Class XII Session 2025-26
Subject - Physics
Sample Question Paper - 5

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 resistivity of a semiconductor at room temperature is in between: **[1]**

a) 10^6 to 10^8 Ω cm
b) 10^{10} to 10^{12} Ω cm
c) 10^{-2} to 10^{-5} Ω cm
d) 10^{-3} to 10^6 Ω cm

2. In a Wheatstone's bridge, all the four arms have equal resistance R. If the resistance of the galvanometer arm is also R, the equivalent resistance of the combination as seen by the battery is: **[1]**

a) $\frac{R}{2}$
b) R
c) $\frac{R}{4}$
d) 2R

3. A converging lens is used to form an image on a screen. When the upper half of the lens is covered by an opaque screen, then **[1]**

a) half the image will disappear
b) no image will be formed
c) intensity of the image will increase
d) complete image will be formed

4. The ratio of magnetic fields due to a small bar magnet in the end on position to the broad side on position is **[1]**

a) 1 : 4
b) 1 : 2
c) 2 : 1
d) 1 : 1

5. A parallel plate capacitor of 1 μF capacity is discharging through a resistor. If its energy reduces to half in one **[1]**

second, the value of resistance will be:

a) $\frac{16}{\ln(2)}\mathrm{M}\Omega$
b) $\frac{4}{\ln(2)}\mathrm{M}\Omega$
c) $\frac{2}{\ln(2)}\mathrm{M}\Omega$
d) $\frac{9}{\ln(2)}\mathrm{M}\Omega$

6. An electron with velocity $\vec{v} = \left(v_x\hat{i} + v_y\hat{j}\right)$ moves through a magnetic field $\vec{B} = \left(B_x\hat{i} - B_y\hat{j}\right)$. The force $\vec{\mathrm{F}}$ on the electron is : (e is the magnitude of its charge) **[1]**

a) $e\left(v_xB_y - v_yB_x\right)\hat{k}$
b) $e\left(v_xB_y + v_yB_x\right)\hat{k}$
c) $-e\left(v_xB_y + v_yB_x\right)\hat{k}$
d) $-e\left(v_xB_y - v_yB_x\right)\hat{k}$

7. When a coil is joined to a cell, current grows with a time constant τ. The current will reach 10% of it's steady-state value in time **[1]**

a) 2τ
b) $\tau\ln(0.9)$
c) τ
d) $\tau\ln(10/9)$

8. Which one of the following has negative value of susceptibility? **[1]**

a) Iron
b) Aluminium
c) Lead
d) Nickel

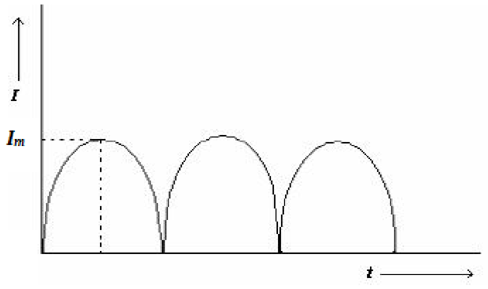
9. Two coherent monochromatic light beams of intensities I and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are **[1]**

a) 5I and 3I
b) 9I and 2I
c) 5I and I
d) 9I and I

10. If an electron has an initial velocity in a direction different from that of an electric field, then the path of the electron is $(\theta \neq 180^\circ)$ **[1]**

a) a circle
b) a parabola
c) an ellipse
d) a straight

11. The output current I versus time (t) curve of a full wave rectifier is shown in the figure. The average value of the output current in this case is **[1]**



a) I_m
b) Zero
c) $\frac{2I_m}{\pi}$
d) $\frac{I_m}{\pi}$

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

a) Become zero
b) Become infinite
c) Remain same as in air
d) Reduce

13. **Assertion (A):** Photoelectric process is instantaneous process. **[1]**

Reason (R): When photons of energy (hv) greater than work function of metal (ϕ_0) are incident on a metal, the electrons from metal are emitted with no time lag.

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):** A capacitor can be given only a limited amount of charge. **[1]**

Reason (R): After a limited value of charge, the dielectric strength of dielectric between the capacitor plates breaks down.

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):** Skiers use air glasses. **[1]**

Reason (R): Light reflected by snow is partially polarised.

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):** Series L-C-R circuit is a **voltage magnifier**. **[1]**

Reason (R): In series L-C-R circuit at resonance voltage drop across inductance ((or capacitance) is Q (quality factor) times the applied voltage.

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. The magnetic field in a plane electromagnetic wave is given by $B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$. Calculate the **[2]**

i. Energy density associated with the Electromagnetic waves
ii. Speed of the wave.

18. The hysteresis loss for a specimen of iron weighing 12 kg is equivalent to 300 Jm^{-3} $cycle^{-1}$. Find the loss of energy per hour at 50 cycle s^{-1}. Density of iron is 7500 kg m^{-3}. **[2]**

OR

An iron sample having mass 8.4 kg is repeatedly taken over cycles of magnetisation and demagnetisation at a frequency of 50 cycles s^{-1}. It is found that 3.2×10^4 J of energy is dissipated as heat in the sample in 30 minutes. Find the energy dissipated per unit volume per cycle in the iron sample. Density of iron = 7200 kg m^{-3}.

