Class XII Session 2023-24
Subject - Physics
Sample Question Paper - 10

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.

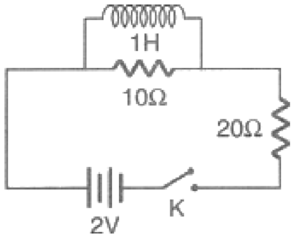
Section A

1. A Ge specimen is doped with Al. The concentration of acceptor atoms is $\approx 10^{21}$ atoms m^{-3}. Given that the intrinsic concentration of electron-hole pair is $\approx 10^{19}$ m^{-3}, the concentration of electrons in the specimen is **[1]**

   a) 10^{17} m^{-3} b) 10^{2} m^{-3}

   c) 10^{15} m^{-3} d) 10^{4} m^{-3}

2. In the adjoining figure what is the final value of current in the 20 Ω resistor when the circuit is completed? **[1]**



   a) 0.3 amp b) zero

   c) 0.2 amp d) 0.1 amp

3. A bird flies down vertically towards a water surface. To a fish inside the water, vertically below the bird, the bird will appear to **[1]**

   a) move faster than its actual speed b) be at its actual distance

c) move slower than its actual speed

d) be closer than its actual distance

4. The force between two magnetic poles is F. If the distance between the poles and pole strengths of each pole are doubled, then the force experienced is: **[1]**

a) F

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

c) 2F

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

5. Increasing order of dielectric constant for air, rubber and copper is: **[1]**

a) $K_{air} < K_{rubber} < K_{copper}$

b) $K_{air} > K_{rubber} > K_{copper}$

c) $K_{air} > K_{rubber} < K_{copper}$

d) $K_{air} < K_{rubber} > K_{copper}$

6. If number of turns, area and current through a coil is given by n, A and i respectively, then its magnetic moment will be **[1]**

a) n^2iA

b) ni A

c) niA^2

d) $ni\sqrt{A}$

7. A circular ring of diameter 20 cm has a resistance of 0.01 Ω. The charge that will flow through the ring if it is turned from a position perpendicular to a uniform magnetic field of 2.0 T to a position parallel to the field is about: **[1]**

a) 0.063 C

b) 63 C

c) 0.63 C

d) 6.3 C

8. 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) $\frac{1}{3}$

9. Polarisation of light proves **[1]**

a) longitudinal wave nature of light

b) quantum nature of light

c) transverse wave nature of light

d) corpuscular nature of light

10. A charge q is located at the centre of a cube. The electric flux through any face is **[1]**

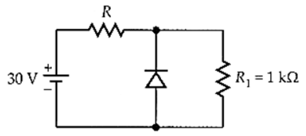
a) $\frac{1}{6}\frac{4\pi q}{4\pi\varepsilon_0}$

b) $\frac{2\pi q}{6(4\pi\varepsilon_0)}$

c) $\frac{\pi q}{6(4\pi\varepsilon_0)}$

d) $\frac{q}{6(4\pi\varepsilon_0)}$

11. If the current in a diode is five times that in R_1 and breakdown voltage of the diode is 6 volt, find the value of R. **[1]**



a) $\frac{1000}{3}\Omega$

b) $\frac{2000}{3}\Omega$

c) 1000 Ω

d) 2000 Ω

12. The graph drawn with object distance along abscissa & image as ordinate for a convex lens is **[1]**

a) straight
b) circle
c) rectangular hyperbola
d) parabola

13. **Assertion (A):** The de Broglie wavelength of a molecule varies inversely as the square root of temperature. **[1]**
Reason (R): The root mean square velocity of the molecule depends on the temperature.

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):** The force between the plates of a parallel plate capacitor is proportional to the charge on it. **[1]**
Reason (R): Electric force is equal to charge per unit area.

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.

15. **Assertion (A):** When Young's double-slit experiment is performed with a source of white light, only black and white fringes are observed. **[1]**
Reason (R): White light does not disperse in different colours in case of interference.

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 and R is also false

16. **Assertion:** When capacitive reactance is smaller than the inductive reactance in series L-C-R circuit, voltage leads the current. **[1]**
Reason: In series L-C-R circuit inductive reactance greater than capacitive reactance

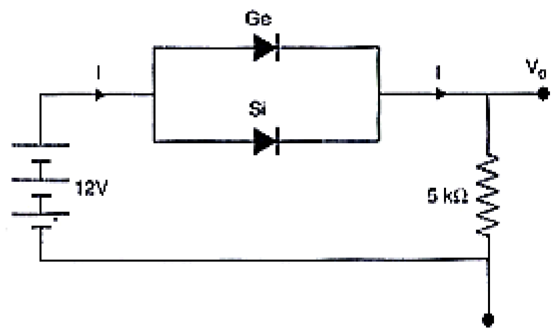
a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c) Assertion is correct statement but reason is wrong statement.
d) Assertion is wrong statement but reason is correct statement.

Section B

17. A light beam travelling in the x-direction is described by the electric field: $E_y = 270 \sin \omega \left(t - \frac{x}{c}\right)$. An electron is constrained to move along the y-direction with a speed of 2.0×10^7 ms^{-1}. Find the maximum electric force and maximum magnetic force on the electron. **[2]**

18. Draw a hysteresis loop with axes labelled and showing remanence and coercive force. What does the area of the loop represent? **[2]**

19. Calculate the value of V_o and I, if the Si diode and the Ge diode conduct at 0.7 V and 0.3 V respectively, in the circuit given in figure. If now Ge diode connections are reversed, what will be the new values of V_o and I. **[2]**



20. Calculate the nearest distance of approach of an α -particle of energy 2.5 eV being scattered by a gold nucleus (Z = 79). **[2]**

21. A length of wire carries a steady current. It is bent first to form a circular plane coil of one turn. The same length is now bent more sharply to give a double loop of smaller radius. When the same current is passed, find the ratio of the magnetic field at the centre with its first value. **[2]**

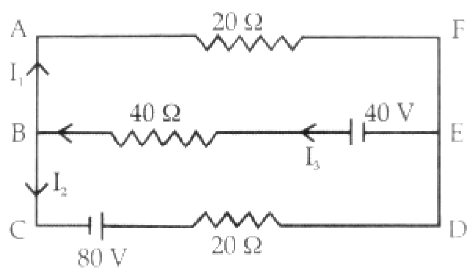
OR

A galvanometer can be converted into a voltmeter of a certain range by connecting a resistance of 980Ω in series with it. When the resistance is 470Ω connected in series, the range is halved. Find the resistance of the galvanometer.

