Class XII Session 2025-26
Subject - Physics
Sample Question Paper - 8

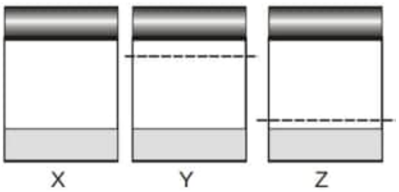
Time Allowed: 3 hours **Maximum Marks: 70**

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 diagrams for three semiconductor samples of silicon are as shown. We can then assert that **[1]**



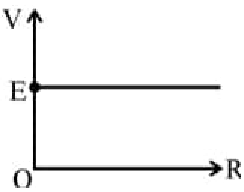
a) Sample X has been doped with equal amounts of third and fifth group impurities while samples Y and Z are undoped

b) Sample X is undoped while both samples Y and Z have been doped with a fifth group impurity

c) Sample X is undoped while samples Y and Z have been doped with a third group and fifth group impurity respectively

d) Sample X is undoped while samples Y and Z have been doped with a fifth group and a third group impurity respectively

2. A cell of emf (E) and internal resistance r is connected across a variable external resistance R. The graph of terminal potential difference V as a function of R is- **[1]**

a)


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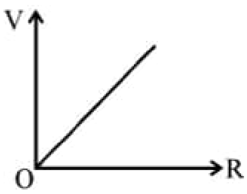
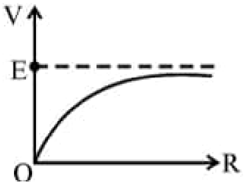
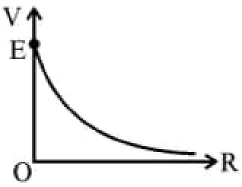


c) 

d) 

3. The focal length of a concave mirror is f. An object is placed at a distance x from the focus. The magnification is **[1]**

a) $\frac{f}{x}$

b) $\frac{f}{(f+x)}$

c) $\frac{x}{f}$

d) $\frac{(f+x)}{f}$

4. The arrangement fo two magnetic poles of equal and opposite strengths separated by a finite distance is called: **[1]**

a) Magnetic dipole

b) Magnetic current

c) Magnetic pole

d) Magnetic field

5. A long, hollow conducting cylinder is kept co-axially inside another long, hollow conducting cylinder of a larger radius. Both the cylinders are initially electrically neutral. **[1]**
Which of the following statements is correct based on the above-mentioned condition?

a) No potential difference appears between the two cylinders when a uniform line charge is kept along the axis of the cylinders.

b) No potential difference appears between the two cylinders when same charge density is given to both the cylinders.

c) A potential difference appears between the two cylinders when inner cylinder is charged.

d) A potential difference appears between the two cylinders when a charge density is given to the outer cylinder.

6. A tape-recorder records sound in the form of **[1]**

a) the magnetic field on the tape

b) electrical energy

c) magnetic energy

d) variable resistance on the tape

7. The electric fan works on the principle of : **[1]**

a) Electric motor

b) Both electric motor and dynamo

c) Electric mechanism

d) Electric dynamo

8. How does the magnetic susceptibility χ of a paramagnetic material change with absolute temperature T? **[1]**

a) $\chi \propto e^T$

b) $\chi \propto T$

c) $\chi \propto T^{-1}$

d) χ = constant

9. Interference is possible in **[1]**

a) neither light nor sound waves

b) both light and sound waves

c) sound waves only

d) light waves only

10. Out of the following which one is not a property of field lines: **[1]**

a) They form closed loops

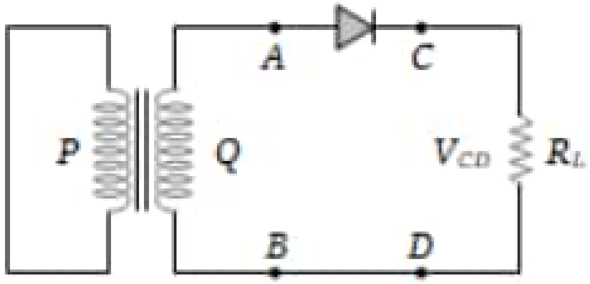
b) Field lines are continuous curves without any breaks

c) Two field lines cannot cross each other

d) Field lines start at positive charges and end at negative charges

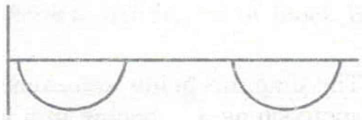
[1]

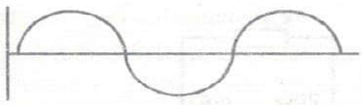
11. In the half wave rectifier circuit shown which one of the following wave forms is true for V_{CD}, the output across C and D?



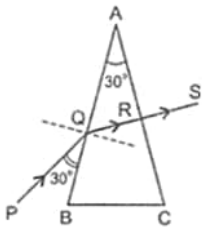
a) 

b) 

c) 

d) 

12. In the diagram, a prism of angle 30° is used. A ray PQ is incident as shown. An emergent ray RS emerges perpendicular to the second face. The angle of deviation is: **[1]**



a) 60^o

b) 0^o

c) 45^o

d) 30^o

13. **Assertion (A):** In the process of photoelectric emission, all emitted electrons have the same kinetic energy. **[1]**

Reason (R): According to Einstein's equation $E_k = hv - \phi_0$.