19. A semiconductor has the electron concentration of 8×10^{13} cm^{-3} and hole concentration of 4×10^{13} cm^{-3}. Is the semiconductor p-type or n-type? Also calculate the resistivity of this semiconductor. Given electron mobility = 24,000 cm^2 V^{-1} s^{-1} and hole mobility = 200 cm^2 V^{-1} s^{-1}. **[2]**

20. a. Differentiate between **impact parameter** and **distance of closest approach** in alpha particle scattering **[2]**

experiment. Identify, situations when impact parameter is (i) minimum, and (ii) very large.

b. An electron cannot revolve around the nucleus in a hydrogen atom at an arbitrary distance. Explain.

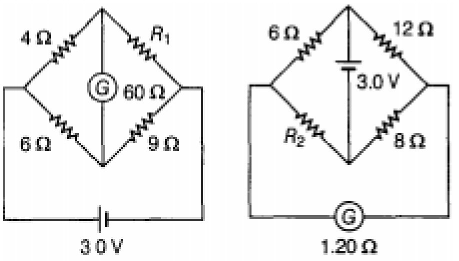
21. State the condition under which a charged particle moving with velocity v goes undeflected in a magnetic field B. **[2]**

Section C

22. Define the current sensitivity of a galvanometer. Write its SI unit. **[3]**

Figure shows two circuits each having a galvanometer and a battery of 3 V.

When the galvanometer in each arrangement do not show any deflection, obtain the ratio R_1/R_2.



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. Draw the energy band diagram of a p-type semiconductor. Deduce an expression for the conductivity of a p-type semiconductor. **[3]**

25. Distinguish between nuclear fission and fusion. Show how in both these processes energy is released. Calculate the energy release in MeV in the deuterium-tritium fusion reaction: ${}_1^2H+{}_1^3H\rightarrow{}_2^4He+_0n^1$ **[3]**

Using the data:

$m\left({}_1^2H\right)$ = 2.014102 u

$m\left({}_1^3H\right)$ = 3.016049 u

$m\left({}_2^4He\right)$ = = 4.002603 u

m_n = 1.008665 u

1amu = 931.5 $\frac{MeV}{c^2}$

26. It is found experimentally that 13.6 eV energy is required to separate a hydrogen atom into a proton and an electron. Compute the orbital radius and the velocity of the electron in a hydrogen atom. **[3]**

27. In a diffraction pattern due to a single slit, how will the angular width of central maximum change, if **[3]**

a. Orange light is used in place of green light,

b. the screen is moved closer to the slit,

c. the slit width is decreased?

Justify your answer in each case.

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

i. Derive the expression for the induced emf and the current in the rod.

ii. Due to the presence of the current in the rod and of the magnetic field, find the expression for the magnitude and direction of the force acting on this rod.

iii. Hence obtain the expression for the power required to rotate the rod.

OR

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.

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.

(a) 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) $\vec{B} \times \vec{E}$

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

(b) Fundamental particle in an electromagnetic wave is

a) proton b) photon

c) phonon d) electron

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

a) polarisation b) diffraction

c) reflection d) interference

OR

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

a) wavelength b) all these depend on each other

c) velocity d) frequency

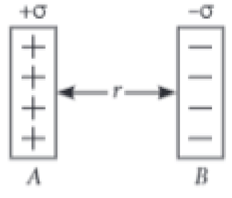
(d) The electric and magnetic fields of an electromagnetic waves are

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

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

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. a. With the help of a labelled ray diagram, explain the construction and working of a Cassegrain reflecting telescope. **[5]**

b. An amateur astronomer wishes to estimate roughly the size of the Sun using his crude telescope consisting of an objective lens of focal length 200 cm and an eyepiece of focal length 10 cm. By adjusting the distance of the eyepiece from the objective, he obtains an image of the Sun on a screen 40 cm behind the eyepiece. The diameter of the Sun's image is measured to be 6.0 cm. Estimate the Sun's size, given that the average Earth-Sun distance is 1.5×10^{11} m.

OR

a. Sketch the refracted wavefront for the incident plane wavefront of light from a distant object passing through a convex lens.
b. Using Huygens' principle, verify the laws of refraction when light from a denser medium is incident on a rarer medium.
c. For yellow light of wavelength 590 nm incident on a glass slab, the refractive index of glass is 1.5. Estimate the speed and wavelength of yellow light inside the glass slab.

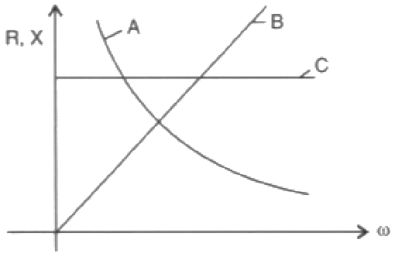
32. Derive an expression for the electric potential at a point due to an electric dipole. Mention the contrasting features of electric potential of a dipole at a point as compared to that due to a single charge. **[5]**

OR

Derive an expression for equivalent capacitance of three capacitors when connected

i. in series and
ii. in parallel.