Section C

22. State Kirchhoff's laws of current distribution in an electrical network. **[3]**

Using these rules determine the value of the current I_1 in the electric circuit given below:



23. i. Distinguish between n-type and p-type semiconductors on the basis of energy band diagrams. **[3]**
ii. Compare their conductivities at absolute zero temperature and at room temperature.

24. a. Draw a graph showing variation of photoelectric current (I) with anode potential (V) for different intensities of incident radiation. Name the characteristic of the incident radiation that is kept constant in this experiment. **[3]**
b. If the potential difference used to accelerate electrons is doubled, by what factor does the de-Broglie wavelength associated with the electrons change?

25. Define the terms (i) mass defect (ii) binding energy for a nucleus and state the relation between the two for a given nuclear reaction for which the B.E. / nucleon of the product nucleus/nuclei is more than that for the original nucleus/nuclei. Is this nuclear reaction exothermic or endothermic in nature? Justify your choice. **[3]**

26. In the study of Geiger-Marsden experiment on the scattering of particles by a thin foil of gold, draw the trajectory of α-particles in the Coulomb field of the target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study. **[3]**

27. In a double-slit experiment, the distance between the slits is 3 mm and the slits are 2 m away from the screen. Two interference patterns can be seen on the screen one due to light with wavelength 480 nm, and the other due to light with wavelength 600 nm. What is the separation on the screen between the fifth-order bright fringes of the two interference patterns? **[3]**

28. Define self-inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf. **[3]**

OR

A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field, 0.30×10^{-4} Wb m^{-2}.

a. What is the instantaneous value of the emf induced in the wire?

b. What is the direction of the emf?

c. Which end of the wire is at the higher electrical potential?

Section D

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

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is $p = \frac{U}{c}$.

When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) The pressure exerted by an electromagnetic wave of intensity I(W m^{-2}) on a non-reflecting surface is (c is the velocity of light)

a) $\frac{I}{c}$ b) $\frac{I}{c^2}$

c) Ic^2 d) Ic

(ii) Light with an energy flux of 18 W/cm^2 falls on a non-reflecting surface at normal incidence. The pressure exerted on the surface is:

a) 2 N/m^2 b) 6×10^{-4} N/m^2

c) 2×10^{-4} N/m^2 d) 6 N/m^2

(iii) Radiation of intensity 0.5 W m^{-2} are striking a metal plate. The pressure on the plate is

a) 0.212×10^{-8} N m^{-2} b) 0.132×10^{-8} N m^{-2}

c) 0.166×10^{-8} N m^{-2} d) 0.083×10^{-8} N m^{-2}

OR

The radiation pressure of the visible light is of the order of

a) 10^{-4} N/m b) 10^{-6} N/m^2

c) 10^{-8} N d) 10^{-2} N m^2

(iv) A point source of electromagnetic radiation has an average power output of 1500 W. The maximum value of electric field at a distance of 3 m from this source (in V m^{-1}) is

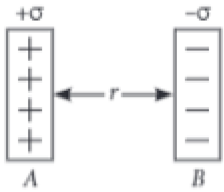
a) 500 b) $\frac{500}{3}$

c) $\frac{250}{3}$ d) 100

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

Surface charge density is defined as charge per unit surface area of surface charge distribution. i.e., $\sigma = \frac{dq}{dS}$.

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} Cm^{-2} as shown. The intensity of electric field at a point is E = $\frac{\sigma}{\varepsilon_0}$, where ε_0 = permittivity of free space.



(i) E in the outer region of the first plate is

a) 1.5×10^{-25} N/C
b) 1.9×10^{-10} N/C
c) 17×10^{-22} N/C
d) zero

(ii) E in the outer region of the second plate is

a) zero
b) 1.9×10^{-10} N/C
c) 17×10^{-22} N/C
d) 1.5×10^{-15} N/C

(iii) E between the plates is

a) 1.9×10^{-10} N/C
b) 1.5×10^{-15} N/C
c) zero
d) 17×10^{-22} N/C

(iv) The ratio of E from right side of B at distances 2 cm and 4 cm, respectively is

a) 1 : 2
b) 1 : $\sqrt{2}$
c) 2 : 1
d) 1 : 1

OR

In order to estimate the electric field due to a thin finite plane metal plate, the Gaussian surface considered is

a) cylindrical
b) none of these
c) spherical
d) straight line

Section E

31. a. Derive the expression for the angle of deviation for a ray of light passing through an equilateral prism of refracting angle A. **[5]**

b. A prism is found to give a minimum deviation of 51°. The same prism gives a deviation of 62°48' for two values of the angles of incidence, namely, $46^{\circ}6'$ and $82^{\circ}42'$. Determine the refractive angle of the prism and the refractive index of its material.

OR

A narrow monochromatic beam of light of intensity I is incident on a glass plate. Another identical glass plate is kept close to the first one and parallel to it. Each plate reflects 25% of the incident light and transmits the remaining. Calculate the ratio of minimum and maximum intensity in the interference pattern formed by two beams obtained after reflection from each plate.

32. The area of parallel plates of an air-filled capacitor is 0.20 m^2 and the distance between them is 0.01 m. The p.d. across the plates is 3000 V. When a 0.01 m thick dielectric sheet is placed between the plates, the p.d. decreases to 1000 V. Determine: **[5]**

i. the capacitance of the capacitor before placing the sheet

ii. charge on each plate

iii. the dielectric constant of the material

iv. the capacitance of the capacitor after placing the dielectric

v. the permittivity of the dielectric. Given $\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1}.