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):** If the distance between parallel plates a capacitor is halved and dielectric constant is made three times then the capacitance becomes six times. **[1]**

Reason (R): Capacitance of the capacitor does not depend upon the nature of the material of the plates of the capacitor.

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):** Young’s double slit experiment can be performed using a source of white light. **[1]**

Reason (R): The wavelength of red light is less than the wavelength of other colours in white 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 and R is also false

16. **Assertion (A):** If the frequency of the applied AC is doubled, then the power factor of a series R-L circuit decreases. **[1]**

Reason (R): Power factor of series R-L circuit is given by $\cos\phi = \frac{2R}{R^2+\omega^2L^2}$.

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 is moving along x-direction. The frequency of the wave is 10^{15} Hz and the electric field at any point is varying sinu-soidally with time with an amplitude of 2 Vm^{-1}. Calculate the average densities of the electric and magnetic fields. **[2]**

18. A magnetic dipole is placed in the position of stable equilibrium in a uniform electric field B. **[2]**

i. How much is the potential energy of the magnet?

ii. If it is rotated through 180°, then what will be the amount of work done?

OR

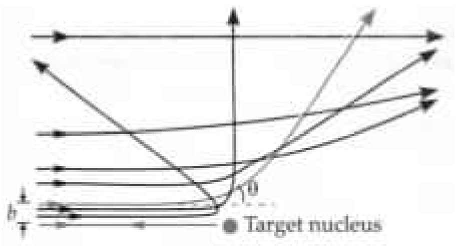
An iron ring of mean circumferential length 30 cm and cross-section 1 cm^2 is wound uniformly with 300 turns of wire. When a current of 0.032 A flows in the windings; the flux in the ring is 2×10^{-6} Wb. Find the flux density in the ring, magnetising field intensity and relative permeability of iron.

19. A semiconductor is known to have an electron concentration of 8×10^{13} per cm^3 and a hole concentration of 5×10^{12} per cm^3, **[2]**

i. Is the semiconductor n-type or p-type?

ii. What is the resistivity of the sample if the electron mobility is 23,000 cm^2 / Vs and hole mobility is 100 cm^2/ Vs?

20. The trajectories, traced by different α-particles, in Geiger-Marsden experiment were observed as shown in Fig. **[2]**



What names are given to the symbols **b** and θ shown here?

What can we say about the values of b for (i) θ = $\mathbf{0^o}$ and (ii) $\theta \simeq \pi$ radians?

21. How is the equation for Ampere's circuital law modified in the presence of displacement current? Explain. **[2]**

Section C

22. A student connects a cell, of emf ε_2 and internal resistance r_2 with a cell of emf ε_1 and internal resistance r_1, such that their combination has a net internal resistance less than r_1. This combination is then connected across a resistance R. **[3]**

Draw a diagram of the 'set-up' and obtain an expression for the current flowing through the resistance.

23. The maximum kinetic energy of the photoelectrons emitted is doubled when the wavelength of light incident on the photosensitive surface changes from λ_1 to λ_2. Deduce expressions for the threshold wavelength and work function for the metal surface in terms of λ_1 and λ_2. **[3]**

24. 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?

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

i. attractive and
ii. repulsive.

Write any two characteristic features of nuclear forces.

26. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength $975\overset{o}{A}$. **[3]**

i. How many different lines are possible in the resulting spectrum?
ii. Calculate the longest wavelength amongst them. You may assume the ionization energy for hydrogen atom as 13.6 eV.

27. For sound waves, the Doppler formula for frequency shift differs slightly between the two situations: **[3]**

a. source at rest; observer moving, and
b. source moving; observer at rest.

The exact Doppler formulas for the case of light waves in vacuum are, however, strictly identical for these situations. Explain why this should be so. Would you expect the formulas to be strictly identical for the two situations in case of light travelling in a medium?

28. Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it. **[3]**

OR

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.

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.

Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(a) As compared to visible light microwave has frequency and energy

a) Frequency is less but energy is more
b) more than visible light
c) less than visible light
d) equal to visible light

(b) When the temperature of a body rises

a) the energy of the random motion of atoms and molecules remains same.
b) the energy of the random motion of atoms and molecules decreases.
c) the random motion of atoms and molecules becomes streamlined.
d) the energy of the random motion of atoms and molecules increases

(c) The frequency of rotation of water molecules is about

a) 2.45 kHz
b) 2.45 GHz
c) 2.45 MHz
d) 2.45 THz

OR

In the microwave oven

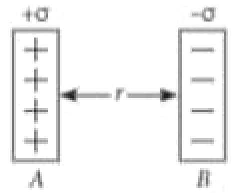
a) The vessel gets heated first, and then the food grains inside
b) The vessel gets heated first and then the water molecules collect heat from the body of the vessel
c) Energy is directly delivered to the food grains.
d) Energy is directly delivered to water molecules which is shared by the entire food

(d) Why should one use porcelain vessels and non-metal containers in a microwave oven?

a) Because it will prevent the food items to become hot
b) Because it may crack due to high frequency
c) Because of the danger of getting a shock from accumulated electric charges
d) Because it will get too much hot

30. Surface charge density is defined as charge per unit surface area of surface charge distribution. i.e., $\sigma = \frac{dq}{dS}$. **[4]**
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. What is E in the outer region of the first plate?
ii. What is E in the outer region of the second plate?
iii. What is E between the plates?
iv. What is the ratio of E from right side of B at distances 2 cm and 4 cm?
v. In order to estimate the electric field due to a thin finite plane metal plate, What is the shape of the Gaussian surface?