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. Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.

ii. A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy? Explain.

iii. A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate:

1. The output voltage across the secondary coil
2. The current in the primary coil if the current in the secondary coil is 2.0 A.

Solution

Section A

1.

(d) 10^{-3} to 10^{6} Ω cm

Explanation:

Resistivity of a semiconductor at room temp, is in between 10^{-3} to 10^{6} Ω cm.

2.

(b) R

Explanation:

In the balanced condition, the resistance R of the galvanometer is ineffective. We now have (R + R) and (R + R) resistances in parallel.

$\therefore R_\alpha = \frac{2R \times 2R}{2R + 2R}$ = R

3.

(d) complete image will be formed

Explanation:

Image formed will be complete when upper half of lens is blocked. Intensity of the image will decrease as the incident rays from upper half are cut off.

4.

(c) 2 : 1

Explanation:

2 : 1

5.

(c) $\frac{2}{\ln(2)}\mathrm{M}\Omega$

Explanation:

$U = \frac{q_0^2}{2C}$

At t = 1 s, energy reduces to half, so

$q = \frac{q_0}{\sqrt{2}}$

Now $q = q_0 e^{-\frac{t}{\tau}}$

$\therefore \frac{q_0}{\sqrt{2}} = q_0 e^{-1}$

$\Rightarrow e^{\frac{1}{t}} = \sqrt{2} \Rightarrow \frac{1}{\tau} = \ln(\sqrt{2})$

$\Rightarrow \tau = \frac{2}{\ln(2)}$

$\Rightarrow RC = \frac{2}{\ln(2)}$

$R = \frac{2}{\mathrm{C}\ln(2)} = \frac{2}{10^{-6}\ln(2)}\Omega = \frac{2}{\ln(2)}\mathrm{M}\Omega$

6. **(a)** $e\left(v_x B_y - v_y B_x\right)\hat{k}$

Explanation:

$e\left(v_x B_y - v_y B_x\right)\hat{k}$

7.

(d) $\tau \ln(10/9)$

Explanation:

$I = I_0\left(1 - e^{\frac{-t}{\tau}}\right)$
and $I = 0.1I_0$
$e^{\frac{-t}{\tau}} = \frac{9}{10}$
$\frac{t}{\tau} = \ln\frac{10}{9}$
$t = \tau\ln\frac{10}{9}$

8.
(c) Lead
Explanation:
as Lead is diamagnetic substance.

9.
(d) 9I and I
Explanation:
$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$
I_1 = I, I_2 = 4I
On putting these values,
$I_{max} = (\sqrt{I} + \sqrt{4I})^2$
I_{max} = 9I
$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$
$I_{min} = (\sqrt{I} - \sqrt{4I})^2$
I_{min} = I

10.
(b) a parabola
Explanation:
The path of an electron in an electric field is determined by the forces acting on it. When an electron has an initial velocity that is not aligned with the electric field, it experiences a force due to the electric field that changes its direction of motion. This results in a curved trajectory. The combination of the initial velocity and the constant acceleration from the electric field leads to a parabolic path, similar to the motion of a projectile under gravity. Thus, the correct answer is that the path of the electron is a parabola.

11.
(c) $\frac{2I_m}{\pi}$
Explanation:
Current waveform can be represented as, $I = I_m sin\omega t$ for $0 \leq \omega t \leq 2\pi$, where I_m = max load current
Average current, $I_{DC} = \frac{I_m}{\pi}\int_0^{\pi}\sin(\omega t)\,\mathrm{d}(\omega t)$
$= \frac{I_m}{\pi}[-cos(\omega t)]_0^{\pi} = \frac{2I_m}{\pi}$

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

13. **(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.

14. **(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.

15.

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

Explanation:

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

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

Explanation:

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

Section B

17. Given:

i. Magnetic field in plane electromagnetic wave $B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$

Now $B_0 = 12 \times 10^{-8}$T

Speed of light $c = 3 \times 10^8$ m/s

From the relation: $E_0 = B_0 c$

$= 12 \times 10^{-8} \times 3 \times 10^8$

$E_0 = 36$ V/m

Now Energy Density can be calculated using:

Energy Density of the electromagnetic waves = $\frac{1}{2}\varepsilon_0 E_0^2$

Energy Density of the electromagnetic waves= $\frac{1}{2} \times \left(8.85 \times 10^{-12}\right) \times (36)^2$

Energy Density of electromagnetic waves = 5.74×10^{-15} J/m^3

ii. Magnetic field in plane electromagnetic wave

$B_y = 12 \times 10^{-8} \sin(1.20 \times 10^7 z + 3.60 \times 10^{15} t)$

Now $k = 1.2 \times 10^7$

$\omega = 3.6 \times 10^{15}$

Since, $\lambda = \frac{2\pi}{k}$ and $f = \frac{\omega}{2\pi}$

Hence the speed of wave: $v = \lambda \times f$

$= \frac{\omega}{k} = 3 \times 10^8 \mathrm{m/s}$

18. Let Q be the energy dissipated per unit volume per hysteresis cycle in the given sample. Then the total energy lost by the volume V of the sample in time t will be

$W = Q \times V \times \nu \times t$

where v is the number of hysteresis cycles per second.