OR

a. Compare the individual dipole moment and the specimen dipole moment for H_2O molecule and O_2 molecule when placed in

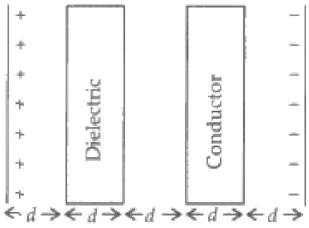
i. Absence of external electric field.

ii. Presence of external electric field. Justify your answer.

b. Given two parallel conducting plates of area A and charge densities + σ and - σ. A dielectric slab of constant k and a conducting slab of thickness d each are inserted in between them as shown

i. Find the potential difference between the plates.

ii. Plot E versus x graph, taking x = 0 at positive plate and x = 5 d at negative plate.



33. i. When an AC source is connected to an ideal capacitor, then show that the average power supplied by the source over a complete cycle is zero. **[5]**

ii. A lamp is connected in series with a capacitor. Predict your observations when the system is connected first across a DC and then an AC source. What happens in each case if the capacitance of the capacitor is reduced?

OR

A series LCR circuit is connected to an a.c. source having voltage $V = V_m \sin \omega t$. Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define power factor. State the conditions under which it is

i. maximum and

ii. minimum.

Solution

Section A

1. **(a)** 10^{17} m^{-3}

   Explanation: Here $n_i = 10^{19}$ m^{-3} and $n_h = 10^{21}$ m^{-3}

   As $n_i^2 = n_e n_h$

   $\therefore n_e = \frac{n_i^2}{n_h}$

   $= \frac{10^{19}\times10^{19}}{10^{21}} = 10^{17}$ m^{-3}

2. **(d)** 0.1 amp

   Explanation: At steady state, $\frac{di}{dt} = 0$

   Potential drop across inductor ,$\Delta V = L\frac{di}{dt}$

   $\Delta V = 0$

   hence no voltage drop across the inductor in steady state. it get short circuited and all the current will pass through the inductor only.

   no current pass through 10 Ω resistor.

   current through 20 Ω resistor

   $I = \frac{V}{R}$

   $= \frac{2}{10}$

   =0.1amp

3. **(a)** move faster than its actual speed

   Explanation: Let h be the actual height and h' be the apparent height of bird at any instant.

   Then, $\frac{h}{h'} = \mu_{aw}$ (refractive index of air with respect to water)

   = $\frac{3}{4}$ (since refractive index of water with respect to air is $\frac{4}{3}$)

   If v is the actual speed and v' be the apparent speed of bird, then

   v = $\frac{dh}{dt}$ and v' = $\frac{dh'}{dt}$

   Thus, $\frac{v}{v'} = \frac{3}{4}$

   or v' = $\frac{4v}{3}$

4. **(a)** F

   Explanation: $F \alpha \frac{q_m q_m'}{r^2}$

   Hence $\frac{F'}{F} = (\frac{2q_m 2q_m'}{4r^2}) / \frac{q_m q_m'}{r^2} = 1$

   or F' = F

5. **(a)** $K_{air} < K_{rubber} < K_{copper}$

   Explanation: $K_{air} < K_{rubber} < K_{copper}$

6. **(b)** ni A

   Explanation: The magnetic moment associated with a coil carrying current is given by the product of its area and the current through it.

   M = niA

7. **(d)** 6.3 C

   Explanation: $q = \frac{\text{Net change in magnetic flux}}{R}$

   $= \frac{BA(\cos 0^\circ - \cos 90^\circ)}{R} = \frac{B\times\pi r^2(1-0)}{R} = \frac{B\pi r^2}{R}$

   $= \frac{2\times3.14\times(0.1)^2}{0.01}$C = 6.28C = 6.3 C

8.

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

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

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

9.

(c) transverse wave nature of light

Explanation: Polarisation of light proves the transverse wave nature of light.

10. **(a)** $\frac{1}{6}\frac{4\pi q}{4\pi\varepsilon_0}$

Explanation: $\phi_E = \frac{q}{\varepsilon_0} = \frac{1}{6}\frac{4\pi q}{(4\pi\varepsilon_0)}$

11.

(b) $\frac{2000}{3}\Omega$

Explanation: Current through R_1,

$I_1 = \frac{\text{Breakdown voltage of diode}}{R_1}$

$= \frac{6\text{ V}}{1\text{k}\Omega} = \frac{6}{1\times10^3}$ A = 6 mA

The current in diode is 5 times that in R_1.

$\therefore$ Total current drawn from the battery

= 6 mA + 30 mA = 36 mA

P.D. across R = 30 - 6 = 24 V

$\Rightarrow$ RI = R $\times$ 36 $\times$ 10^{-3} = 24

$\therefore$ R = $\frac{24}{36\times10^{-3}} = \frac{2000}{3}\Omega$

12.

(c) rectangular hyperbola

Explanation:

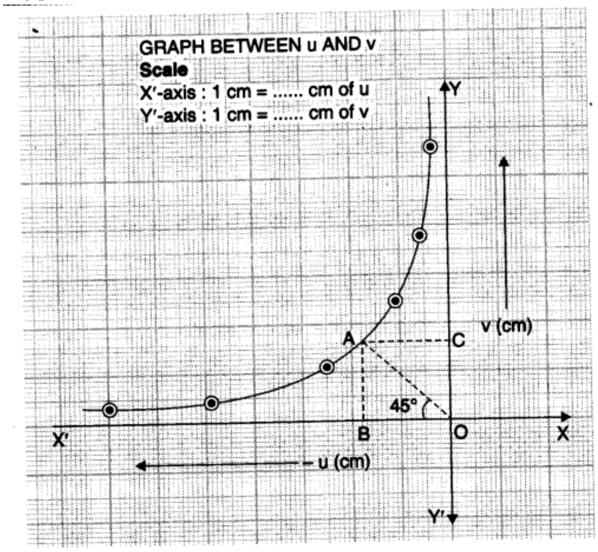


Fig. Graph between u and v. It is a rectangular hyperbola.

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

Explanation: $v_{rms} \propto \sqrt{T}$

$\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{v}$

14.

(c) A is true but R is false.

