CAREERS 360

PRACTICE Series

CBSE Class 12

Physics

Answer Key and Solution 2025 - (All Sets)

SET- 2, QP Code- 55/5/2			
Question Number	Correct Option	Question Number	Correct Option
1	A	9	C
2	D	10	A
3	A	11	B
4	D	12	C
5	C	13	A
6	D	14	D
7	B	15	C
8	C	16	B

SET- 1, QP Code- 55/6/1			
Question Number	Correct Option	Question Number	Correct Option
1	B	9	C
2	C	10	A

3	C	11	B
4	B	12	D
5	C	13	A
6	B	14	C
7	C	15	D
8	A	16	A

SET- 3, QP Code- 55/6/3			
Question Number	Correct Option	Question Number	Correct Option
1	D	9	A
2	C	10	D
3	C	11	C
4	C	12	B
5	D	13	D
6	**A**	14	A
7	B	15	A

8	C	16	C

Ans. 17

In an n-type semiconductor, the majority charge carriers are electrons, while the minority carriers are holes. At room temperature, electron-hole recombination is a continuous process, meaning electrons combine with holes, reducing their numbers. However, the electron concentration remains greater than the hole concentration due to the following reasons:
- Doping Effect: n-type semiconductors are doped with pentavalent impurities (e.g., phosphorus, arsenic), which donate free electrons, significantly increasing the electron concentration.
- Thermal Excitation: At room temperature, intrinsic electron-hole pairs are created due to thermal energy, but since the majority carriers are electrons, the hole concentration remains relatively small.
- Charge Balance: Since the number of electrons contributed by doping atoms is much greater than thermally generated holes, electron concentration remains dominant.

Hence, despite continuous recombination, the electron concentration in an n-type semiconductor remains much greater than the hole concentration.

Ans 18

(a). Velocity refers to the general motion of electrons within a conductor. Electrons move in random directions due to thermal energy, leading to high-speed but uncoordinated movement. On the other hand, drift velocity is the slow, uniform motion of electrons in a specific direction under the influence of an electric field. Unlike the random high-speed movement of electrons, drift velocity is relatively slow and determines the net flow of charge in a conductor.

(b). Using the formula for drift velocity:

$v_d = \frac{I}{neA}$

Where:
- $v_d = 0.2 \mathrm{~mm/s} = 0.2 \times 10^{-3} \mathrm{~m/s}$
- $I = 3.4 \mathrm{~A}$
- $n = 8.5 \times 10^{28}$ electrons $/ \mathrm{m}^3$
- $e = 1.6 \times 10^{-19} \mathrm{C}$
- $A =$? (cross-sectional area)

Rearranging for A :

$A = \frac{I}{n e v_d}$

Substituting values:

$A = \frac{3.4}{\left(8.5 \times 10^{28}\right) \times \left(1.6 \times 10^{-19}\right) \times \left(0.2 \times 10^{-3}\right)}$

$$A = \frac{3.4}{(8.5 \times 1.6 \times 0.2) \times 10^6}$$
$$A = \frac{3.4}{2.72 \times 10^6}$$
$A \approx 1.25 \times 10^{-6} \mathrm{~m}^2 = 1.25 \mathrm{~mm}^2$

Hence, the cross-sectional area of the wire is $1.25 \mathrm{~mm}^2$.

Ans. 19

(a) Intensity at a Point in Young's Double-Slit Experiment

The resultant intensity at any point on the screen due to interference is given by:

$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$

Since both interfering waves have intensity I_0 :

$I = 2 I_0 (1 + \cos \phi)$

(i) For path difference $\frac{\lambda}{3}$:

Phase difference ϕ is given by:

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$
$$\cos\frac{2\pi}{3} = -\frac{1}{2}$$
$$I = 2I_0\left(1 - \frac{1}{2}\right) = 2I_0 \times \frac{1}{2} = I_0$$

(ii) For path difference $\frac{\lambda}{2}$:

Phase difference ϕ is:

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$$
$$\cos\pi = -1$$
$$I = 2I_0(1-1) = 0$$

Hence,
- For path difference $\lambda/3$, the intensity is I_0.
- For path difference $\lambda/2$, the intensity is zero (destructive interference).

OR

(b): Image Formation by a Convex Spherical Surface
We use the spherical refraction formula:

$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

Given:
- Object distance, $u = -12$ cm (as per sign convention)
- Refractive index of air, $n_1 = 1$
- Refractive index of glass, $n_2 = 1.5$
- Radius of curvature, $R = 30$ cm

Solving for image distance v :

$$\frac{1.5}{v} - \frac{1}{-12} = \frac{1.5-1}{30}$$

$$\frac{1.5}{v} + \frac{1}{12} = \frac{0.5}{30}$$

$$\frac{1.5}{v} = \frac{0.5}{30} - \frac{1}{12}$$

$$\frac{1.5}{v} = \frac{1}{60} - \frac{5}{60} = -\frac{4}{60} = -\frac{1}{15}$$

$$v = -22.5 \text{ cm}$$

Interpretation:
Since v is negative, the image is formed on the same side as the object (virtual image).
- The image is virtual and upright.
- It is formed 22.5 cm behind the convex surface inside the glass medium.

Ans. 20

The distance of closest approach is given by:

$r_0 = \frac{1}{4\pi\epsilon_0} \times \frac{Ze^2}{K}$

where:
- $Z =$ Atomic number of the target nucleus
- $e =$ Elementary charge
- $K =$ Kinetic energy imparted to the particle

When an alpha particle (α) and deuterium ion $(D^+)$are accelerated through the same potential difference, their kinetic energy is given by:

$K = qV$

where q is the charge of the particle and V is the potential difference.
- The alpha particle (α) has charge $2e$ and mass $4m_p$.
- The deuterium ion (D^+)has charge e and mass $2m_p$.

Since kinetic energy K depends on charge q and potential V, we find:

$K_\alpha = 2eV, \quad K_D = eV$

For distance of closest approach:

$r_0 \propto \frac{Ze^2}{K}$

For an alpha particle, with twice the charge and twice the kinetic energy, and for a deuterium ion, both experience the same effect on distance of closest approach due to proportionality. Thus, the distance of closest approach remains the same for both particles.