Section E

31. i. Draw a ray diagram to show the working of a compound microscope. Obtain the expression for the total magnification for the final image to be formed at the near point. **[5]**
ii. In a compound microscope an object is placed at a distance of 1.5 cm from the objective of focal length 1.25 cm. If the eye-piece has a focal length of 5 cm and the final image is formed at the near point, find the magnifying power of the microscope.

OR

a. Derive the relation a sin $\theta = \lambda$ for the first minimum of the diffraction pattern produced due to a single slit of width **a** using light of wavelength λ.
b. State with reason, how the linear width of central maximum will be affected if (i) monochromatic yellow light is replaced with red light, and (ii) distance between the slit and the screen is increased.
c. Using the monochromatic light of same wavelength in the experimental set-up of the diffraction pattern as well as in the interference pattern where the slit separation is 1 mm, 10 interference fringes are found to be within the central maximum of the diffraction pattern. Determine the width of the single slit, if the screen is kept at the same distance from the slit in the two cases.

32. Calculate potential on the axis of a disc of radius R due to a charge Q uniformly distributed on its surface. **[5]**

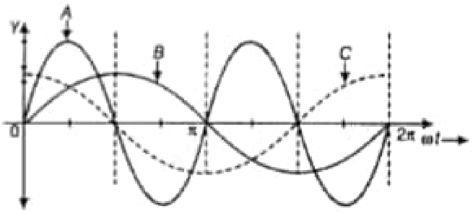
OR

a. Describe briefly the process of transferring the charge between the two plates of a parallel plate capacitor when connected to a battery. Derive an expression for the energy stored in a capacitor.
b. A parallel plate capacitor is charged by a battery to a potential difference V. It is disconnected from the battery and then connected to another uncharged capacitor of the same capacitance. Calculate the ratio of the energy stored in the combination to the initial energy on the single capacitor.

33. i. An ac source generating a voltage V = V_0 sin ωt is connected to a capacitor of capacitance C. Find the expression of the current I flowing through it. Plot a graph of V and I versus ωt to show that the current is $\frac{\pi}{2}$ ahead of the voltage. **[5]**
ii. A resistor of 200 Ω and a capacitor of 15 μF are connected in series to a 220 V, 50 Hz ac source. Calculate the current in the circuit and the rms voltage across the resistor and the capacitor. Why the algebraic sum of these voltages is more than the source voltage?

OR

A device X is connected to an AC source, V = V_0 sin ωt. The variation of voltage, current and power in one cycle is shown in the following graph.



i. Identify the device X.
ii. Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify the answer.
iii. How does its impedance vary with the frequency of the AC source? Show graphically.
iv. Obtain an expression for the current in the circuit and its phase relation with AC voltage.

Solution

Section A

1.

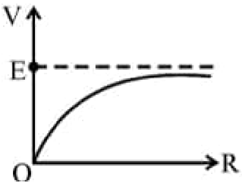
(d) Sample X is undoped while samples Y and Z have been doped with a fifth group and a third group impurity respectively

Explanation:

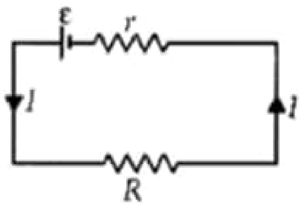
The solution is correct because it accurately identifies the doping characteristics of the semiconductor samples based on their energy band diagrams. In semiconductor physics, undoped silicon has a specific energy band structure, while doping with third group (p-type) or fifth group (n-type) impurities alters this structure. Sample X, being undoped, shows a typical band gap without any significant shifts in the energy levels. In contrast, samples Y and Z exhibit shifts in their energy levels indicative of doping: sample Y shows characteristics of n-type doping (fifth group), while sample Z shows characteristics of p-type doping (third group).

Thus, the assertion in correct option aligns with the expected behavior of the energy band diagrams for the respective doping types.

2.

(c) 

Explanation:



Current in the circuit, I = $\frac{\varepsilon}{R+r}$

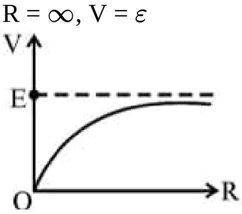
Potential difference across R,

V = IR = $\left(\frac{\varepsilon}{R+r}\right)R$

V = $\frac{\varepsilon}{1+\frac{r}{R}}$

When R = 0, V = 0

R = ∞, V = ε



3. **(a)** $\frac{f}{x}$

Explanation:

u = f + x

Using mirror formula,

$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

Or, $\frac{1}{v}-\frac{1}{(f+x)}=-\frac{1}{f}$

$\therefore$ v = -$\frac{f(f+x)}{x}$

So, the magnification = |m| = $\frac{v}{u}=\frac{f}{x}$

4. **(a)** Magnetic dipole
Explanation:
Magnetic dipole

5.
(c) A potential difference appears between the two cylinders when inner cylinder is charged.
Explanation:
When the charge is given to inner cylinder, then an electric field is produced between cylinders which is given by $E = \frac{\lambda}{2\pi\varepsilon_0 r}$ and due to this a potential difference is developed between two cylinders.