Explanation: $F = \frac{1}{2}qE \Rightarrow F \propto q$

F cannot be equal to charge per unit area.

15.

(d) A is false and R is also false

Explanation: A is false and R is also false

16\.

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

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

Section B

17\. Maximum electric field,

$E_0 = 270\ Vm^{-1}$

Maximum magnetic field,

$B_0 = \frac{E_0}{c} = \frac{270}{3 \times 10^8} = 9 \times 10^{-7}$ T,

directed along z-direction

Maximum electric force on the electron,

$F_e = qE_0 = 1.6 \times 10^{-19} \times 270 = 4.32 \times 10^{-17}$ N

Maximum electric force on the electron

$F_m = qvB_0 = 1.6 \times 10^{-19} \times 2.0 \times 10^7 \times 9 \times 10^{-7}$

$= 2.88 \times 10^{-18}$ N.

18\. Hysteresis occurs in a system that involves a magnetic field. Hysteresis is the common property of ferromagnetic substances. Generally, when the magnetization of ferromagnetic materials lags behind the magnetic field this effect can be described as the hysteresis effect.

Definition: The meaning of hysteresis is "lagging". Hysteresis is characterized as a lag of magnetization intensity (B) behind the magnetic field intensity (H).

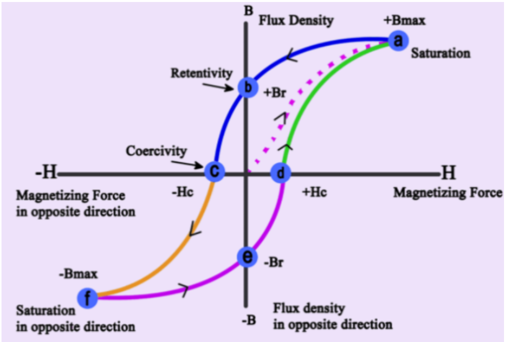
All ferromagnetic materials exhibit the phenomena of hysteresis. To give you a better understanding of the concept, we will take an instance where a ferromagnetic substance is placed inside a current-carrying coil. Due to the magnetic field that is present the substance gets magnetized. If we reverse the direction of current then the substance gets demagnetized, this process is known as hysteresis.

There are two types of hysteresis;

i. Rate-dependent hysteresis
ii. rate-independent hysteresis

Hysteresis Loop

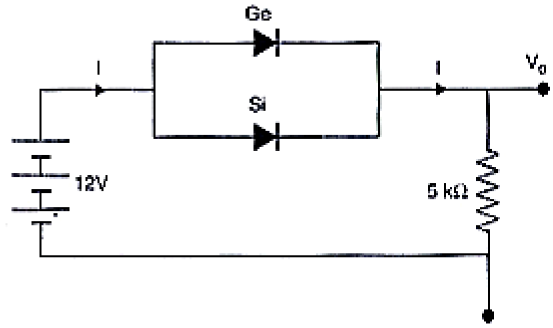
The hysteresis loop shows the relationship between the intensity of magnetization and the magnetizing field. The loop is generated by measuring the magnetic flux coming out from the ferromagnetic substance while changing the external magnetizing field.



Looking at the graph, if B is measured for various values of H and if the results are plotted in graphic forms then the graph will show a hysteresis loop.

i. The intensity of the magnetism (B) is increased when the magnetic field (H) is increased from 0 (zero).
ii. With increasing the magnetic field there is an increase in the value of magnetism and finally reaches point A which is called saturation point where B is constant.
iii. With a decrease in the value of the magnetic field, there is a decrease in the value of magnetism. But at B and H are equal to zero, substance or material retains some amount of magnetism is called retentivity or residual magnetism.
iv. When there is a decrease in the magnetic field towards the negative side, magnetism also decreases. At point C the substance is completely demagnetized.
v. The force required to remove the retentivity of the material is known as Coercive force (C).
vi. In the opposite direction, the cycle is continued where the saturation point is D, retentivity point is E and coercive force is F.
vii. Due to the forward and opposite direction process, the cycle is complete and this cycle is called the hysteresis loop.

19.



Current, $I = \frac{12-0.3}{5\times10^3}$ = 2.34 mA

Output voltage, $V_o = RI = (5\times10^3)\times(2.34\times10^{-3})$ = 11.7 V

When the connections of Ge diode are reversed, then current will be through silicon.

In this case, $I' = \frac{12-0.7}{5\times10^3}$ = 2.26 mA

and

$V_o' = I'R = (2.26\times10^{-3})\times(5\times10^3)$ = 11.3 V

20. The nearest distance of approach of an α -particle,

$x = \frac{2Ze^2}{4\pi\varepsilon_0}\times\frac{1}{\left(\frac{mv^2}{2}\right)}$

Now energy of α-particle $= \frac{1}{2}mv^2$ = 2.5 MeV

$= 2.5\times10^6\times1.6\times10^{-19}J$

$= 2.5\times1.6\times10^{-13}J$

Substituting values we get,

$x = \frac{2\times79\times1.6\times1.6\times10^{-38}\times9\times10^9}{2.5\times1.6\times10^{-13}}$

$= 9.101\times10^{-14}m$

21. Let Z be the length of the wire. When the wire is bent in the form of one turn circular coil,

$l = 2\pi r_1$ or $T_1 = \frac{l}{2\pi}, N = 1$

$\therefore \quad B_1 = \frac{\mu_0 NI}{2r} = \frac{\mu\times1\times I}{2\times(l/2\pi)} = \frac{\mu_0\pi I}{l}$

When the wire is bent in form of two-turn coil

$l = 2\times2\pi r_2$ or $r_2 = \frac{1}{4\pi}, N = 2$

$\therefore \quad B_2 = \frac{\mu_0\times2\times I}{2\times(1/4\pi)} = \frac{4\mu_0\pi I}{l}$

$\therefore \quad \frac{B_2}{B_1} = 4:\mathbf{1}$

OR

The current for full scale deflection of a voltmeter is given by

$I_g = \frac{V}{R_g+R}$

In first case, $I_g = \frac{V}{R_g+980}$

In second case, $I_g = \frac{V/2}{R_g+470}$

$\therefore \frac{V}{R_g+980} = \frac{V}{2(R_g+470)}$

or $2R_g + 940 = R_g + 980$

or $R_g = 40\ \Omega$

Section C

22. i. Kirchhoff's first law is known as junction rule which states that for a given junction or node in a circuit, sum of the currents entering will be equal to sum of currents leaving. Or It states In any electrical network the algebraic sum of currents meeting at a point or junction is zero.