Ans. 21

We use the concept of total internal reflection where the critical angle (θ_c) is given by:

$\sin\theta_c = \frac{n_1}{n_2}$

where:
- $n_1 = 1$ (air)
- $n_2 = \sqrt{2}$ (liquid)

Solving for θ_c :

$$\sin\theta_c = \frac{1}{\sqrt{2}} = 0.707$$
$$\theta_c = 45^\circ$$

Using the relation for the diameter of the opaque disc:

$D = 2h\tan\theta_c$

Given $h = 30$ cm :

$D = 2 \times 30 \times \tan 45^\circ$

$D = 2 \times 30 \times 1$

$D = 60$ cm

SECTION C

Ans. 22

Electromagnetic Waves and Their Uses
(i) Radar uses microwaves, which have a wavelength range of 1 mm to 1 m . Microwaves are used in radar systems for detecting and locating objects.
(ii) Eye surgery uses ultraviolet (UV) rays, with a wavelength range of 10 nm to 400 nm . UV rays are utilized in laser-based eye treatments like LASIK for corneal reshaping.
(iii) Diagnostic tools in medicine use X-rays, which have a wavelength range of 0.01 nm to 10 nm . Xrays are used for medical imaging, such as detecting fractures and internal organ scans.

Ans. 23

(a) Difference between Nuclear Fission and Nuclear Fusion

Nuclear fission is the process in which a heavy nucleus (such as uranium-235 or plutonium-239) splits into two or more smaller nuclei, releasing a large amount of energy. This process is used in nuclear reactors and atomic bombs. Example:

$$^{235}U + 1n \rightarrow {}^{144}Ba + {}^{89}Kr + 3n + \text{ Energy}$$

In this example, uranium-235 absorbs a neutron and splits into barium-144 and krypton-89, releasing additional neutrons and energy.

Nuclear fusion occurs when two light nuclei (such as hydrogen isotopes) combine to form a heavier nucleus, releasing an enormous amount of energy. This process powers the sun and hydrogen bombs. Example:

$$^{2}H + {}^{3}H \rightarrow {}^{4}He + 1n + \text{ Energy}$$

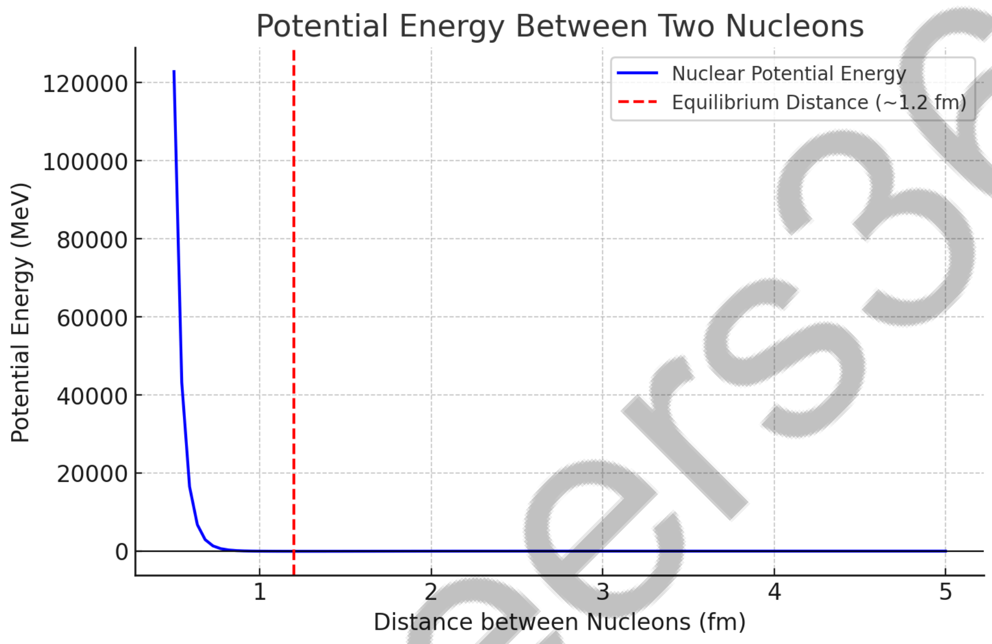
Here, deuterium ($^{2}\mathrm{H}$) and tritium $\left({}^{3}\mathrm{H}\right)$ combine to form helium $\left({}^{4}\mathrm{He}\right)$ and a neutron, releasing massive energy.

Main Differences:
- Fission occurs in heavy elements, while fusion occurs in light elements.

- Fission produces nuclear waste, whereas fusion is cleaner.
- Fusion releases more energy than fission but requires extreme temperatures and pressure.

(b). Graph of Potential Energy Between Nucleons

The potential energy between two nucleons as a function of their separation distance is represented by a graph known as the nuclear potential well. It shows:
- At very short distances, strong repulsion occurs due to the nuclear force, leading to a steep rise in potential energy.
- At intermediate distances ($\sim 1-2 \mathrm{fm}$), an attractive nuclear force dominates, minimizing potential energy.
- Beyond 2 fm , the nuclear force weakens, and potential energy approaches zero.



The graph above represents the potential energy between two nucleons as a function of their separation.
- At very short distances ($<1 \mathrm{fm}$), the repulsive force dominates, increasing the potential energy sharply.
- At an optimal distance ($\sim 1.2 \mathrm{fm}$), the nuclear attractive force is strongest, leading to a minimum in potential energy. This is where nucleons remain bound within the nucleus.
- Beyond 2 fm , the nuclear attraction weakens, and potential energy approaches zero, as the strong nuclear force has a short range.