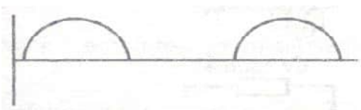
6. **(a)** the magnetic field on the tape
Explanation:
A tape is coated with tiny magnet particles. These particles get magnetized when the electric signal passes through them. Thus, a tape recorder records sound in the form of a magnetic field on the tape.

7. **(a)** Electric motor
Explanation:
Electric motor

8.
(c) $\chi \propto T^{-1}$
Explanation:
$\chi \propto T^{-1}$

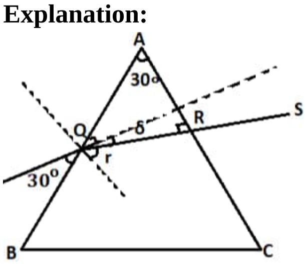
9.
(b) both light and sound waves
Explanation:
Interference is possible both in light and sound waves.

10. **(a)** They form closed loops
Explanation:
Electric field lines may not always form closed loops.

11. **(a)** 

Explanation:
When an alternating voltage is applied across a half wave rectifier, a pulsating voltage appears across the load only during the half cycles of the ac input i.e., only when the diode is forward biased.

12.
(d) 30^o
Explanation:



In △AQR

∠A + ∠Q + ∠R = 180^o

30° + 90 - r + 90 = 180^o

r = 30^o

δ = 90^o - 30^o - r

δ = 90° - 30° - 30°

δ = 30°

so angle of deviation is 30 degree.

13.

(d) A is false but R is true.

Explanation:

A is false but R is true.

14.

(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.

15.

(d) A is false and R is also false

Explanation:

A is false and R is also false

16.

(c) A is true but R is false.

Explanation:

$\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+\omega^2L^2}}$

When ω is doubled, power factor ($\cos\phi$) decreases.

So, A is true but R is false.

Section B

17. Here, v = 6 $\times$ 10^{14} Hz, E_0 = 2Vm^{-1}

i. Average energy density of the electric field

$u_E = \frac{1}{4} \in_0 E_0^2 = \frac{1}{4} \times \left(8.85 \times 10^{-12}\right) \times 2^2$

= 8.85 $\times$ $10^{-12}$$Jm^{-3}$

ii. Average energy density of magnetic field

$u_B = \frac{B_0^2}{4\mu_0} = \frac{1}{4} \times \frac{(E_0/c)^2}{\mu_0} = \frac{1}{4}\frac{E_0^2}{\mu_0c^2}$

$= \frac{1}{4} \times \frac{2^2}{\left(4\pi\times10^{-7}\right)\times\left(3\times10^8\right)^2}$

= 8.85 $\times$ $10^{-12}$$Jm^{-3}$

18. i. In stable equilibrium,

U = -mB cos 0° = -mB

ii. When the dipole is rotated through 180°, the work done is

W = - mB (cos 180° - cos 0°)

= - mB (- 1 - 1)

= + 2mB

OR

Here l = 30cm = 0.30 m, A = 1 cm^2 = 10^{-4} m, N = 300, I = 0.032 A, ϕ = 2 $\times$ 10^{-6} Wb,

n = $\frac{N}{l} = \frac{300}{0.30}$ = 1000 m^{-1}

Magnetic flux density,

B = $\frac{\phi}{A} = \frac{2\times10^{-6}}{10^{-4}}$ = 2 $\times$ 10^{-2} Wb m^{-2}

Magnetising field intensity,

H = nI = 1000 $\times$ 0.032 = 32 A turns m^{-1}

Permeability,

$\mu = \frac{B}{H} = \frac{2\times10^{-2}}{32}$ = 6.25 $\times$ 10^{-4} T mA^{-1}

Relative permeability, $\mu_r = \frac{\mu}{\mu_0} = \frac{6.25\times10^{-4}}{4\pi\times10^{-7}}$ = 500

19. Here n_e = 8 $\times$ 10^{13} cm^{-3}, n_h = 5 x 10^{12} cm^3, μ_e = 23,000 cm^2 V^{-1} s^{-1}, μ_h = 100 cm^2 V^{-1} s^{-1}

  i. As $n_e > n_h$, the semiconductor must be n-type.
  ii. Resistivity,
  $\rho = \frac{1}{e(n_e\mu_e + n_h\mu_h)}$
  $= \frac{1}{1.6\times10^{-19}(8\times10^{13}\times23\times10^3+5\times10^{12}\times10^2)}\Omega$ cm
  $= \frac{1}{1.6\times10^{-19}(184\times10^{16}+5\times10^{14})}\Omega$ cm
  $= \frac{1}{1.6\times10^{-5}\times18405}\Omega$ cm = 3.395 Ω cm

20. The symbol b represents impact parameter and θ represents the scattering angle.

  i. When $\theta = 0^\circ$ the impact parameter b is large and the α -particle passes almost undeflected.
  ii. When $\theta = \pi$ radians, the impact parameter b = 0 and the α -particle is reversed back along its original path.