Kirchhoff's second law is also known as loop rule which shows that around any closed loop in a circuit, sum of the potential differences across all elements will be zero. or The algebraic sum of the changes in potential around any closed loop involving resistors and cells in the loop is zero.

ii. Now from the given figure,

$I_1 + I_2 = I_3$ ...(i)

$I_2 = I_3 - I_1$ ...(ii)

For ABEFA

$- 20I_i - 40I_3 = -40$

$- 20(I_1 + 2I_3) = -40$

$I_1 + 2I_3 = 2$ ...(iii)

For BCDEB

$40I_3 + 20I_2 = 80 + 40$

$20(2I_3 + I_2) = 120$

$2I_3 + (I_3 - I_1) = 6$

$2I_3 + I_2 = 6$

$2I_3 + (I_3 - I_1) = 6$ using eq. (i)

$2I_3 + I_3 - I_1 = 6$

$3I_3 - I_1 = 6$ ...(iv),

$5I_3 = 8$ We get $I_3 = \frac{8}{5} = 1.6$ A

and $I_1 = -\frac{6}{5}$ A = -1.2 A

Now from equation (ii),

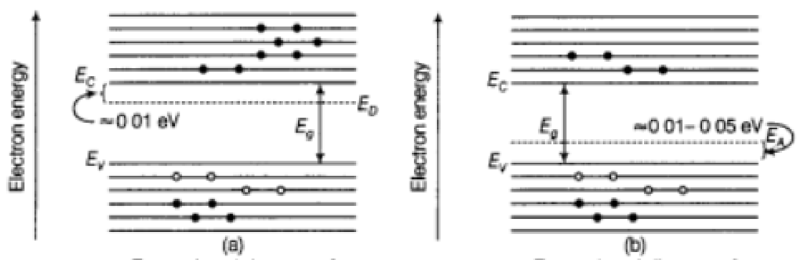
$I_2 = I_3 - I_1$

= 1.6 - (-1.2)

= 1.6 + 1.2

= 2.8 A

23. i. In n-type semiconductor, the donor energy level E_D is slightly below the bottom E_C of the conduction band and electrons from this level move into conduction band with a very small supply of energy. Fermi-level shifts towards the conduction band where higher number of electrons are available for conduction. In a n-type semiconductor, energy gap decreases.

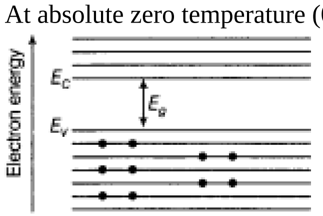


(a) Energy band diagram of *n*-type semiconductor at *T*>0 K

(b) Energy band diagram of *p*-type semiconductor at *T*>0 K

In p-type semiconductor, the acceptor energy level E_A is above the top E_V of the valence band, therefore with a small supply of energy, the electrons can jump from valence band to acceptor energy level. Fermi levels shift closer to the valence bond because holes are the majority carriers. In a p-type semiconductor, energy band increases.

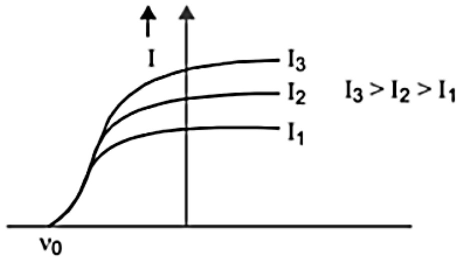
ii. At absolute zero temperature (0 K) conduction band of semiconductor is completely empty, i.e., $\sigma = 0$.



Energy band diagram of semiconductor at *T*=0 K

Hence, the semiconductor behaves as an insulator. At room temperature, some valence electrons acquire enough thermal energy and jump to the conduction band where they are free to conduct electricity. Thus, the semiconductor acquires a small conductivity at room temperature.

24. a. The frequency of the incident radiation was kept constant



b. from the de-Broglie wavelength,

$\lambda \propto \frac{1}{\sqrt{\nu}}$

If potential difference V is doubled, the de-Broglie wavelength is decreased to $\frac{1}{\sqrt{2}}$ times.

25. i. Mass defect (ΔM), of any nucleus ${}_{Z}^{A}X$ is the difference in the mass of the nucleus (= M) and the sum of masses of its constituent nucleons (= M').

$\Delta M = M' - M$

$= [Zm_p + (A - Z)m_n] - M$

where m_p and m_n denote the mass of the proton and the neutron respectively.

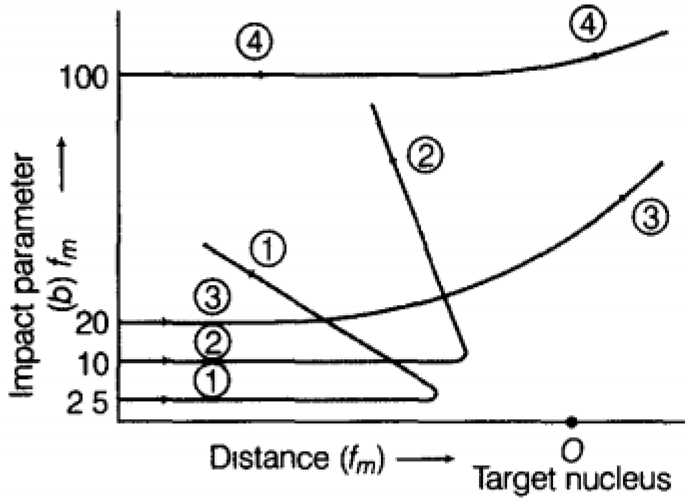
ii. Binding energy is the energy required to separate a nucleus into its constituent nucleons. Or Nuclear binding energy is the minimum energy that would be required to disassemble the nucleus of an atom into its component parts. These component parts are neutrons and protons, which are collectively called nucleons. The relation between the two is

B.E. = ΔMc^2

iii. There is a release of energy, i.e., the reaction is exothermic.