This graph helps explain why nucleons remain bound within a nucleus and why fusion requires high energy to overcome repulsion at short distances. [3-]

Ans. 24

Given Data:
- Current in the long straight wire: $I_1 = 2A$
- Current in the rectangular loop: $I_2 = 1 \text{ A}$
- Distance of the nearer side of the loop from the wire: $d_1 = 1 \text{ cm} = 0.01 \text{ m}$
- Width of the loop: $w = 1 \text{ cm} = 0.01 \text{ m}$
- Height of the loop: $h = 5 \text{ cm} = 0.05 \text{ m}$
(i) Torque Acting on the Loop

Torque is given by:

$$\vec{\tau} = \vec{r} \times \vec{F}$$

In this case, the forces acting on the two vertical sides of the loop (which are at different distances from the wire) will not be equal, causing a torque.
- Magnetic field at a distance r from a long wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

Using this, the force on a small element dl of the loop is:

$$dF = I_2(dl \times B)$$

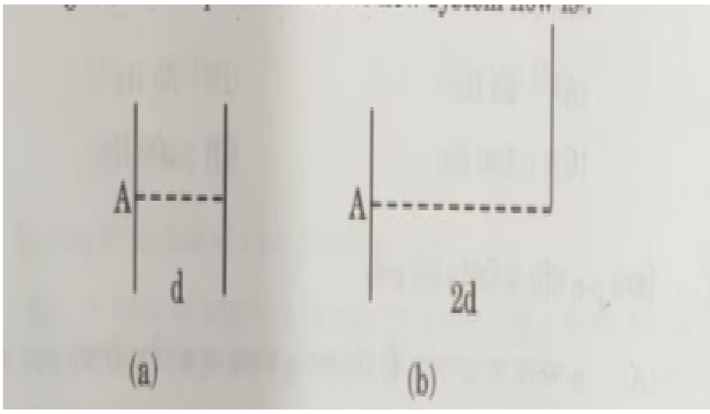
Since the forces act at different distances, they create a net torque. However, the two vertical sides experience forces in opposite directions, but at different distances. The net torque will be calculated by integrating the force over the length of the loop.
(ii) Net Force on the Loop

The forces on the two horizontal sections of the loop are equal and opposite, canceling each other out.
The net force is primarily due to the two vertical sides, which experience different magnetic fields because they are at different distances from the long wire.

The force per unit length on a segment of the loop is:

$$F = I_2 LB$$

Since the force on the farther side is smaller than the force on the nearer side, the net force will be in the direction of the stronger force, which means towards the long wire.



1. Net force on the loop:

$$F_{\text{net}} = 1.0 \times 10^{-6} \text{ N}$$

- Direction: Towards the long straight wire (attractive force).
2. Torque acting on the loop:

$$\tau = 1.5 \times 10^{-8} \text{Nm}$$

- The torque is due to the difference in forces acting on the vertical sides, causing a rotational effect.

These values indicate that the rectangular loop will experience an attractive force towards the wire and a slight torque that may attempt to rotate it. [उ]]

Ans. 25

(a): Object Distance and Image Location
We use the mirror formula:

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

Given:
- Radius of curvature, $R = 20$ cm
- Focal length, $f = \frac{R}{2} = 10$ cm
- Magnification, $m = -2$

Using the magnification formula:

$$m = -\frac{v}{u}$$

Substituting $m = -2$:

$-2 = -\frac{v}{u} \Rightarrow v = 2u$

Now, substituting into the mirror formula:

$$\frac{1}{10} = \frac{1}{u} + \frac{1}{(2u)}$$
$$\frac{1}{10} = \frac{3}{2u}$$

Solving for u :

$u = 15 \text{ cm}$

Now, substituting into $v = 2u$:

$v = 2(15) = 30 \text{ cm}$

Final Answers:
- Object distance: $u = 15 \text{ cm}$ (in front of the mirror)
- Image distance: $v = 30 \text{ cm}$ (on the same side as the object)

Since v is positive, the image is real and inverted.

(b) Effect of Removing Silver Coating at the Centre

If the silver coating at the centre of a concave mirror is removed, the mirror can still form an image.
However:
- The reflection will only take place from the remaining silvered part of the mirror.
- The image characteristics (position, size, and nature) remain unchanged because reflection follows the mirror equation.
- However, the brightness of the image may be reduced because less surface area is available for reflection.

Thus, the mirror can still form an image, but with reduced intensity. [3-]

Ans. 26

Kirchhoff's Laws
1. Kirchhoff's Current Law (KCL) (Junction Rule):
- The algebraic sum of currents at any junction in a circuit is zero.
- Mathematically,

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

- This follows from the conservation of charge.
2. Kirchhoff's Voltage Law (KVL) (Loop Rule):
- The algebraic sum of potential differences around any closed loop is zero.
- Mathematically,

$$\sum V = 0$$

- This follows from the conservation of energy.

Applying Kirchhoff's Laws to the Given Circuit

Let:
- I_1 be the current in the leftmost loop (flowing from the 5 V battery).
- I_2 be the current in the middle branch (flowing from the 10 V battery).
- I_3 be the current in the bottom 2Ω resistor.

By KCL at the bottom junction:

$$I_1 + I_2 = I_3$$

$$5V - (2\Omega \cdot I_1) - (2\Omega \cdot I_3) = 0$$
$$5 = 2I_1 + 2I_3$$
$$2I_1 + 2I_3 = 5 \quad (\text{ Equation 1})$$

$$10 \text{ V} - (1\Omega \cdot I_2) - (2\Omega \cdot I_3) = 0$$
$$10 = I_2 + 2I_3$$
$$I_2 + 2I_3 = 10 \quad (\text{ Equation 2})$$

We now have three equations:
1. $I_1 + I_2 = I_3$
2. $2I_1 + 2I_3 = 5$
3. $I_2 + 2I_3 = 10$

I will now solve these equations to find the values of I_1, I_2, and I_3.