21. $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 i$

There is an inconsistency in the Ampere's Circuital law.

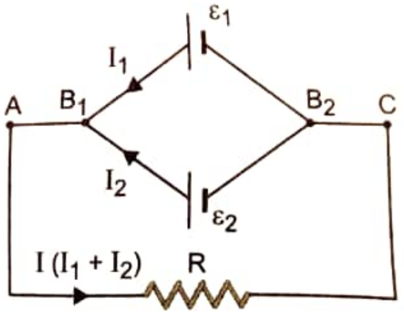
Maxwell modified it as

$\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 (i_c + i_d)$

where $i_d = \varepsilon_0 \frac{d\phi_E}{dt}$

Section C

22. As the effective internal resistance of two cells is less than the internal resistance r_1 of one cells so the cell are connected in parallel between the two point R_1 and R_2. The circuit is the potential difference between point R_1 and R_2. The potential difference between the terminal of the first cell is



$V = V_{B_1} - V_{B_2} = \varepsilon_1 - I_1 r_1$ or $I_1 = \frac{\varepsilon_1 - V}{r_1}$

Potential difference between the terminal of second cell is

$V = V_{B_1} - V_{B_2} = \epsilon_2 - I_2 r_2$ or $I_2 = \frac{\varepsilon_2 - V}{r_2}$

Hence current in external resistance

$I = I_1 + I_2 = \frac{\varepsilon_1 - V}{r_1} + \frac{\varepsilon_2 - V}{r_2}$

$= \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - V\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

or $I = \left(\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right) - IR\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$ [$\because$ V = IR]

or $I\left[1 + R\left(\frac{1}{r_1} + \frac{1}{r_2}\right)\right] = \left(\frac{\epsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}\right)$

or $\left[\frac{r_1 r_2 + R(r_2 r_1)}{r_1 r_2}\right] = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 r_2}$

or $I = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{(r_1 \times r_2) + R(r_2 + r_1)}$

23. Given that

Initial kinetic energy of photoelectrons is given by = K_1

Final kinetic energy of photoelectrons is given by $K_2 = 2K_1$

Wavelength of light changes from λ_1 to λ_2

Let the threshold frequency is ν_0 and work function is ϕ_0

Now, we know that:-

$\frac{hc}{\lambda} = \phi_0 + KE$

$\frac{hc}{\lambda_1} = \phi_0 + K_1$ ...(i)

$\frac{hc}{\lambda_2} = \phi_0 + K_2$ ...(ii)

$K_2 = 2K_1$

$\frac{hc}{\lambda_2} = \phi_0 + 2K_1$ ...(iii)

$\frac{2hc}{\lambda_1} = 2\phi_0 + 2K_1$ (eq (i) $\times$ 2)

$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = \phi_0$

$\Rightarrow \phi_0 = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

We know

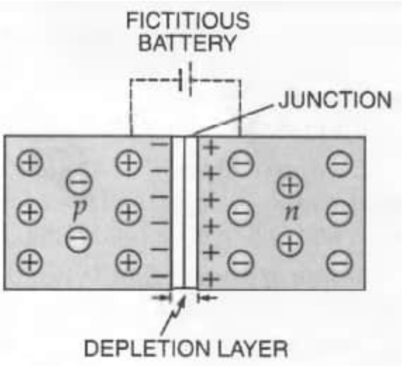
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$

$\frac{hc}{\lambda_0} = hc\left(\frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$

$\frac{1}{\lambda_0} = \frac{2\lambda_2 - \lambda_1}{\lambda_1\lambda_2}$

$\lambda_0 = \frac{\lambda_1\lambda_2}{2\lambda_2 - \lambda_1}$

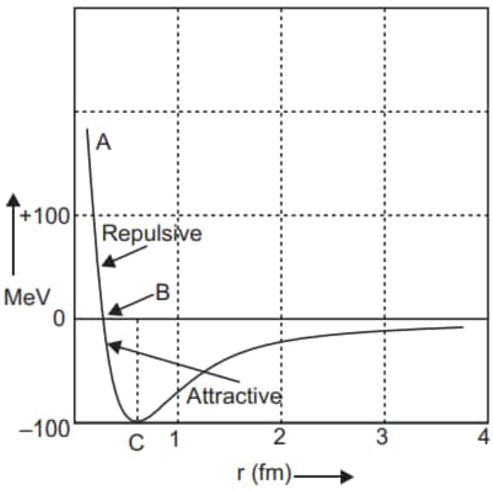
24. A p-n juntion is a basic semiconductor device.



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.