Reason: Increase in B.E/nucleon implies that mass has been converted into energy. This would result in the release of energy.

26. The trajectory of α-particles in the Coulomb field of the target nucleus is shown below:



From this experiment, the following is observed.

1. Most of the α-particles pass straight through the gold foil. It means that they do not suffer any collision with gold atoms.
2. About one α-particle in every 8000 α-particles deflect by more than 90°. As most of the α-particles go undeflected and only a few get deflected, this shows that most of the space in an atom is empty. Thus, with the help of these observations regarding the deflection of a-particles, the size of the nucleus was predicted.

At the distance of head on approach, the entire kinetic energy of α-particle is converted into electrostatic potential energy. This distance of head on approach gives an upper limit of the size of nucleus (denoted by r_0) and is given by:

$E_k = \frac{1}{4\pi\varepsilon_0} \frac{(Ze)(2e)}{r_0}$

$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{2Ze^2}{E_k}$

This is about 10^{-14}m.

27. Here d = 3 mm = 3×10^{-3} m, D = 2 m

Position of 5th bright fringe of wavelength 480 nm,

$x_5 = 5\frac{D\lambda}{d} = \frac{5\times2\times480\times10^{-9}}{3\times10^{-3}}$ m

Position of 5th bright fringe of wavelength 600 nm,

$x_5' = \frac{5\times2\times600\times10^{-9}}{3\times10^{-3}}$ m

Separation between the 5th order bright fringes of the two patterns,

$\Delta x = x_5' - x_5 = \frac{10^{-5}}{3}$ (600 - 480)m

$= \frac{10^{-5}\times120}{3}$ m = 4×10^{-4} m

28. Self-inductance of a coil is the property of the coil in which it opposes the change of current flowing through it. Inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it.

Self-induction of the long solenoid of inductance L, (A long solenoid is one which length is very large as compared to its cross-section area.) the magnetic field inside such a solenoid is constant at any point and given by

$B = \frac{\mu_0 NI}{l}$

Magnetic flux through each turn of solenoid

ϕ = B $\times$ area of each turn

$\phi = \frac{\mu_0 NI}{l} \times A$

total flux = flux $\times$ total number of turns

$N\phi = N\left(\frac{\mu_0 NI}{l} \times A\right)$ ... (i)

If L is the coefficient of inductance of solenoid

$N\phi$ = LI ... (ii)

from equation (i) and (ii)

$LI = N\left(\frac{\mu_0 NI}{l} \times A\right)$

$L = \frac{\mu_0 N^2 A}{l}$ ... (iii)

The magnitude of emf is given by

|e| or $e = L\frac{dI}{dt}$ ... (iv)

multiplying I to both sides

eIdt = LIdI

but $I = \frac{dq}{dt}$

Idt = dq

Also work done (dW)= voltage $\times$ Charge(dq)

or dW = e$\times$dq = eIdt

substituting the values in equation (iv)

dW = LIdt

By integrating both sides

$\int_0^w dW = \int_0^{I_0} LIdt$

$W = \frac{1}{2}LI_0^2$

this work done is in increasing the current flow through inductor is stored as potential energy (U) in the magnetic field of inductor

$U = \frac{1}{2}LI_0^2$

OR

Length of the wire, l = 10 m

Falling speed of the wire, v = 5.0 m/s

Magnetic field strength, B = 0.3×10^{-4} wb m^{-2}

a. the instantaneous value of Emf induced in the wire,

   e = Blv

   $= 0.3 \times 10^{-4} \times 5 \times 10$

   = 1.5×10^{-3} V

b. Using Fleming's right-hand rule, it can be inferred that the direction of the induced emf is from West to East.

c. The eastern end of the wire is at a higher potential.

Section D

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

An electromagnetic wave transports linear momentum as it travels through space. If an electromagnetic wave transfers a total energy U to a surface in time t, then total linear momentum delivered to the surface is $p = \frac{U}{c}$. When an electromagnetic wave falls on a surface, it exerts pressure on the surface. In 1903, the American scientists Nichols and Hull succeeded in measuring radiation pressures of visible light where other had failed, by making a detailed empirical analysis of the ubiquitous gas heating and ballistic effects.

(i) **(a)** $\frac{I}{c}$

Explanation: Pressure exerted by an electromagnetic radiation, $P = \frac{I}{c}$

(ii) **(b)** 6×10^{-4} N/m^2

Explanation: $P_{\text{rad}} = \frac{\text{Energy flux}}{\text{Speed of light}} = \frac{18 \text{ W/cm}^2}{3 \times 10^8 \text{ m/s}}$

$= \frac{18 \times 10^4 \text{ W/m}^2}{3 \times 10^8 \text{ m/s}} = 6 \times 10^{-4}$ N/m^2

(iii) **(c)** 0.166×10^{-8} N m^{-2}

Explanation: $P = \frac{I}{c} = \frac{0.5}{3 \times 10^8} = 0.166 \times 10^{-8}$ N m^{-2}

OR

(b) 10^{-6} N/m^2

Explanation: The radiation pressure of visible light

$= 7 \times 10^{-6}$ N/m^2

(iv) **(d)** 100

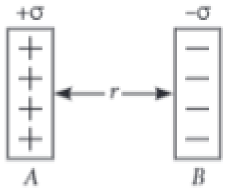
Explanation: Intensity of EM wave is given by $I = \frac{P}{4\pi R^2}$ $V_{av} = \frac{1}{2}\varepsilon_0 E_0^2 \times c$

$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}} = \sqrt{\frac{1500}{2 \times 3.14(3)^2 \times 8.85 \times 10^{-12} \times 3 \times 10^8}}$

$= \sqrt{10,000} = 100$ V m^{-1}

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

Surface charge density is defined as charge per unit surface area of surface charge distribution. i.e., $\sigma = \frac{dq}{dS}$. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} Cm^{-2} as shown. The intensity of electric field at a point is E = $\frac{\sigma}{\varepsilon_0}$, where ε_0 = permittivity of free space.



