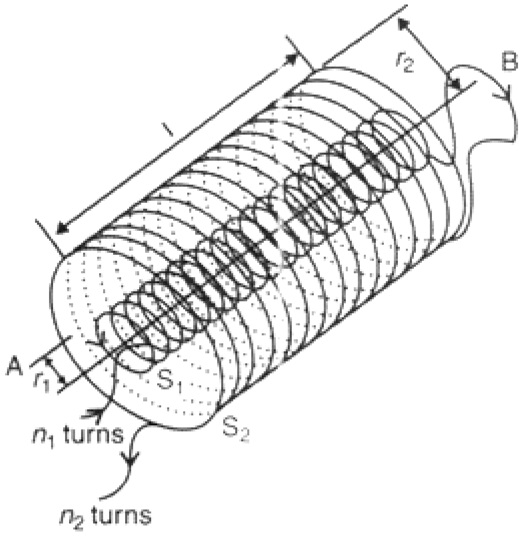
b. As λ decreases, β also decreases so spacing between fringes also decreases.

c. As whole apparatus is submerged in oil, λ decreases So β decreases and spacing between fringes will be narrow.

28. i. Self-Inductance is the property by which an opposing induced emf is produced in a coil due to a change in current, or magnetic flux, linked with the coil.

The S.I. unit of self-inductance is Henry (H).

ii. In this question, a long co-axial solenoids S_1 and S_2 wound one over the other, each of length L and radii r_1 and r_2 and n_1 and n_2 number of turns per unit length, when a current I is set up in the outer solenoid S_2.



Let a current l_2 flow in the secondary coil

$\therefore$ $B_2 = \frac{\mu_0 N_2 i_2}{l}$

$\therefore$ Flux linked with the primary coil = $\frac{\mu_0 N_2 N_1 A_1 i_2}{l}$

= $M_{12} i_2$

Hence, $M_{12} = \frac{\mu_0 N_2 N_1 A_2}{l}$

$\mu_0 n_2 n_1 A_1 l \left(n_1 = \frac{N_1}{l}; n_2 = \frac{N_2}{l}\right)$

OR

The maximum back electromotive force (u) will be maximum when there is a maximum rate of change of magnetic flux which is directly proportional to the rate of change of current.

Maximum change or rate of current will be where (t - I) graph for the solenoid makes a maximum angle with time axis which is in part AB

So the maximum back e.m.f. will occur between 5 s to 10 s. As the back e.m.f. at t = 3 s it is e (given)

Rate of change of current at t = 3 s-slope of OA graph with time axis So the rate of change of current at 3s = $\frac{1}{5} A/s$

So back electromotive force at t = 3s $= L \times \frac{1}{5} = \frac{L}{5} = e$ (given)

$\because e = L \cdot \frac{dI}{dt}$ and L = constant for the solenoid.

Similarly back e.m.f. u between 5 to 10 sec.

$u_1 = L\left(\frac{-3}{5}\right) = -3\frac{L}{5} = -3e$

back e.m.f. between 10 to 30 sec

$u_2 = L\frac{[0-(-2)]}{(30-10)} = \frac{+2L}{20} = \frac{+1}{2}\frac{L}{5}$

$u_2 = +\frac{1}{2}e$

So back e.m.f. at 7 sec = -3 e

Back e.m.f. at 15 sec $= +\frac{1}{2}e$

At 40 sec graph is along the time axis, i.e. its slope with time axis is zero.

So, $\frac{dI}{dt} = 0$

Or back e.m.f. at 40 sec = 0

Section D

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

In an electromagnetic wave both the electric and magnetic fields are perpendicular to the direction of propagation, that is why electromagnetic waves are transverse in nature. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields. Energy density of an electromagnetic waves is the energy in unit volume of the space through which the wave travels.

(i) **(c)** $\vec{E} \times \vec{B}$

Explanation: Electromagnetic waves propagate in the direction of $\vec{E} \times \vec{B}$.

(ii) **(a)** photon

Explanation: Photon is the fundamental particle in an electromagnetic wave.

(iii) **(c)** polarisation

Explanation: Polarisation establishes the wave nature of electromagnetic waves.

OR

(a) frequency

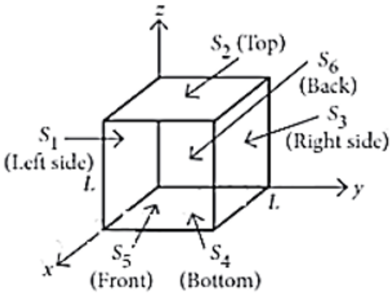
Explanation: Frequency ν remains unchanged when a wave propagates from one medium to another. Both wavelength and velocity get changed.

(iv) **(c)** in phase and perpendicular to each other

Explanation: The electric and magnetic fields of an electromagnetic wave are in phase and perpendicular to each other.