Solving the system of equations, we get:

$$I_1 = -\frac{5}{8}\ \mathrm{A} = -0.625\ \mathrm{A}$$
$$I_2 = \frac{15}{4}\ \mathrm{A} = 3.75\ \mathrm{A}$$
$$I_3 = \frac{25}{8}\ \mathrm{A} = 3.125\ \mathrm{A}$$

Ans. 27

(i) Angular Momentum of Electron

Using Bohr's quantization condition:

$L = n\frac{h}{2\pi}$

Substituting $n = 2$ and $h = 6.626 \times 10^{-34}\ \mathrm{J} \cdot \mathrm{s}$:

$$L = 2 \times \frac{6.626 \times 10^{-34}}{2\pi}$$
$$L = 2.11 \times 10^{-34} J.s$$

(ii) Radius of the Orbit

The radius of the n^{th} orbit in hydrogen is given by:

$r_n = n^2 \times r_1$

where $r_1 = 0.5 = 0.5 \times 10^{-10}$ m.
For $n = 2$:

$$r_2 = 2^2 \times \left(0.5 \times 10^{-10}\right)$$
$$r_2 = 2.0 \times 10^{-10}\ \mathrm{m} = 2.0\backslash AA$$

(iii) Kinetic Energy of Electron

The kinetic energy of an electron in the Bohr orbit is given by:

$KE = \frac{e^2}{8\pi\varepsilon_0 r_n}$

Substituting values:

$$KE = \frac{\left(1.6 \times 10^{-19}\right)^2}{8\pi\left(8.85 \times 10^{-12}\right)\left(2.0 \times 10^{-10}\right)}$$

$$KE = 5.75 \times 10^{-19} \text{ J}$$

Ans. 28

(a) Lenz's Law and Induced EMF in a Rotating Rod

Lenz's Law:
Lenz's Law states that the direction of an induced current is always such that it opposes the change in magnetic flux that caused it. It ensures conservation of energy in electromagnetic induction.

Induced EMF in a Rotating Rod:
Consider a rod MN of length L rotating about one end M with constant angular velocity ω in a uniform magnetic field B parallel to the axis of rotation.

The velocity of any point P at distance x from M is:

$$v = \omega x$$

Since the EMF induced in a small element dx of the rod is given by:

$$dE = Bvdx = B(\omega x)dx$$

Total induced EMF across MN:

$$E = \int_0^L B\omega x dx$$

$$E = B\omega \int_0^L x dx$$

$$E = B\omega \left[\frac{x^2}{2}\right]_0^L$$

$$E = \frac{1}{2}B\omega L^2$$

Thus, the induced EMF between ends M and N is:

$E = \frac{1}{2} B\omega L^2$

OR

(b) Self-Inductance of a Long Solenoid

Definition of Self-Inductance:
Self-inductance (L) of a coil is the property of the coil by which it opposes the change in current flowing through it, producing an induced EMF proportional to the rate of change of current.

$E = -L\frac{dI}{dt}$

Derivation of Self-Inductance of a Solenoid:
For a long solenoid with:

- Number of turns per unit length $= n$,
- Cross-sectional area $= A$,
- Length of solenoid $= l$,
- Current flowing $= I$,

The magnetic field inside the solenoid is:

$B = \mu_0 n I$

The magnetic flux through one turn:

$\phi = BA = (\mu_0 n I) A$

Total flux linkage:

$\lambda = N\phi = (nl)(\mu_0 n I A)$

Since $L = \frac{\lambda}{I}$:

$L = \mu_0 n^2 A l$

Ans. 29 (i).

(a).

- Capacitors A, B, and M each have a capacitance C.
- Capacitor N has a capacitance $2C$.
- The given circuit suggests that A, B, and M are in series, and this series combination is in parallel with capacitor N .

For capacitors in series, the equivalent capacitance C_{eq} is given by:

$$\frac{1}{C_{\text{eq}}}=\frac{1}{C}+\frac{1}{C}+\frac{1}{C}$$

$$\frac{1}{C_{\text{eq}}}=\frac{3}{C}$$

$$C_{\text{eq}}=\frac{C}{3}$$

$$C_{\text{total}}=C_{\text{eq}}+C_N$$

$$C_{\text{total}}=\frac{C}{3}+2C$$

$$C_{\text{total}}=\frac{C}{3}+\frac{6C}{3}=\frac{7C}{3}$$

From the formula for charge:

$$Q=CV$$

1. Total Charge on the Network:

$$Q_{\text{total}}=C_{\text{total}}V=\frac{7C}{3}V$$

2. Charge on Capacitor N (Parallel Component):

$$Q'=C_NV=2CV$$

3. Charge on Capacitor A (Series Component):
- In series, all capacitors carry the same charge.
- So, $Q_A=Q$ for capacitor A.
- The charge on any series capacitor is determined by:

$$Q=C_{\text{eq}}V=\frac{C}{3}V$$

$$\frac{Q'}{Q} = \frac{2CV}{\frac{C}{3}V}$$

$$\frac{Q'}{Q} = \frac{2C}{\frac{C}{3}}$$

$$\frac{Q'}{Q} = 6$$

(b).

For a parallel plate capacitor with:
- Plate area $= A$,
- Plate separation $= d$,
- Permittivity of free space $= \varepsilon_0$,

The capacitance without a dielectric is:

$C_0 = \frac{\varepsilon_0 A}{d}$

A dielectric slab of thickness $d/2$ and dielectric constant K is inserted between the plates.
This divides the capacitor into two capacitors in series:
1. Region with Dielectric:
- Thickness $= d/2$,
- Permittivity $= \varepsilon_0 K$,
- Capacitance:

$C_1 = \frac{K\varepsilon_0 A}{d/2} = \frac{2K\varepsilon_0 A}{d}$

2. Region without Dielectric:
- Thickness $= d/2$,
- Permittivity $= \varepsilon_0$,
- Capacitance:

$C_2 = \frac{\varepsilon_0 A}{d/2} = \frac{2\varepsilon_0 A}{d}$

For two capacitors in series, the total capacitance is:

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

Substituting C_1 and C_2 :

$$\frac{1}{C} = \frac{1}{\frac{2K\varepsilon_0 A}{d}} + \frac{1}{\frac{2\varepsilon_0 A}{d}}$$

$$\frac{1}{C} = \frac{d}{2K\varepsilon_0 A} + \frac{d}{2\varepsilon_0 A}$$

$$\frac{1}{C} = \frac{d}{2\varepsilon_0 A}\left(\frac{1}{K} + 1\right)$$

$$C = \frac{2\varepsilon_0 A}{d} \times \frac{1}{\frac{1}{K} + 1}$$

$$C = \frac{2C_0}{\frac{1}{K} + 1}$$

$$C = \frac{2KC_0}{K + 1}$$

$\frac{C}{C_0} = \frac{2K}{K+1}$

(ii) Energy Stored in an Air-Filled Parallel Plate Capacitor

The energy stored in a parallel plate capacitor is given by:

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

Since the electric field E between the plates is:

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

The capacitance of a parallel plate capacitor is:

$C = \frac{\varepsilon_0 A}{d}$

The volume enclosed between the plates is:

$V = Ad$

The energy density (energy per unit volume) in an electric field is:

$u = \frac{1}{2}\varepsilon_0 E^2$

Thus, the total energy stored in the capacitor:

$U = u \times V = \frac{1}{2}\varepsilon_0 E^2 \times V$

Final Answer:

$\frac{1}{2}\varepsilon_0 E^2 V$

(iii) Expression for Dielectric Constant K in a Charged Capacitor with a Dielectric Slab

When a dielectric slab is inserted between the charged plates of a capacitor:
- The dielectric polarizes, creating induced charges on its surfaces.
- The charge density on the plates is σ.
- The surface charge density induced on the dielectric slab is σ_p.

The relation between the dielectric constant K and the charge densities is:

$$K = \frac{\text{Total surface charge density}}{\text{Free charge density remaining on the capacitor plates}}$$

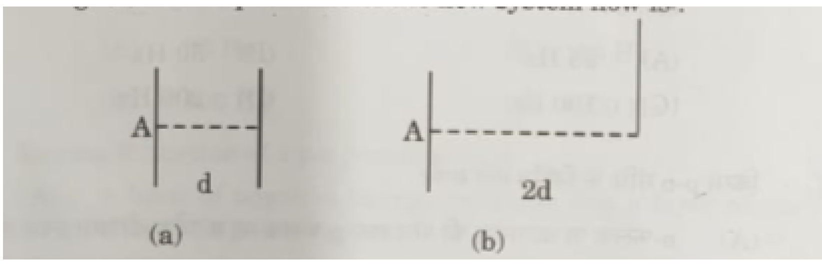
This is given by:

$$K = \frac{\sigma}{\sigma - \sigma_p}$$

Final Answer:

$\frac{\sigma}{\sigma - \sigma_p}$ (Option B)

(iv).



For a parallel plate capacitor with:
- Plate area = A,
- Plate separation = d,
- Permittivity of free space = ε_0,

The capacitance is given by:

$C = \frac{\varepsilon_0 A}{d}$

When the distance between the plates is doubled, the new capacitance C' becomes:

$$C' = \frac{\varepsilon_0 A}{2d}$$
$$C' = \frac{C}{2}$$

In the second figure (b), one plate is shifted, making it an arrangement similar to two capacitors in series:
- Each capacitor has a separation of $2d$, but only half of the original plate area contributes to each capacitor.
- The capacitance of each new capacitor is:

$C_1 = \frac{\varepsilon_0 (A/2)}{2d} = \frac{C}{4}$

Since the two capacitors are in parallel, the total capacitance is:

$C_{\text{new}} = C_1 + C_1 = \frac{C}{4} + \frac{C}{4} = \frac{C}{2}$

Ans 30

1).

(a) In a reverse-biased p-n junction:

Answer: (B) The applied voltage mostly drops across the depletion region.

Explanation: In a **reverse-biased p-n junction**, the depletion region becomes wider as more majority carriers move away from the junction. The applied voltage primarily **drops across this widened depletion region**, creating a strong electric field that prevents the movement of majority charge carriers. The drift current remains **very small (in microamperes or nanoamperes)** due to minority carrier movement.

(b).

The output frequency of a full-wave rectifier with a 50 Hz input frequency is:

Answer: (C) 100 Hz
Explanation: In a full-wave rectifier, both halves of the AC cycle are converted into DC, effectively doubling the frequency of the output signal. If the input frequency is 50 Hz , then the output frequency becomes:

$$f_{\text{output}} = 2 \times f_{\text{input}} = 2 \times 50 = 100 \text{ Hz}$$

(ii).

During the formation of a p-n junction:

Answer: (A) A layer of negative charge on n-side and a layer of positive charge on p -side appear.
Explanation:
- When a p-n junction is formed, electrons from the n -region diffuse into the p -region and holes from the p -region diffuse into the n -region.
- This leads to the formation of immobile ionized donor atoms in the n-region (creating a negative charge layer) and immobile ionized acceptor atoms in the p-region (creating a positive charge layer).
- This charge separation forms the depletion region, creating a potential barrier that opposes further charge movement.

(iii) Energy Required to Free the Fifth Electron in a Pentavalent Atom in Si

Answer: (C) 0.05 eV
Explanation:
- When a pentavalent atom (such as phosphorus, arsenic, or antimony) replaces a silicon atom in the crystal lattice, four of its electrons participate in covalent bonding with neighboring silicon atoms.
- The fifth electron is loosely bound to the donor atom and requires only a small amount of energy to become free and contribute to conduction.
- For silicon (Si), the energy required to free this extra electron is

approximately 0.05 eV , making it available as a free charge carrier in an n-type semiconductor.

(iv) Donor Impurity for Germanium (Ge)

Answer: (B) Antimony
Explanation:
- Donor impurities are pentavalent elements that donate free electrons when doped into a semiconductor.
- Antimony (Sb) is a pentavalent element, and when added to germanium (Ge), it donates an extra electron, making Ge an n-type semiconductor.
- Boron (B), Aluminium (Al), and Indium (In) are trivalent elements, which act as acceptor impurities and are used for p-type semiconductors.

Ans. 31 (a).

(i): Work Done in Moving a Unit Charge
The given electric field in the region is:

$\vec{E} = 40x\hat{i}\ \mathrm{N/C}$

The work done in moving a unit positive charge $(q = 1)$ from $(0, 3)$ to $(5, 0)$ depends only on the x component of displacement because the field exists only along the x-direction.