25. The following graph shows the variation of potential energy with the separation of nucleons



1. Part BC of the graph shows the attractive force.
2. Part AB of the graph shows the repulsive force.

The characterstic features of the nuclear force are as under:

1. Nuclear forces are attractive and stronger than the electrostatic force.
2. Nuclear forces are charge-independent and short range forces.

26. i. Energy of the ground state (n = 1) = – (ionization energy) = –13.6 eV

The wavelength of the incident radiation, $\lambda = 975\ \mathring{A}$

$\therefore$ The energy of the incident photon = hc/λ

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{975\times10^{-10}\times1.6\times10^{-19}}$ = 12.75 eV

Let electron is exerted to nth orbit,

$\Rightarrow$ 12.75 = 13.6 $\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$

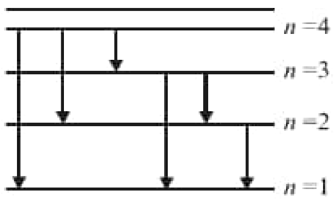
$\Rightarrow$ n = 4

The quantum transitions to the less excited states gives six possible lines as follows:

n = 4 : (4 $\to$ 3), (4 $\to$ 2), (4 $\to$ 1)

n = 3 : (3 $\to$ 2), (3 $\to$ 1)

n = 2 : (2 $\to$ 1)



ii. The longest wavelength emitted is for the transitions (4 $\to$ 3) where energy difference is minimum.

E_{min} = (E_4 - E_3) = 13.6 $\left(\frac{1}{3^2}-\frac{1}{4^2}\right)$ = 0.661 eV

Thus $\lambda_{max} = \frac{hc}{E_{min}}$

$= \frac{6.63\times10^{-34}\times3\times10^{8}}{0.661\times1.6\times10^{-19}}$m

$\approx 18807\ \mathring{A}$

27. Sound waves can propagate only through a medium. Thus, even though both the situations may correspond to the same relative motion (between the source and the observer), they are not identical physically since, the motion of the observer, relative to the medium is different in the two situations. Hence, we cannot expect Doppler formulas for sound to be identical for (a) and (b).

For light waves in vacuum, there is clearly nothing to distinguish between two cases given. Here only the relative motion between the source and the observer counts and the relativistic Doppler formula is the same for both

cases.

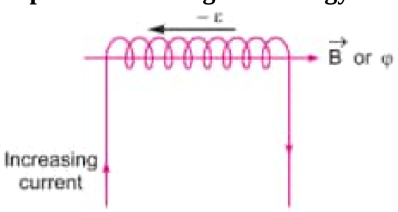
For light propagation in a medium, once again like for sound waves, the two situations are not identical and we should expect the Doppler formulas for this case to be different for the two situations (a) and (b).

28. Using formula, $|-\varepsilon| = L\frac{dI}{dt}$

If $\frac{dI}{dt} = 1$ A/s, then L = $|-\varepsilon|$

Self inductance of the coil is equal to the magnitude of induced emf produced in the coil itself when the current varies at rate 1 A/s.

Expression for magnetic energy:



When a time varying current flows through the coil, back emf $(-\varepsilon)$ produces, which opposes the growth of the current flow. It means some work needs to be done against induced emf in establishing a current I. This work done will be stored as magnetic potential energy.

For the current I at any instant, the rate of work done is

$\frac{dW}{dt} = (-\varepsilon)I$

Only for inductive effect of the coil $|-\varepsilon| = L\frac{dI}{dt}$

$\therefore \quad \frac{dW}{dt} = L\left(\frac{dI}{dt}\right)I \quad \Rightarrow dW = LIdI$

From work-energy theorem,

dU = LIdI

$\therefore U = \int_0^I LIdI = \frac{1}{2}LI^2$

OR

i. In the one revolution, change of area,
   $dA = \pi l^2$
   $\therefore$ 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) = {tex}\frac {d\phi}{dt} = \frac {Bπl^2}{T} = Bπl^2 \nu{/tex} ($\because \nu = \frac{1}{T}$)
   b. Induced current in the rod,
      $I = \frac{e}{R} = \frac{\pi\nu Bl^2}{R}$
      (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,
   $P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

Section D

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

Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(i) **(c)** less than visible light
Explanation:
Microwaves have frequency and energy smaller than visible light and wavelength larger than it.

(ii) **(d)** the energy of the random motion of atoms and molecules increases
Explanation:
When the energy of the random motion of atoms and molecules of a substance increases and the molecules travel or vibrate or rotate with higher energies, the substance becomes hot.

(iii) **(b)** 2.45 GHz
Explanation:
The frequency of rotation of water molecules is about 2.45 gigahertz.

OR

(d) Energy is directly delivered to water molecules which is shared by the entire food

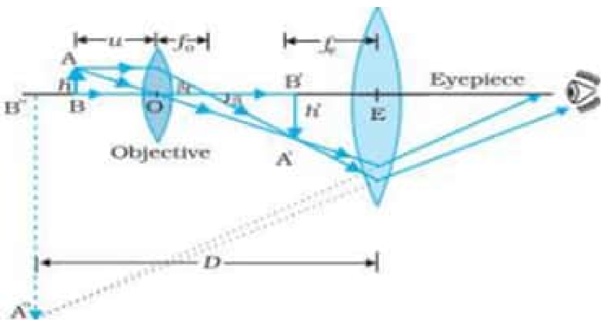
Explanation:
In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(iv) **(c)** Because of the danger of getting a shock from accumulated electric charges
Explanation:
One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies and thus cannot absorb microwaves. Hence, they do not get heated up.