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

Net electric flux through a cube is the sum of fluxes through its six faces. Consider a cube as shown in figure, having sides of length L = 10.0 cm. The electric field is uniform, has a magnitude E = 4.00 $\times$ $10^3 NC^{-1}$ and is parallel to the xy plane at an angle of 37^o measured from the +x -axis towards the +y -axis.



(i) **(c)** -32 $Nm^2\ C^{-1}$

Explanation: Electric flux, $\phi = \vec{E} \cdot \vec{A} = EA\cos\theta$

where $\vec{A} = A\hat{n}$

For electric flux passing through S_6, $\hat{n}_{S_6} = -\hat{i}$ (Back)

$\therefore \phi_{S_6}$ = -(4 $\times$ 10^3 NC^{-1})(0.1 m)^2 cos 37^o

= -32 N m^2 C^{-1}

(ii) **(b)** -24 $Nm^2\ C^{-1}$

Explanation: For electric flux passing through S_1, $\hat{n}_{S_1} = -\hat{j}$ (Left)

$\therefore \phi_{S_1}$ = -(4 $\times$ 10^3 NC^{-1})(0.1 m)^2 cos 90^o = 0

= -24 Nm^2 C^{-1}

(iii) **(a)** S_2 and S_4

Explanation: Here, $\hat{n}_{S_2} = +\hat{k}$ (Top)

$\therefore \phi_{S_2}$ = -(4 $\times$ 10^3 NC^{-1})(0.1 m)^2 cos 90^o = 0

$\hat{n}_{S_3} = +\hat{j}$ (Right)

$\hat{n}_{S_4} = -\hat{k}$ (Bottom)

$\therefore \phi_{S_4}$ = -(4 $\times$ 10^3 NC^{-1})(0.1 m)^2 cos 90^o = 0

And, $\hat{n}_{S_5} = +\hat{i}$ (Front)

$\therefore \phi_{S_5}$ = +(4 $\times$ 10^3 NC^{-1})(0.1 m)^2 cos 37^o

= 32 N m^2 C^{-1}

S_2 and S_4 surface have zero flux.

(iv) **(d)** zero

Explanation: As the field is uniform, the total flux through the cube must be zero, i.e., any flux entering the cube must leave it.

OR

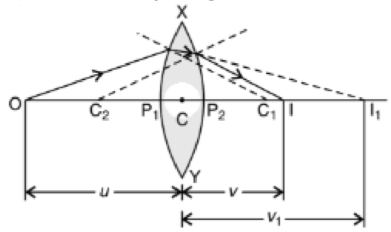
(c) [M L^3 T^{-3} A^{-1}]

Explanation: Surface integral $\oint \vec{E} \cdot d\vec{S}$ is the net electric flux over a closed surface S.

$\therefore [\phi_E]$ = [M L^3 T^{-3} A^{-1}]

Section E

31. i. Consider the ray diagram shown below:



For refraction at the first surface

$\frac{\mu_2}{v_1}$ - $\frac{\mu_1}{u}$ = $\frac{\mu_2-\mu_1}{R_1}$ ....(i)

For the second surface, I_1 acts as a virtual object (located in the denser medium) whose final real image is formed in the rarer medium at I.

So for refraction at this surface, we have

$\frac{\mu_1}{v}$ - $\frac{\mu_2}{v_1}$ = $\frac{\mu_1-\mu_2}{R_2}$ ....(ii)

From equations (i) and (ii),

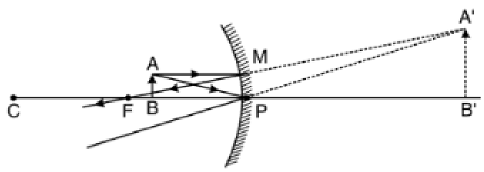
$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{\mathrm{R}_1} - \frac{1}{\mathrm{R}_2}\right)$

The point, where image of an object, located at infinity is formed, is called the focus F, of the lens and the distance f gives its focal length.

So for u = ∞, v = +f

$\Rightarrow \frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{\mathrm{R}_1} - \frac{1}{\mathrm{R}_2}\right)$

ii. The ray diagram to show that image formation by a concave mirror when the object is kept between its focus and the pole is shown below.



Here, $\triangle$ABP is similar to $\triangle$A'B'P.