Here $Q = 300$ Jm^{-3} cycle^{-1}, $\nu = 50$ cycle s^{-1}, t = 1 h = 3600s

Volume, $V = \frac{\text{Mass}}{\text{Density}} = \frac{12}{7500}$ m^3

$\therefore$ Hysteresis loss,

$W = 300 \times \frac{12}{7500} \times 50 \times 3600$ J = 86400 J

OR

Here $W = 3.2 \times 10^4$ J, v = 50 cycle s^{-1}, t = 30 min = 1800 s

Volume, $V = \frac{\text{Mass}}{\text{Density}} = \frac{8.4}{7200}$ = kg m^{-3}

Energy dissipated per unit volume per cycle,

$Q = \frac{W}{V \times v \times t} = \frac{3.2 \times 10^4 \times 7200}{8.4 \times 50 \times 1800}$

= 304.8 Jm^{-3} cycle^{-1}

19. Since $n_e > n_h$, the semiconductor is n-type. The conductivity of the semi conductor is $e(n_e\mu_e + n_h\mu_h)$

$= 1.6 \times 10^{19}((8 \times 10^{13})(24000) + (4 \times 10^{13})(200))$mho/cm

$= 0.32$ mho cm^{-1}

$=320$ m mho cm^{-1}

20. a. Impact parameter is the perpendicular distance of the initial velocity vector of the α – particle from the centre of the nucleus.
    Distance of closest approach: It is the minimum distance between the projected α – particle and the nucleus of target atom at which the kinetic energy of the α – particle becomes equal to potential energy of α-particle in the field of nucleus.
    Minimum: When α-particle rebounds back $(\theta = \pi)$
    Very large: when α-particle goes nearly undeviated and has a small deflection $(\theta = 0^o)$
    b. According to Bohr's second postulate electron revolves only in those orbit for which angular momentum is $\frac{nh}{2\pi}$.
21. Force on a charge moving parallel or antiparallel to the direction of the magnetic field is zero $F = qvB\sin\theta$

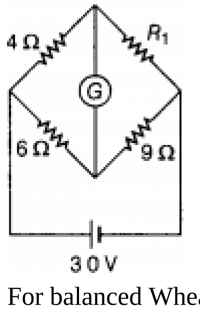
for (0^o or 180^o)

$\sin\theta = 0$

So Force =0

Section C

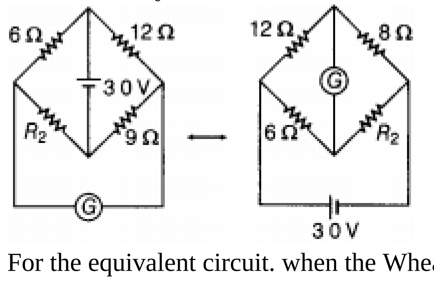
22. Current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer when a unit current flows through it. The SI unit of current sensitivity is rad. A^{-1}. Current sensitivity is expressed as $\frac{\theta}{I} = \frac{NAB}{K}$ where N, A, B and K are number of turns, cross-sectional area, magnetic field intensity and galvanometer's constant respectively.



For balanced Wheatstone bridge, there will be no deflection in the galvanometer.

$\therefore \frac{4}{R_1} = \frac{6}{9}$

$\Rightarrow \quad R_1 = \frac{4\times9}{6} = 6\Omega$



For the equivalent circuit. when the Wheatstone bridge is balanced, there will be no deflection in the galvanometer.

$\therefore \quad \frac{12}{8} = \frac{6}{R_2}$

$\Rightarrow \quad R_2 = \frac{6\times8}{12} = 4\Omega$

$\therefore \quad \frac{R_1}{R_2} = \frac{6}{4} = \frac{3}{2}$

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

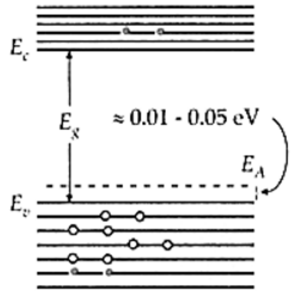
work function is given by $\phi_0 = \frac{hc}{\lambda_0}$

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

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

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

24. For energy band diagram,



The expression for the conductivity of a p-type semiconductor: A p-type semiconductor has holes as the majority charge carriers.

$\therefore$ I = $I_h = en_hAv_h$

Also R = $\rho\frac{l}{A}$

$\therefore$ V = RI = $\rho\frac{l}{A}\cdot en_hAv_h$

E = $\frac{V}{l} = \rho en_hv_h = \rho en_h\cdot\mu_hE$ $[\because \mu_h = \frac{v_h}{E}]$

$\therefore$ Conductivity, $\rho = \frac{1}{\rho} = en_h\mu_h$

25. Nuclear fission is a process of splitting of a heavier nucleus into two lighter nuclei. It generally occurs in elements of high atomic mass.