Using the formula for work done in an electric field:

$W = \int_{x_{\text{initial}}}^{x_{\text{final}}} E_x dx$

Substituting $E_x = 40x$:

$$W = \int_0^5 40x dx$$

$$W = 40 \times \left.\frac{x^2}{2}\right|_0^5$$

$W = 40 \times \frac{25}{2} = 500\ \mathrm{J}$

(ii): Electric Field and Potential at the Common Center of Concentric Hollow Spheres

Given Data:
- Two concentric hollow spheres of radii r and R (where $R > r$).
- Total charge Q is distributed such that the surface charge densities are equal.

Since the surface charge densities are equal for both spheres, we have:

$$\sigma = \frac{Q}{4\pi(r^2+R^2)}$$

where σ is the surface charge density.

(I) Electric Field at the Common Center
- For a conducting sphere, the electric field inside a hollow shell is always zero.
- Since the common center lies inside both spheres, the net electric field at the center is:

$$E_{\text{center}} = 0$$

(II) Potential at the Common Center

The potential due to a conducting shell at any point inside the shell is the same as the potential at its surface.

Using:

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

The potential at the center due to each shell:
1. Potential due to the inner sphere:

$$V_r = \frac{1}{4\pi\varepsilon_0} \times \frac{\sigma \cdot 4\pi r^2}{r}$$

2. Potential due to the outer sphere:

$$V_R = \frac{1}{4\pi\varepsilon_0} \times \frac{\sigma \cdot 4\pi R^2}{R}$$

Total potential at the center:

$$V_{\text{center}} = V_r + V_R$$
$$V_{\text{center}} = \frac{1}{4\pi\varepsilon_0} \times \frac{Q(R+r)}{\varepsilon_0\left(R^2+r^2\right)}$$

(b)

(i): Electric Field Due to a Dipole at an Equatorial Point
An electric dipole consists of:
- Two equal and opposite charges $+q$ and $-q$ separated by a small distance $2a$.
- The dipole moment is:

$$\vec{p} = q(2a)$$

We need to find the electric field at a point on the equatorial plane of the dipole.
Consider a point $\mathbf{P}$ on the equatorial plane at a distance r from the center of the dipole.
The electric field due to each charge at P :
- The two individual fields cancel their horizontal components.
- The net field is directed opposite to the dipole moment and is given by:

$$E_{\perp} = \frac{1}{4\pi\varepsilon_0} \times \frac{p}{\left(r^2+a^2\right)^{3/2}}$$

where $p = q(2a)$.
Thus, the electric field at the equatorial point is:

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \times \frac{p}{\left(r^2+a^2\right)^{3/2}}(-\hat{p})$$

- The negative sign indicates that the field is opposite to the dipole moment.
- Direction: The field points towards the dipole (along -p direction).
(I) Electric Field at the Center of the Dipole ($r = 0$)

At the center $(r = 0)$:

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{p}{\left(0+a^2\right)^{3/2}}$$

$$E = \frac{1}{4\pi\varepsilon_0} \times \frac{p}{a^3}$$

Since this is a theoretical point, in practical cases, the dipole approximation doesn't apply at $r = 0$.

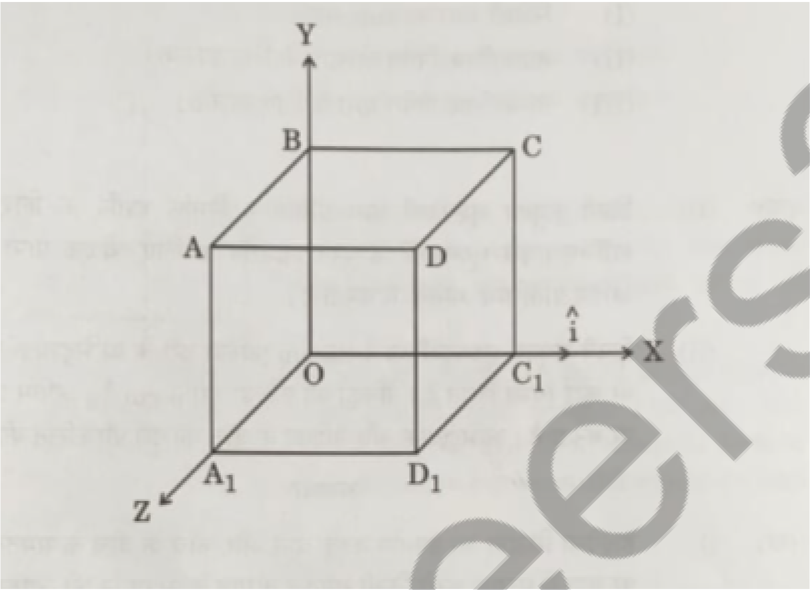
(II) Electric Field at a Far Point $(r \gg a)$

For points far from the dipole $(r \gg a)$:

$E_{\perp} \approx \frac{1}{4\pi\varepsilon_0} \times \frac{p}{r^3}$

since $\left(r^2 + a^2\right)^{3/2} \approx r^3$ for large r.

(ii)



Gauss's Law states that the net electric flux through a closed surface is given by:

$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0}$

Since there is no charge enclosed inside the cube, by Gauss's Law:

$Q_{\text{enc}} = 0 \Rightarrow \Phi_E = 0$

The given electric field is:

$\vec{E} = (10x + 5)\hat{\imath} \quad (\text{ in N/C })$

This field depends on x-position, meaning the flux contributions across opposite cube faces may not cancel completely.