So, $\frac{A'B'}{AB}$ = $\frac{B'P}{BP}$

Nor A'B' = I, AB = O, B'P = +v and BP = -u

So magnification, m = $\frac{I}{O}$ = -$\frac{v}{u}$

OR

a. Let the separation between the plates at a distance x from the line of contact be y. Then

tan $\theta = \frac{y}{x} = \frac{s}{l}$ or y = $\frac{x \times s}{l}$

For normal incidence, the path difference between two waves reflected from the upper and lower surfaces of the air wedge at distance x will be twice the thickness of the wedge at that point, i.e.,

p = 2y = $\frac{2xs}{l}$

The wave reflected from the lower surface suffers an extra path difference of $\frac{\lambda}{2}$, so that

p = $\frac{2xs}{l} + \frac{\lambda}{2}$

$\therefore$ Condition for nth dark fringe can be written as

p = $\frac{2xs}{l} + \frac{\lambda}{2}$ = (2n + 1) $\frac{\lambda}{2}$

or x = $\frac{n\lambda l}{2s}$

The position of (n - 1)th dark fringe would be

x' = $\frac{(n-1)\lambda l}{2s}$

$\therefore$ Fringe width,

β = x' - x = $\frac{\lambda l}{2s}$ [n - (n - 1)] or $\beta = \frac{\lambda l}{2s}$

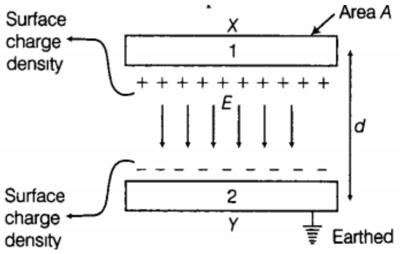
This proves the required result.

b. The wave reflected from the upper surface (denser to rarer medium) of the wedge suffers no phase change while the wave reflected from the lower surface (rarer to denser medium) suffers a phase change of π radians. Hence there will be a dark fringe along the line of contact.

c. Glass is denser than water. So the line of contact is still a dark fringe. But wavelength in water is less than that in air by a factor of 1.33. Therefore, the fringe width is reduced by this factor.

d. By choosing the upper plate material, medium filling the wedge, and the lower plate material in increasing (or decreasing) order of refractive index, we get a bright fringe along the line of contact.

32. a. Parallel plate capacitor consists of two thin conducting plates each of area A held parallel to each other at a suitable distance d. One of the plates is insulated and other is earthed. Say, there is vacuum or air between the plates. Structure of a parallel plate capacitor is shown below:



Suppose, the plate X is given a charge of +q coulomb. By induction, -q coulomb of charge is produced on the inner surface of the plate Y and +q coulomb on the outer surface. Since, the plate Y is connected to the earth, hence the relatively weak charge +q residing far away i.e. on the outer surface flows to the earth. Thus, the plates X and Y have equal and opposite charges +q and -q respectively

Suppose, the surface density of charge on each plate is σ, We know that the intensity of electric field at a point between two plane parallel sheets of equal and opposite charges is = $\frac{\sigma}{2\epsilon_0} - (-\frac{\sigma}{2\epsilon_0}) = \sigma/\varepsilon_0$, where ε_0 is the permittivity of free space. The intensity of electric field between the plates will be given by, $E = \frac{\sigma}{\varepsilon_0}$

The charge on each plate is q and the area of each plate is A. Thus electric field is given by ,

$\sigma = \frac{q}{A}$ and $E = \frac{q}{\varepsilon_0 A}$ ....(i)

Now, let the potential difference between the two plates be V volt. Then, the electric field between the plates is given by

$E = \frac{V}{d}$ or $V = Ed$ .....(ii)

Substituting the value of E from equation (i) into equation (ii), we get

$V = \frac{qd}{\varepsilon_0 A}$

Now capacitance of the parallel plate capacitor is given by ;

$C = \frac{q}{V} = \frac{q}{qd/\varepsilon_0 A} = \frac{\varepsilon_0 A}{d}$

Where, $\varepsilon_0 = 8.85 \times 10^{-12} \mathrm{C}^2 - \mathrm{Nm}^{-2}$ is the permittivity of vacuum or air.

b. Surface charge density of a spherically charged body is given by

$\sigma = \frac{q}{4\pi R^2}$

After connecting both the conductors, their potentials will become equal, $V_1 = V_2$ .Hence,

$\Rightarrow \frac{q_1}{R_1} = \frac{q_2}{R_2}$ [For a spherically charged conductor with charge q potential is given by, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$]

$\Rightarrow \frac{q_1}{q_2} = \frac{R_1}{R_2}$

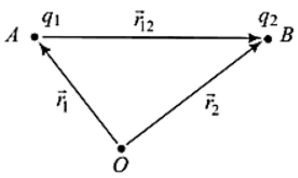
Now, $\frac{\sigma_1}{\sigma_2} = \frac{q_1/4\pi R_1^2}{q_2/4\pi R_2^2}$

$= \frac{q_1}{q_2}\left(\frac{R_2}{R_1}\right)^2 = \frac{R_1}{R_2} \times \left(\frac{R_2}{R_1}\right)^2 = \frac{R_2}{R_1}$