Nuclear fusion is a process of a combination of two light nuclei to form heavier nuclei. It generally occurs in elements of low atomic mass. This process releases a tremendous amount of energy because some mass is converted into energy.

In both processes, the total mass of the products is slightly less than the mass of the original nuclei. This difference in mass is converted to energy.

In the given problem, mass defect is

Δm = 2.014102 + 3.016049 - 4.002603 - 1.008665

Δm = 0.018883 u

Energy released, $\Delta E = \Delta mc^2$

ΔE = 0.018883 $\times$ 931.5 = 17.589 MeV

26. Total energy of the electron in hydrogen atom is –13.6 eV = –13.6 $\times$ 1.6 $\times$ 10^{-19} J = –2.2 $\times 10^{-18}$ J.

Thus from Eq., we have

$-\frac{e^2}{8\pi\varepsilon_0 r}$ = E

This gives the orbital radius

$$r = -\frac{e^2}{8\pi\varepsilon_0 E} = -\frac{\left(9\times10^9\mathrm{Nm}^2/\mathrm{C}^2\right)\left(1.6\times10^{-19}\mathrm{C}\right)^2}{(2)\left(-2.2\times10^{-18}\mathrm{J}\right)}$$

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

The velocity of the revolving electron can be computed from Eq. with m = 9.1 $\times$ 10^{-31} kg,

$\frac{1}{2}mv^2 = \frac{e^2}{4\pi\epsilon_0 r^2}$ thus velocity of electron is given by :-

$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr^2}} = 2.2\times10^6\mathrm{m/s}$

27. angular width of central maxima of a single slit diffraction is given as $2\theta = \frac{2\lambda}{a}$

   a. As λ increases (orange light has greater wave length) diffraction angle 2θ will also increase.
   b. Increasing or decreasing closeness of screen and slit does not affect angular width.
   c. If a (slit width) decreases, 2θ will increase as $2\theta\propto\frac{1}{a}$

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

   $dA = \pi l^2$

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

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

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

If period of revolution is T,

a. Induced emf (e) = {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,

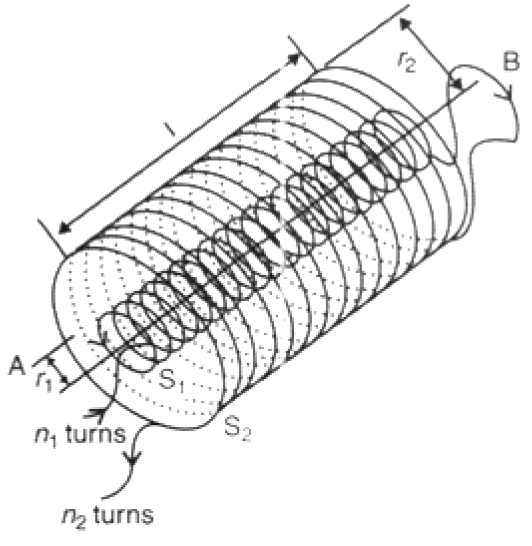
$P = \vec{F}.\vec{v} = Fvcos0^0 = \frac{\pi\nu B^2 l^3 v}{R}$

OR

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

∴ $B_2 = \frac{\mu_0 N_2 i_2}{l}$

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

= $M_{12}i_2$

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

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

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) **(d)** $\vec{E} \times \vec{B}$

Explanation:

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

(ii) **(b)** photon

Explanation:

Photon is the fundamental particle in an electromagnetic wave.

(iii) **(a)** polarisation

Explanation:

Polarisation establishes the wave nature of electromagnetic waves.

OR

(d) frequency

Explanation:

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

(iv) **(b)** 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. 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.

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

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

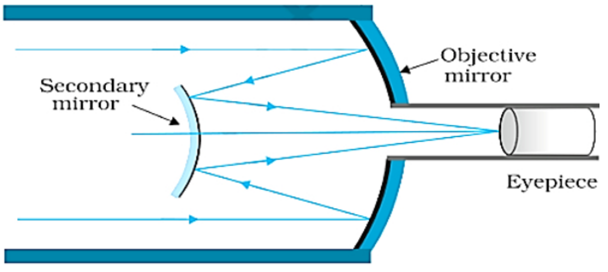
$E = 1.9 \times 10^{-10}$ NC^{-1}

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. a.



It consists for large concave (primary) paraboidal mirror having in its central part a hole. There is a small convex (secondary) mirror near the focus of concave mirror. Eye pieces if placed near the hole of the concave mirror.

The parallel rays from distance object are reflected by the large concave mirror. These rays fall on the convex mirror which reflects these rays outside the hole. The final magnified image in formed.

b. For eyepiece.