(i) **(d)** zero

Explanation: There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on B, respectively. According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

(ii) **(a)** zero

Explanation: The electric field in region III is also zero.

$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$

(iii) **(a)** 1.9×10^{-10} N/C

Explanation: In region II or between the plates, the electric field.

$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$

$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$

$E = 1.9 \times 10^{-10}$ NC^{-1}

(iv) **(d)** 1 : 1

Explanation: Since, electric field due to an infinite-plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge. So, for the given distances, the ratio of E will be 1 : 1.

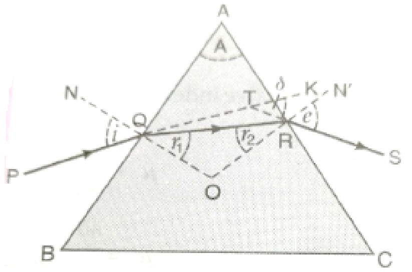
OR

(a) cylindrical

Explanation: In order to estimate the electric field due to a thin finite plane metal plate, we take a cylindrical cross-sectional area A and length 2r as the gaussian surface.

Section E

31. a. Consider that a ray of light PQ is incident on the refracting face AB of the prism at point Q as shown in figure. When light passes through a prism refraction takes place at both the surfaces of the prism.



In figure, i and e are the angle of incidence and emergence respectively. Angles r_1 and r_2 are angle of refraction at both the surfaces of the prism. A is the angle of prism and δ be the angle of deviation.

The rays PQ, QR and RS are called incident ray, refracted ray and emergent ray respectively. Produce SR backwards, so as to meet the ray PQ at point T, when produced. Then, KTS = δ is called the angle of deviation.

Since $\angle$ TQO = i and $\angle$RQO = r_1, we have

$\angle$TQR = i - r_1

Also, $\angle$TRO = e and $\angle$QRO = r_2. Therefore,

$\angle$TRQ = e - r_2

Now, in triangle TQR, the side QT has been produced outwards. Therefore,

δ = $\angle$TQR + $\angle$TRQ = (i - r_1) + (e - r_2)

or δ = (i + e) - (r_1 + r_2) ....(i)

In triangle QRO, the sum of the angles is 180^o. Therefore,

$r_1 + r_2 + \angle QOR = 180^o$ ...(ii)

In quadrilateral AQOR, each of the angles AQO and ARO is 90^o. Since the sum of the four angles of a quadrilateral is four angles, the sum of the remaining two angles should be 180^o i.e.

A + $\angle$QOR = 180^o ....(iii)

From the equation (ii) and (iii), we have

$r_1 + r_2$ = A ...(iv)

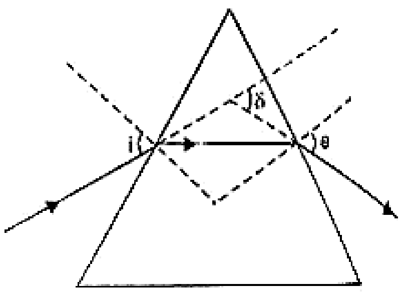
In the equation (i), substituting for ($r_1 + r_2$) we have

δ = (i + e) - A

or A + δ = i + e

Hence, $\delta = (i + e) - A$

b. The incident ray is deviated through $\delta = 62^\circ 48'$ when angle i = $40^o6'$. From the principle of reversibility of light, it is clear from the figure that the emergent ray (for which angle e = $82^o42'$) is also deviated through the same angle δ. Now,



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

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

$= 40^\circ 6' + 82^\circ 42' - 62^\circ 48'$

or A = 60°

which is the refractive angle of the prism.

For minimum deviation, i = e

Hence, $\delta_{\min} = 2i - A$

or $i = \left(\frac{\delta_{\min}+A}{2}\right)$

$= \frac{(51^\circ+60^\circ)}{2} = 55^\circ 30'$

which is the angle of incidence at minimum deviation? The refractive index of the material of the prism is given by

$\mu = \frac{\sin\frac{(\delta_{\min}+A)}{2}}{\sin\frac{A}{2}}$

or $\mu = \frac{\sin\left(\frac{51^\circ+60^\circ}{2}\right)}{\sin\frac{60^\circ}{2}}$

or $\mu = 1.648$

OR

Let I be the intensity of beam 1 incident on the first glass plate. Each plate reflects 25% of light incident on it and transmits 75%. Therefore,

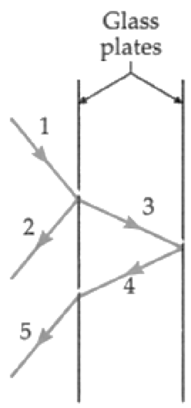
$I_1 = I$;

$I_2 = \frac{25}{100} I = \frac{I}{4}$

$I_3 = \frac{75}{100} I = \frac{3}{4} I$

$I_4 = \frac{25}{100} I_3 = \frac{1}{4} \times \frac{3}{4} I = \frac{3}{16} I$

$I_5 = \frac{75}{100} I_4 = \frac{3}{4} \times \frac{3}{16} I = \frac{9}{64} I$



$\therefore$ Amplitude ratio of beams 2 and 5 is

$r = \sqrt{\frac{I_2}{I_5}} = \sqrt{\frac{I}{4} \times \frac{64}{9I}} = \frac{4}{3}$

$\frac{I_{\min}}{I_{\max}} = \left[\frac{r-1}{r+1}\right]^2 = \left[\frac{\frac{4}{3}-1}{\frac{4}{3}+1}\right]^2 = \frac{1}{49}$ = 1 : 49

32. i. Capacitance of an air-filled capacitor is

$C_0 = \frac{\varepsilon_0 A}{d} = \frac{8.85\times10^{-12}\times0.20}{0.01} =$ = 1.77×10^{-10} F.

ii. Charge on each plate,

$q = C_0V_0 = 1.77 \times 10^{-10} \times 3000 = 5.31 \times 10^{-7}$ C

iii. Dielectric constant of the material is $\kappa = \frac{C}{C_0} = \frac{q/V}{q/V_0} = \frac{V_0}{V} = \frac{3000}{1000}$ = 3

iv. Capacitance after the dielectric sheet is introduced

$C = \kappa C_0 = 3 \times 1.77 \times 10^{-10} = 5.31 \times 10^{-10}$ F

v. Permittivity of the dielectric is $\varepsilon = \kappa\varepsilon_0$ $= 3 \times 8.85 \times 10^{-12} = 2.65 \times 10^{-11}$ Fm^{-1}

OR

a.