30. i. 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. 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. In region II or between the plates, the electric field.
$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$
$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0\times10^{-22}}{8.85\times10^{-12}}$
$E = 1.9 \times 10^{-10}$ NC^{-1}
iv. 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.
v. 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. i.



Linear magnification due to the objective is
$\tan \beta = \left(\frac{h}{f_0}\right) = \left(\frac{h'}{L}\right)$
$m_0 = \frac{h'}{h} = \frac{L}{f_0}$
Here L is the distance between the second focal point of the objective and the first focal point of the eyepiece.
Linear magnification due to eyepiece is
$m_e = \left(1 + \frac{D}{f_e}\right)$
Thus, the total magnification is, $m = m_0 \times m_c$
$m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$
Hence the expression for the total magnification for the final image to be formed at the near point is $m = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$.

ii. Given:
$u_0 = -1.5$ cm
$f_0 = 1.25$ cm
$f_c = 5$ cm

D = 25 cm

$\frac{1}{f_0} = \frac{1}{v_0} - \frac{1}{u_0}$

$\frac{1}{v_0} = \frac{1}{1.25} - \frac{1}{1.5} = \frac{2}{15}$

$v_0 = \frac{15}{2}$ cm

$|m_0| = \frac{v_0}{u_0} = \frac{15}{2} \times \frac{1}{1.5} = 5$

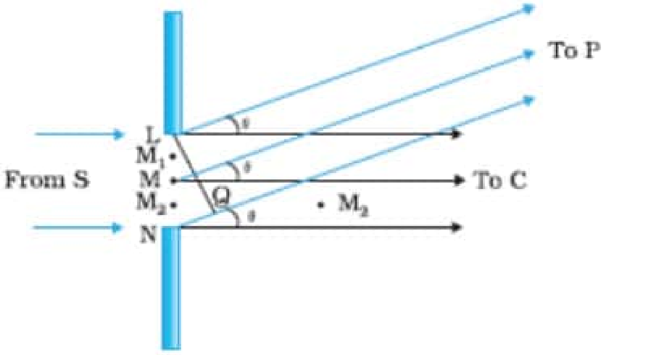
$|m_e| = \left(1 + \frac{D}{f_e}\right)$

$|m_e| = 1 + \frac{25}{5} = 6$

$m = m_0 \times m_c = 5 \times 6 = 30$

hence,the magnifying power of the microscope is 30

OR

a. 

From diagram path difference between the waves from L and N = a sinθ

When first minimum is obtained at P then path difference $= \lambda$

[imagine the slit be divided into two halves, for each wavelets from first half of the slit has a corresponding wavelet from second half of the slit differing by a path of $\frac{\lambda}{2}$ and cancel each other]

Condition for first minimum

$\therefore \lambda = a \sin \theta$

b. $\beta_{cm} = \frac{2\lambda D}{d}$

i. As we know that wave length (λ) of red light is more than yellow light.

$\therefore \lambda_{red} > \lambda_{yellow}$

So, $\therefore \beta_{red} > \beta_{yellow}$

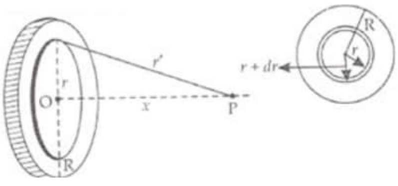
Hence, the linear width of the central maximum will increase if monochromatic yellow light is replaced with the red light.

ii. If the distance between the slit and screen (d) is increased then also the linear width of the central maximum will increase.

c. $10\frac{\lambda}{d} = 2\frac{\lambda}{a}$

$a = \frac{d}{5}$ = 0.2 mm

32. Consider a point P on the axis perpendicular to the plane of disc and at distance x from the center O of the disc as shown in the figure.



Now consider a ring of radius r of thickness dr on a disc of radius R, as shown in the figure, Let us consider disc is divided into a large number of rings, Again let the charge on the ring is dq then potential dV due to ring at P, will be

$dV = \frac{kdq}{r'} \left[\because r' = \sqrt{r^2 + x^2}\right]$

dq is the charge on the ring = σ area of ring

$= \sigma \cdot \left[\pi(r + dr)^2 - \pi r^2\right]$

$dq = \sigma \cdot \pi \left[r^2 + dr^2 + 2rdr - r^2\right]$

Because dr is small, therefore, dr_2 is negligible.