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

or $\frac{1}{u_e} = \frac{1}{v_e} - \frac{1}{f_e} = \frac{1}{40} - \frac{1}{10}$

$u_e = \frac{40}{3}$ cm

Magnification produced by eye pieces is

$m_e = \frac{v_e}{|u_e|} = \frac{40}{\frac{40}{3}} = 3$

Diameter of the image formed by the objective is

$d = \frac{6}{3} = 2$ cm

If D be the diameter of the SUN then the angle subtended by it on the objective will be

$\alpha = \frac{D}{1.5 \times 10^{11}} \text{rad}$

Angle subtended by the image at the objective

= angle subtended by the SUN

$\therefore \alpha = \frac{\text{size of image}}{f_o} = \frac{2}{200} = \frac{1}{100} \text{rad}$.

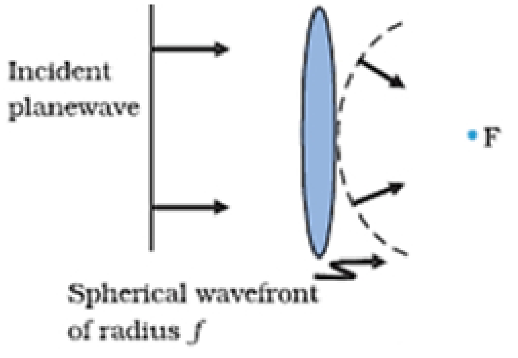
$\therefore \frac{D}{1.5 \times 10^{11}} = \frac{1}{100}$

or

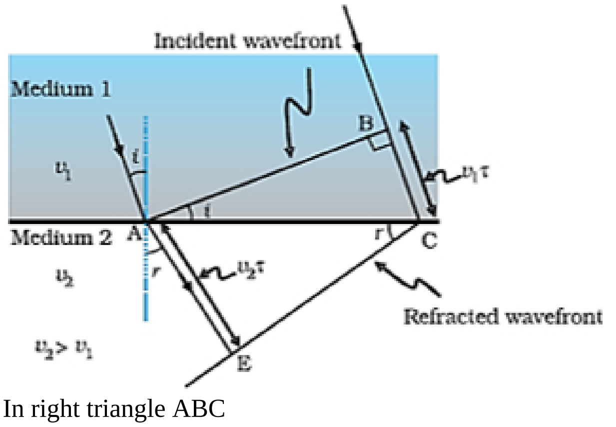
D = 1.5 $\times$ 10^9 m

OR

a.



b.



In right triangle ABC

$\sin i = \frac{BC}{AC}$

In $\triangle AEC$ $\sin r = \frac{AE}{AC}$

$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 \tau}{v_2 \tau} = \frac{v_1}{v_2} = \mu$

c. Speed of yellow light inside the glass slab

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

$= \frac{3 \times 10^8}{1.5}$ m/s

$= 2 \times 10^8$ m/s

Wavelength of yellow light inside the glass slab

$\lambda' = \frac{\lambda}{\mu}$

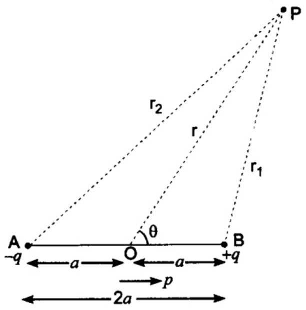
$= \frac{590}{1.5}$ nm

= 393.33 nm

32. Consider an electric dipole having charges -q and +q at separation '2a'. The dipole moment of dipole is $\vec{p} = q(\overrightarrow{2a})$, directed from -q to +q.

The electric potential due to dipole is the algebraic sum of potentials due to charges +q to -q

If r_1 and r_2 are distances of any point P from charge +q to -q respectively as shown in the figure, then the potential due to electric dipole at point P, is



$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0}\frac{q}{r_2} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$ ...(i)

If (r, θ) are polar coordinates of point P with respect to mid-point O of dipole, then

By geometry,

$r_1^2 = r^2 + a^2 - 2ar\cos\theta$ ...(ii)

and, $r_2^2 = r^2 + a^2 - 2ar\cos\theta$ ...(iii)

From (ii), $r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r} + \frac{a^2}{r^2}\right]$

If r >> a i e.,$\frac{a}{r}$ <<1, then it is sufficient to retain terms only upto first order in $\left(\frac{a}{r}\right)$.

$\therefore r_1^2 = r^2\left[1 - \frac{2a\cos\theta}{r}\right] \Rightarrow r_1 = r\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(iv)

Similarly from (iii), ${r_2}^2 = r^2\left[1 + \frac{2a\cos\theta}{r}\right] \Rightarrow r_2 = r\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{1}{2}}$ ...(v)

From (iv) and (v), $\frac{1}{r_1} = \frac{1}{r}\left[1 - \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$ and, $\frac{1}{r_2} = \frac{1}{r}\left[1 + \frac{2a\cos\theta}{r}\right]^{\frac{-1}{2}}$

Using binomial theorem and retaining terms upto first order in $\left(\frac{a}{r}\right)$ only, we have

$\frac{1}{r_1} = \frac{1}{r}\left[1 - \left(-\frac{1}{2}\right)\frac{2a\cos\theta}{r}\right] = \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta\right]$ ...(vi)

and, $\frac{1}{r_2} = \frac{1}{r}\left[1 - \frac{a}{r}\cos\theta\right]$ ...(vii)

Substituting these values in (i), we get

$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) - \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right)\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[1 + \frac{a}{r}\cos\theta - 1 + \frac{a}{r}\cos\theta\right]$

$= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}\left[\frac{2a}{r}\cos\theta\right] = \frac{1}{4\pi\varepsilon_0}\frac{(q\cdot 2a)\cos\theta}{r^2}$

or, $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$ ...(viii)

But, $p\cos\theta = \vec{p}\cdot\hat{r}$ where, $\hat{r}$ is unit vector along position vector $\vec{OP} = \vec{r}$.