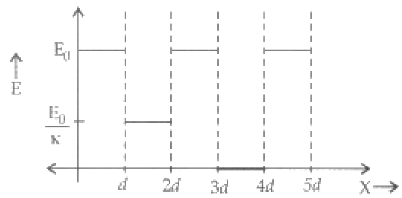
	Non-polar (O_2)	**Polar (H_2O)**
In the absence of electric field		

Individual	No dipole moment exists.	Dipole moment exists
Specimen	No dipole moment exists.	Dipoles are randomly oriented. Net P=0
In the presence of electric field		
Individual	Dipole moment exists (molecules become polarised.)	Torque acts on the molecules to align them parallel to E
Specimen	The dipole moment exists.	Net dipole moment exists parallel to E.

b. i. $V = E_0 d + \frac{E_0}{\kappa} d + E_0 d + 0 + E_0 d$, k is the dielectric constant.

$V = 3 E_0 d + \frac{E_0}{\kappa} d$ thus $V= E_0 d (3+1/k)$ or $V= E_0 d(3k+1)/k$

ii. Graph:



33. i. When a source of AC is connected to a capacitor of capacitance C, the charge on it grows from zero to maximum steady value Q_0 .

The energy stored in a capacitor is, $E = \frac{1}{2}CV_0^2$ where, V_0 is maximum potential difference across the plates of the capacitor.

The alternating voltage applied is

$V = V_0 \sin \omega t$

and the current leads the emf by a phase angle of $\pi/2$

$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right) = I_0 \cos \omega t$

$\therefore$ Work done over a complete cycle is,

$W = \int_0^T VIdt = \int_0^T (V_0 \sin \omega t)(I_0 \cos \omega t)\, dt$

$= \frac{V_0 I_0}{2} \int_0^T 2 \sin \omega t \cos \omega t dt$

$\therefore W = \frac{V_0 I_0}{2} \int_0^T \sin 2\omega t dt$

$W = \frac{V_0 I_0}{2} \left[1 - \frac{\cos 2\omega t}{2\omega}\right]_0^T = 0$

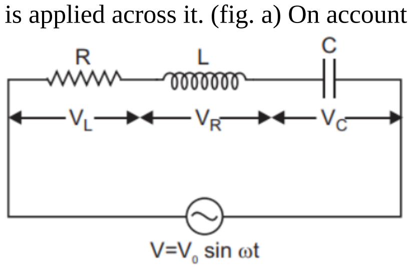
Now as the work done is zero, hence the average power is also zero (as, time can never be zero).

ii. When a DC source is connected, the condenser is charged but no current flows in the circuit. Because a condenser offers infinite resistance for a DC source and never allows a DC current to flow through it. Therefore, the lamp does not glow. No change occurs even when capacitance of capacitor is reduced.

Now when an AC source is connected with the circuit, the capacitor offers capacitive reactance $X_C = 1/\omega C$ (where ω is the angular frequency of the applied AC voltage). The current flows in the circuit and the lamp glows. On reducing the value of C, the capacitive reactance, X_C increases. Therefore, the glowing of the bulb reduces.

OR

Suppose resistance R, inductance L and capacitance C are connected in series and an alternating source of voltage $V = V_0 \sin \omega t$ is applied across it. (fig. a) On account of being in series, the current (i) flowing through all of them is the same.



(a)

Suppose the voltage across resistance R is V_R, voltage across inductance L is V_L and voltage across capacitance C is V_C. The voltage V_R and current i are in the same phase, the voltage V_L will lead the current by angle 90^o while the voltage V_C will lag behind the current by angle 90^o. Clearly V_C and V_L are in opposite directions, therefore their resultant potential difference = V_C - V_L (if $V_C > V_L$).

Thus V_R and (V_C - V_L) are mutually perpendicular and the phase difference between them is 90^o. As applied voltage across the circuit is V, the resultant of V_R and (V_C - V_L) will also be V.

From fig.

$V^2 = V_R^2 + (V_C - V_L)^2 \Rightarrow V = \sqrt{V_R^2 + (V_C - V_L)^2}$ ......(i)

But $V_R = Ri$, $V_C = X_C i$ and $V_L = X_L i$ .....(ii)

capacitance reactance and $X_L = \omega$ L = inductive reactance

$\therefore V = \sqrt{(Ri)^2 + (X_C i - X_L i)^2}$

$\therefore$ Impedance of circuit, $Z = \frac{V}{i} = \sqrt{R^2 + (X_C - X_L)^2}$

i.e., $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}$

Instantaneous current

$I = \frac{V_0 \sin(\omega t + \phi)}{\sqrt{R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2}}$

Condition for resonance to occur in series LCR ac circuit:

For resonance, the current produced in the circuit and emf applied must always be in the same phase.

Phase difference (ϕ) in series LCR circuit is given by

$\tan \phi = \frac{X_C - X_L}{R}$

For resonance $\phi = 0 \Rightarrow X_C - X_L = 0$

or $X_C = X_L$

If ω_r is resonant frequency, then

and $X_L = \omega_r L$

$\therefore \frac{1}{\omega_r C} = \omega_r L \Rightarrow \omega_r = \frac{1}{\sqrt{LC}}$

Power factor is the cosine of phase angle ϕ, i.e., cos ϕ = R/Z.

For maximum power cos ϕ = 1 or Z = R

i.e., circuit is purely resistive.

For minimum power cos ϕ = 0 or R = 0

i.e., circuit should be free from ohmic resistance.