OR

i. Work done to bring q_1 from ∞ in external electric field $\vec{E}$

$w_1 = q_1 V(\vec{r}_1)$



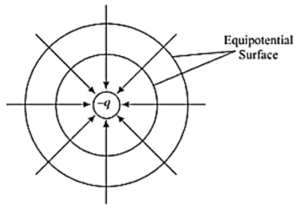
Work done to bring q_2 in the external electric field $\vec{E}$ and of the field of q_2

$w_2 = q_2V(\vec{r}_2) + \frac{Kq_1q_2}{r_{12}}$

Potential energy of the system

$U = w_1 + w_2$

$= q_1V(\vec{r}_1) + q_2V(\vec{r}_2) + \frac{Kq_1q_2}{r_{12}}$

ii. 

iii. Three point charges + 1 μC, - 1 μC and + 2 μC are initially infinite distance apart. Potential energy of the system

$U = U_{12} + U_{23} + U_{13}$

$U = \frac{1}{4\pi\varepsilon_0 r}[q_1q_2 + q_2q_3 + q_1q_3]$

$U = \frac{9\times10^9}{10\times10^{-2}}[+1 \times (-1) + (+1) \times (-2) + (1)(+2)] \times 10^{-12}$

$U = 9 \times 10^{-2} (-1 - 2 + 2)$

U = -0.009 J

33. i. The figure shows the variation of resistance and reactance versus angular frequency, thus the Curve B corresponds to inductive reactance and curve C corresponds to resistance.

ii. At resonance,

$X_L = X_C$

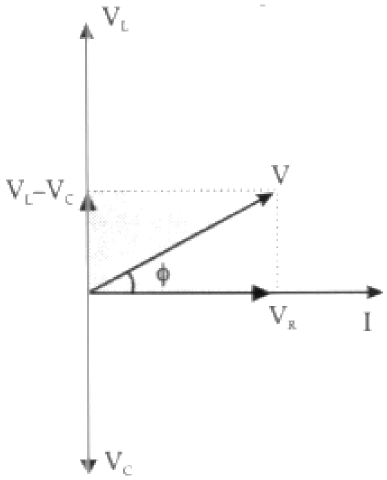
Therefore, impedance is given as:

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

Z = R

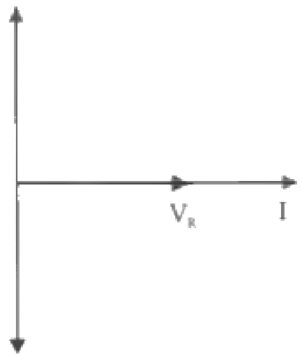
Thus, a series LCR circuit at resonance behaves as a purely resistive circuit.

Fr $X_L > X_C$, $V_L > V_C$. Therefore a phasor diagram is:



Here, ϕ is phase difference.

For $X_L = X_C$, $V_L = V_C$. Therefore phasor diagram is:

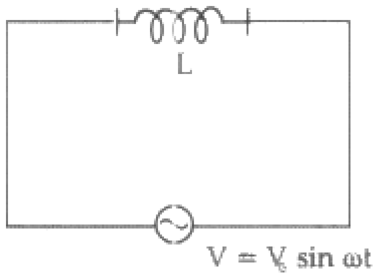


iii. A Series resonance LCR circuit is called an acceptor circuit.
They are widely used in the tuning mechanism of a radio or a TV.

OR

i. Given: V = $V_0 \sin \omega t$

V = $L\frac{di}{dt} \Rightarrow di = \frac{V}{L}dt$



$\therefore di = \frac{V_0}{L}\sin \omega t dt$

Integrating, I= $-\frac{V_0}{\omega L}\cos \omega t$

$\therefore I = -\frac{V_0}{\omega L}\sin\left(\frac{\pi}{2} - \omega t\right) = -I_0 \sin\left(\frac{\pi}{2} - \omega t\right)$

where, $I_0 = \frac{V_0}{\omega L}$

Average power,

$P_{av} = \int_0^T VI dt$

$= \frac{-V_0^2}{\omega L}\int_0^T \sin \omega t \cos \omega t \, dt$

$= \frac{-V_0^2}{2\omega L}\int_0^T \sin (2\omega t)$ dt sin is an odd function so integral results into 0.

= 0, thus the power dissipated by the conductor is zero.

ii.

a. $\omega_0 = \frac{1}{\sqrt{LC}}$

$= \frac{1}{\left(200\times10^{-3}\times400\times40^{-6}\right)^{1/2}}$

$= \frac{1}{\sqrt{8\times10^{-5}}}\text{rad/s}$

$= \frac{10^3}{\sqrt{80}}\text{rad/s}$

= 111 rad/s

$I = \frac{V}{R} = \frac{50}{10}$ = 5A

b. $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

$= \frac{1}{10}\sqrt{\frac{200\times10^{-3}}{400\times10^{-6}}} = \sqrt{5}$