Electric potential due to an electric dipole is

$V = \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$ (for r >> a) $= \frac{1}{4\pi\epsilon_0}\frac{\vec{p}\cdot\vec{r}}{r^3}$ ...(ix)

Contrasting features: The electric potential due to a dipole depends on distance r and also on the angle between position vector $\vec{r}$ and dipole moment $\vec{p}$. The electrostatic potential at large distances falls off, as $\frac{1}{r^2}$ and not as $\frac{1}{r}$ which is the characteristic of potential due to a single charge.

Special Cases:

i. When point P lies on the axis of dipole, then θ = 0^o

$\therefore$ cos θ = cos 0 = 1

$\therefore V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

ii. When point P lies on the equatorial plane of the dipole, then

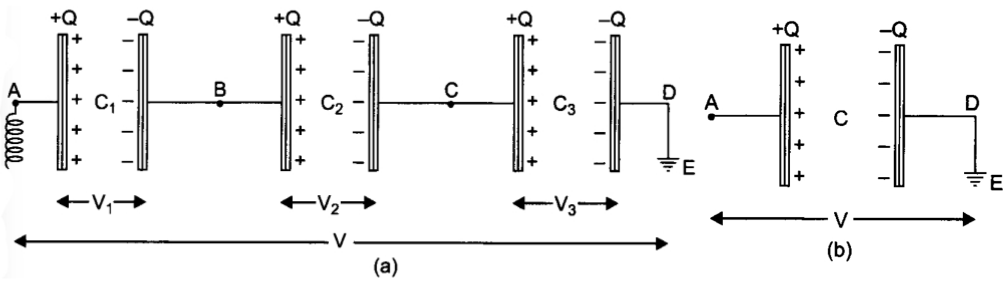
$\therefore$ cos θ = cos 90^o = 0

$\therefore$ V = 0

It may be noted that the electric potential at any point on the equitorial line of a dipole is zero.

OR

i. In fig. (a) three capacitors of capacitances C_1, C_2, C_3 are connected in series between points A and D.



In series first plate of each capacitor has charge +Q and second plate of each capacitor has charge -Q i.e., charge on each capacitor is Q.

Let the potential differences across the capacitors C_1, C_2, C_3 be V_1, V_2, V_3 respectively. As the second plate of first capacitor C_1 and first plate of second capacitor C_2 are connected together, their potentials are equal. Let this common potential be V_B. Similarly the common potential of second plate of C_2 and first plate of C_3 is V_C. The second plate of capacitor C_3 is connected to earth, therefore its potential $V_D = 0$. As charge flows from higher potential to lower potential, therefore $V_A > V_B > V_C > V_D$.

For the first capacitor, $V_1 = V_A - V_B = \frac{Q}{C_1}$ ...(i)

For the second capacitor, $V_2 = V_B - V_C = \frac{Q}{C_2}$ ...(ii)

For the third capacitor, $V_3 = V_C - V_D = \frac{Q}{C_3}$ ...(iii)

Adding (i), (ii) and (iii), we get

$V_1 + V_2 + V_3 = V_A - V_D = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(iv)

If V be the potential difference between A and D, then

$V_A - V_D = V$

$\therefore$ From (iv), we get

$V = (V_1 + V_2 + V_3) = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ ...(v)

If in place of all the three capacitors, only one capacitor is placed between A and D such that on giving it charge Q, the potential difference between its plates become V, then it will be called **equivalent capacitor**. If its capacitance is C, then

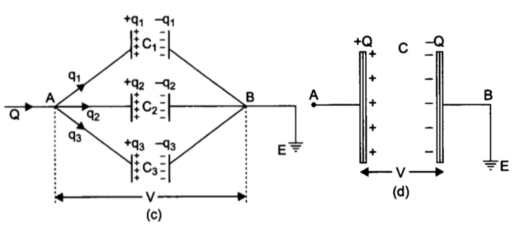
$V = \frac{Q}{C}$ ...(vi)

Comparing (v) and (vi), we get

$\frac{Q}{C} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$ or $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...(vii)

Thus in series arrangement, "The reciprocal of equivalent capacitance is equal to the sum of the reciprocals of the individual capacitors."

ii. **Parallel Arrangement:** In fig. (c) three capacitors of capacitance C_1, C_2, C_3 are connected in parallel.