$\therefore dq = \sigma\pi(2rdr) = 2\pi r\sigma \cdot dr$

$\therefore dV = \frac{k.2\pi r\sigma dr}{\sqrt{(r^2+x^2)}}$

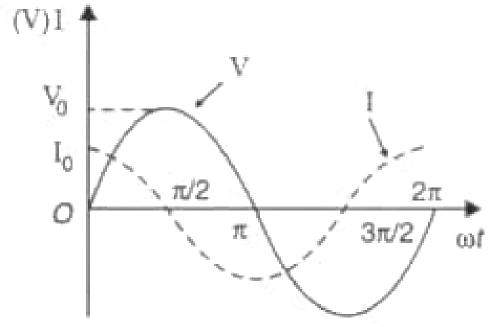
So the potential due to charged disc
$\int_0^V dV = \int_0^R \frac{k.2\pi\sigma dr}{\sqrt{r^2+x^2}}$
$V = k.2\pi\sigma \cdot \int_0^R \frac{rdr}{(r^2+x^2)^{12}} = k.\pi\sigma \int_0^R r \cdot (r^2+x^2)^{-1/2} 2dr$ = $\frac{k\pi\sigma[\sqrt{r^2+x^2}]_0^R}{1/2}$
$= 2\pi k\sigma \left[(R^2+x^2)^{1/2} - x\right] = \frac{2\pi\sigma}{4\pi\varepsilon_0}\left[(R^2+x^2)^{1/2} - x\right]$
[$\because$ $\pi R^2\sigma$ = Q(charge on disc) $\sigma = \frac{Q}{\pi R^2}$
$= \frac{\pi 2R^2\sigma}{4\pi\varepsilon_0 R^2}[\sqrt{R^2+x^2} - x]$ thus the potential due to a disc is given by,
$V = \frac{2Q}{4\pi\varepsilon_0 R^2}[\sqrt{R^2+x^2} - x]$

OR

a. Consider a parallel plate capacitor which is connected across a battery. The electrons are transferred from the negative terminal of the battery to the metallic plate connected to the negative terminal and acquires a negative charge. Similarly, the electrons move from the second plate to the positive terminal of the battery and acquire a positive charge. This process continues until the potential difference between the two plates becomes equal to the potential difference between the terminals of the battery. Thus, the charge is developed on the capacitor.
Let 'dW' be the work done by the battery in increasing the charge on the capacitor is given by, having the charge q and potential V is:
dW = V dq
where V = $\frac{q}{C}$
$\therefore$ dW = $\frac{q}{C}$dq
Total work done in charging up the capacitor is given by,
W = $\int$ dW = $\int_0^Q \frac{q}{c}$dq
$\therefore$ W = $\frac{Q^2}{2C}$
Hence total energy stored in the plates of the capacitor is given by, W = $\frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$

b. Charge on the plates of the capacitor is given by q = CV
When uncharged capacitor of same capacitance is connected to the charged capacitor, sharing of charges takes place between the two capacitors till both the capacitors acquire same potential $\frac{V}{2}$
Energy stored in the combination of capacitors is given by,
$U_2 = \frac{1}{2}C(\frac{V}{2})^2 + \frac{1}{2}C(\frac{V}{2})^2 = \frac{CV^2}{4}$
Energy stored by a single capacitor before connecting is given by, $U_1 = \frac{1}{2}CV^2$
Ratio of energy stored in the combination to that in the single capacitor is given by,
$\frac{U_2}{U_1} = \frac{CV^2/4}{CV^2/2}$ = 1 : 2 , Hence these are required results.

33. i. V = $V_0 \sin \omega t$, V = $\frac{Q}{C}$
A.C. source containing capacitor: Let a source of alternating e.m.f. $V=V_m\sin\omega t$ be connected to a capacitor of capacitance C only.
$l = \frac{dQ}{dt}$
$I_0 = \frac{V_0}{\left(\frac{1}{\omega C}\right)}$
I = $I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$



ii. $X_C = \frac{1}{2\pi fC}$ = 212.3 Ω

$Z = \sqrt{R^2 + X_C^2}$ = 291.5 Ω

$I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{291.5}$ = 0.755 A

V_R (rms) = 151 V

V_C (rms) = 160.3 V

Two voltages are out of phase, hence they are added vectorially.

OR

i. Device X is a capacitor.

As the current is leading voltage by $\frac{\pi}{2}$ radians and it happens only then when an ac source is connected with a pure capacitive circuit.

ii. Curve A represents power, Curve B represents voltage and Curve C represents current.

As, V(t) = $V_0 \sin \omega t$

Current, I(t) = $I_0 \cos \omega t$, with $I_0 = \frac{V_0}{X_C}$ (X_C being capacitive reactance)

As, in the case of capacitor,

$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ [current is leading the voltage]

Average power, $P = V(t)I(t) = \frac{V_0 I_0}{2} \cos\phi$

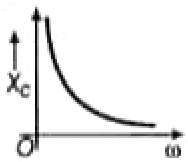
where, ϕ = phase difference

iii. As, X_C = capacitive reactance = $\frac{1}{C\omega}$

where ω is angular frequency and C being capacitance of the capacitor.

So, reactance or impedance decreases with increase in frequency.

Graph of X_C versus ω is shown below:



iv. For a capacitor fed with an AC supply,

$V = \frac{q}{C}$ or $q = CV = CV_0 \sin \omega t$

$\therefore \quad I = \frac{dq}{dt} = V_0 \omega C \cos \omega t = \frac{V_0}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right)$, since $\omega C = \frac{1}{X_C}$