- The cube is placed such that its faces are perpendicular to the X -axis.
- The two opposite faces (one at $x=0$ and the other at $x=L$) will contribute to the flux.
- The electric field at these faces:
- At $x=0$:

$$E_{\text {in }}=(10(0)+5)=5 \mathrm{~N} / \mathrm{C}$$

- At $x=L$:

$$E_{\text {out }}=(10 L+5) \mathrm{N} / \mathrm{C}$$

- The flux through a surface is given by:

$$\Phi=\int \vec{E} \cdot d \vec{A}$$

Since the field is uniform over each face, the flux through each face is:

$$\Phi_{\text {in }}=E_{\text {in }} \cdot A=(5) \cdot L^2=5 L^2$$
$$\Phi_{\text {out }}=E_{\text {out }} \cdot A=(10 L+5) \cdot L^2$$

The net flux through the cube is:

$$\Phi_{\text {net }}=\Phi_{\text {out }}-\Phi_{\text {in }}$$

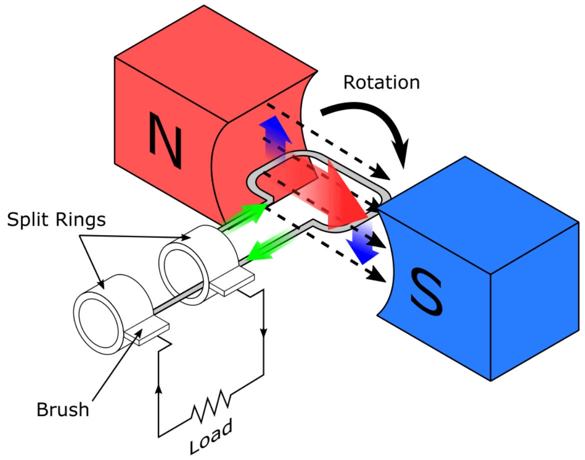
$$\Phi_{\text {net }}=(10 L+5) L^2-5 L^2$$
$$\Phi_{\text {net }}=10 L^3+5 L^2-5 L^2$$
$$\Phi_{\text {net }}=10 L^3$$

Ans 32 (a)

(i): Principle and Working of an AC Generator
Principle of an AC Generator
An AC generator works on the principle of electromagnetic induction. When a coil rotates in a magnetic field, the magnetic flux linked with the coil changes, inducing an alternating emf (electromotive force) according to Faraday's Law of Induction.

Diagram of an AC Generator
The AC generator consists of:

1. Armature coil (ABCD): A rectangular coil that rotates inside a magnetic field.
2. Magnetic field (N-S poles): Produces the necessary flux.
3. Slip rings and Brushes: Conduct the induced current to the external circuit.
4. Axis of rotation: The coil rotates about this axis.



Working of an AC Generator
1. The armature coil (ABCD) rotates inside the magnetic field produced by the N-S poles.
2. As the coil rotates, the magnetic flux linked with the coil changes.
3. According to Faraday's Law, a varying magnetic flux induces an electromotive force (emf) in the coil.
4. Slip rings ensure a continuous connection between the coil and the external circuit.
5. Due to the coil's rotation, the induced emf varies sinusoidally, producing an alternating current (AC output).

(ii): RMS Voltages Across Circuit Elements
Given an AC source:

$$v = 140 \sin(100\pi t) \mathrm{V}$$

we calculated the RMS voltages across the three circuit elements.
Final Answers:
- RMS voltage across the resistor (V_R) : 79.20 V
- RMS voltage across the inductor (V_L) : 98.99 V
- RMS voltage across the capacitor (V_C) : 39.60 V

- Algebraic sum of these voltages: 217.79 V
- RMS voltage of the source: 98.99 V

Why is the Sum of the Voltages Greater than the Source Voltage?
The sum of individual voltage drops is greater than the source voltage because:

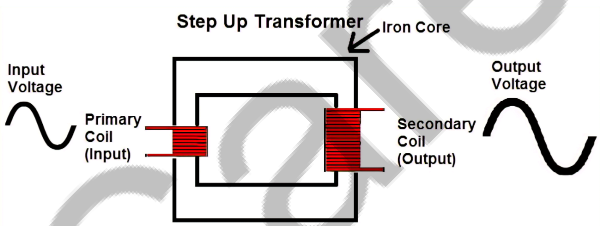
1. The voltages across inductor and capacitor are out of phase with each other.
2. In a series AC circuit, voltages do not add algebraically, instead they vectorially add.
3. The actual total voltage drop across the circuit is determined by the impedance Z, not by individual component voltages.

(b).

(i) Principle and Working of a Transformer

Principle of a Transformer
A transformer works on the principle of mutual induction, which states that: "When an alternating current (AC) flows through a primary coil, it generates a time-varying magnetic flux. This changing flux links with the secondary coil and induces an alternating electromotive force (emf) in it according to Faraday's Law of Electromagnetic Induction."

A step-up transformer increases the voltage while decreasing the current in the secondary coil.



Working of a Step-Up Transformer
1. AC voltage is applied to the primary coil, which creates a time-varying magnetic field in the laminated iron core.
2. The magnetic flux links with the secondary coil, inducing an emf according to Faraday's Law.
3. In a step-up transformer, the number of turns in the secondary coil (N_s) is greater than in the primary coil (N_p), leading to an increase in voltage.
4. The transformer follows the relation:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

where:
- V_p and V_s are the primary and secondary voltages.
- N_p and N_s are the number of turns in the primary and secondary coils.
5. Since energy is conserved, the power remains the same:

$$P_{\text{input }}=P_{\text{output}}$$
$$V_p I_p=V_s I_s$$
This means that **if voltage increases, current decreases**.

(ii): Transformer Calculations
Given Data
- Primary Voltage $V_p=50 \mathrm{~V}$
- Secondary Voltage $V_s=250 \mathrm{~V}$
- Power Input $P=200 W$
- Input Voltage Equation:

$$v_i=20 \sin (100 \pi t) \mathrm{V}$$

(I) RMS Value of Input Current

Using the formula:

$$P=V_{\mathrm{rms}} I_{\mathrm{rms}}$$

Solving for $I_{\mathrm{p,rms}}$:

$$I_{\mathrm{p,rms}}=\frac{P}{V_{\mathrm{p,rms}}}$$

$$I_{\mathrm{p,rms}}=\frac{200}{50}=4.0 \mathrm{~A}$$

(II) Expression for Instantaneous Output Voltage

Since transformers maintain the same frequency, the secondary voltage follows the same sinusoidal form as the primary voltage.