In parallel the potential difference across each capacitor is same V (say). Clearly the potential difference between plates of each capacitor

$V_A - V_B = V$ (say)

The charge Q given to capacitors is divided on capacitors C_1, C_2, C_3.

Let q_1, q_2, q_3 be the charges on capacitors C_1, C_2, C_3 respectively.

Then $Q = q_1 + q_2 + q_3$ ...(I)

and $q_1 = C_1V, q_2 = C_2V, q_3 = C_3V$

Substituting these values in (i), we get

$Q = C_1V + C_2V + C_3V$ or $Q = (C_1 + C_2 + C_3)V$ ...(ii)

If, in place of all the three capacitors, only one capacitor of capacitance C be connected between A and B; such that on giving it charge Q the potential difference between its plates be V, then it will be called equivalent capacitor. If C be the capacitance of equivalent capacitor, then

Q = CV ...(iii)

Comparing equations (ii) and (iii), we get

$CV = (C_1 + C_2 + C_3)V$ or $C = (C_1 + C_2 + C_3)$

Important Note: It may be noted carefully that the formula for the total capacitance in series and parallel combination of capacitors is the reverse of corresponding formula for combination of resistors in current electricity.

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,

$X_L = X_C$

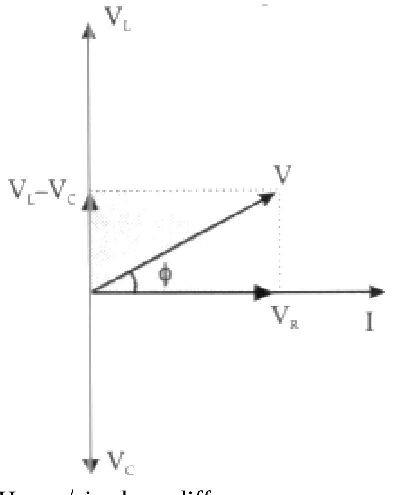
Therefore, impedance is given as:

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

Z = R

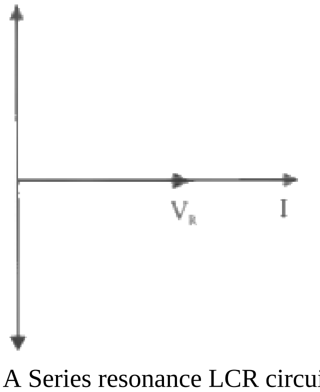
Thus, a series LCR circuit at resonance behaves as a purely resistive circuit.

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:

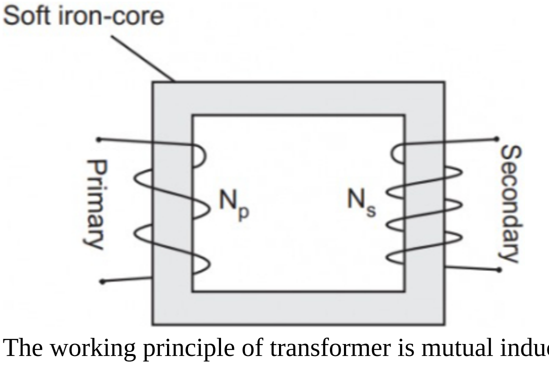


iii. A Series resonance LCR circuit is called an acceptor circuit.

They are widely used in the tuning mechanism of a radio or a TV.

OR

i.



The working principle of transformer is mutual induction.

When an alternating voltage is applied to the primary, the resulting current produces an alternating magnetic flux which links the secondary and induces an emf in it.

Causes of energy losses

a. **Copper Losses (I^2R Losses):**
Explanation: These losses occur due to the resistance of the wire in the coils. When current flows through the wire, some energy is dissipated as heat due to the resistance.
Mitigation: Using thicker wires with lower resistance and cooling mechanisms can help reduce these losses.

b. **Core Losses (Iron Losses):**
Explanation: Core losses include hysteresis loss and eddy current loss. Hysteresis loss occurs due to the lagging of magnetic domains behind the changing magnetic field. Eddy current loss is caused by circulating currents induced within the core material due to the changing magnetic field.
Mitigation: Using laminated silicon steel cores reduces eddy currents, and using materials with low hysteresis loss minimizes core losses.

c. **Leakage Flux:**
Explanation: Not all magnetic flux produced by the primary coil links with the secondary coil. Some flux "leaks" and does not contribute to energy transfer between coils, leading to inefficiency.
Mitigation: Improving core design and using better core materials can help reduce leakage flux.

ii. A step-up transformer does not violate the conservation of energy. It increases voltage by decreasing current proportionally. The power input (low voltage, high current) equals the power output (high voltage, low current), ensuring energy conservation. The transformer merely transfers energy, with losses typically due to inefficiencies.

iii. 1. $\frac{V_s}{V_P} = \frac{N_s}{N_P}$
$V_s = \frac{N_s}{N_P} \times V_P = \frac{3000}{200} \times 90$
$V_s = 1350 \text{ V}$

2. $\frac{I_P}{I_s} = \frac{N_s}{N_P}$
$I_P = \frac{3000}{200} \times 2 = 30 \text{ A}$