The RMS voltage relation:

$$V_{\mathrm{s,rms}}=\frac{V_s}{V_p} V_{\mathrm{p,rms}}$$

Since $V_{\text{p, rms }}=\frac{V_p}{\sqrt{2}}$:

$$V_{\text{s,rms}} = \frac{250}{50} \times \frac{50}{\sqrt{2}}$$
$$V_{\text{s,rms}} = \frac{250}{\sqrt{2}}$$

The instantaneous output voltage equation:

$$v_o = V_{\text{s,max}} \sin(100\pi t)$$

where:

$$V_{\text{s,max}} = V_{\text{s,rms}}\sqrt{2} = 250 \text{ V}$$
$$v_o = 250 \sin(100\pi t)\text{V}$$

(III) Expression for Instantaneous Output Current

Using power conservation in an ideal transformer:

$$P_{\text{input }} = P_{\text{output}}$$
$$V_{\text{s,rms}} I_{\text{s,rms}} = 200$$

Solving for $I_{\text{s,rms}}$:

$I_{\text{s,rms}} = \frac{200}{250} = 0.8 \text{ A}$

The instantaneous output current equation:

$$i_s = I_{\text{s,max}} \sin(100\pi t)$$

where:

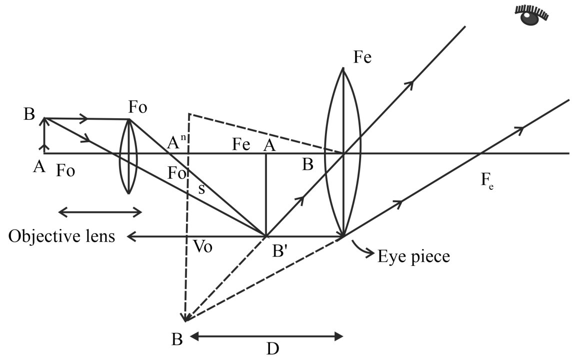
$$I_{\text{s,max}} = I_{\text{s,rms}}\sqrt{2} = 1.13 \text{ A}$$
$$i_s = 1.13 \sin(100\pi t)\text{A}$$

Ans. 33 (a).

(i).

A compound microscope consists of:
1. Objective Lens: Forms a real, inverted, and magnified intermediate image.

2. Eyepiece Lens: Acts as a magnifier, further enlarging the intermediate image to form the final virtual image.



The total magnification (M) of a compound microscope when the final image is formed at infinity is given by:

$$M = M_o \times M_e$$

where:
- $M_o =$ magnification by the objective lens
- $M_e =$ magnification by the eyepiece lens

Step 1: Magnification by the Objective Lens

$$M_o = \frac{L}{f_o}$$

where:
- $L =$ Optical tube length (distance between the objective lens and the eyepiece, typically around 25 cm).

- $f_o =$ Focal length of the objective lens.
When the final image is at infinity:

$$M_e = \frac{D}{f_e}$$

where:
- $D =$ Least distance of distinct vision (usually 25 cm),
- $f_e =$ Focal length of the eyepiece.

Thus, the total magnification is:

$$M = \frac{L}{f_o} \times \frac{D}{f_e}$$

This equation gives the total magnification of a compound microscope when the final image is at infinity.

(ii): Distance Between Objective and Eyepiece in a Compound Microscope

Given Data:
- Object distance from the objective lens: $u_o = 1.5$ cm
- Focal length of the objective lens: $f_o = 1.25$ cm
- Focal length of the eyepiece: $f_e = 5$ cm
- Final image formed at infinity: $u_e = f_e$

Using the lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$
$$\frac{1}{1.25} = \frac{1}{v_o} - \frac{1}{1.5}$$

Solving for v_o :

$v_o = 5.68$ cm

The distance between the objective and the eyepiece is:

$L = v_o + u_e$
$L = 5.68 + 5$
$L = 5.68$ cm

OR

(b).

(i) Refraction of a Plane Wavefront Using Huygens' Principle \& Verification of Snell's Law

Huygens' Principle:
Huygens' principle states that:
1. Each point on a wavefront acts as a secondary source of new wavelets.
2. The envelope of these secondary wavelets at a later time forms the new wavefront.

Refraction of a Plane Wavefront at an Air-Glass Interface
Consider a plane wavefront moving from air (refractive index n_1) into glass (refractive index n_2) at an angle i.

1. Incident Wavefront:
- A plane wavefront AB approaches the air-glass interface at an angle i.
- Each point on AB acts as a secondary source

2. Refracted Wavefront:
- As the wave propagates into the denser medium (glass), the speed of light decreases from v_1 in air to v_2 in glass.
- The secondary wavelets in glass travel slower than in air.
- The new refracted wavefront $A'B'$ is formed by the envelope of secondary wavelets.

Verification of Snell's Law
From Huygens' construction, the time taken for wavefronts to move:

$$\frac{\text{Distance in air}}{\text{Speed in air}}=\frac{\text{Distance in glass}}{\text{Speed in glass}}$$
$$\frac{AB}{v_1}=\frac{A'B'}{v_2}$$

Since $\sin i=\frac{AB}{tv_1}$ and $\sin r=\frac{A'B'}{tv_2}$,

$\frac{\sin i}{\sin r}=\frac{v_1}{v_2}$

Using $v=c/n$,

$\frac{\sin i}{\sin r}=\frac{n_2}{n_1}$

which is Snell's Law:

$n_1 \sin i=n_2 \sin r$

Conclusion
Thus, Snell's Law is verified using Huygens' principle.

(ii) Mirror Formula \& Virtual Image in a Convex Mirror

Mirror Formula:
The mirror equation is:

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

where:
- $f =$ focal length of the mirror,
- $u =$ object distance,
- $v =$ image distance.

Convex Mirror Always Forms a Virtual Image
For a convex mirror:
1. The focal length is positive $(f > 0)$.
2. The object is always in front $(u < 0)$.

Using the mirror equation:

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

Since $f > 0$ and $u < 0$, we get:

$$\frac{1}{v} > 0$$

which means:

$$v > 0$$

Thus, the image distance v is always positive, meaning:
- The image is always formed behind the mirror.
- The image is virtual and upright.

Conclusion:
A convex mirror always forms a virtual image because:
1. The mirror equation always results in a positive image distance.
2. The image is always behind the mirror, making it virtual and upright.
3. The image is always diminished.

This proves that a convex mirror cannot form a real , image for any real object placed in front of it.