UP Board Class 12 Physics 2026 Set 346 DX Question Paper with Solutions

ZOLLEGE

General Instructions

(i) This booklet contains 30 questions, each provided with a complete, step-by-step solution.

(ii) It comprises 6 single-correct multiple-choice questions.

(iii) Attempt each question on your own before reviewing the given solution.

1. In the followings, dimension of electric field is:

(A) $[MLT^2A]$

(B) $[MLT^{-1}A^{-1}]$

(C) $[MLT^{-3}A^{-1}]$

(D) $[ML^2T^{-3}A^{-1}]$

Correct Answer: (C) $[MLT^{-3}A^{-1}]$

SOLUTION:

Step 1: Use the potential-based definition of field.

Electric field magnitude equals potential gradient: $E = V/d$.

Step 2: Find the dimension of potential V.

Potential $=$ work per unit charge $= \dfrac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$.

Step 3: Divide by length $d = [L]$.

$[E] = \dfrac{[ML^2T^{-3}A^{-1}]}{[L]} = [MLT^{-3}A^{-1}]$.

Step 4: This confirms option (C). Note option (D) is exactly the potential dimension, so it is the common trap.

$$\boxed{[MLT^{-3}A^{-1}]}$$

Quick Tip: Electric field = force/charge, and charge has dimension $[AT]$.

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2. In photoelectric emission, the frequency of incident light is doubled. Kinetic energy of emitted photoelectrons will become:

(A) double

(B) somewhat more than double

(C) less than double

(D) four times

Correct Answer: (B) somewhat more than double

SOLUTION:

Step 1: Think in terms of what part of photon energy scales.
Only the photon energy $h\nu$ scales with frequency; the work function ϕ is a fixed property of the metal.
Step 2: Split the kinetic energy.
$K = h\nu - \phi$. Doubling frequency doubles the $h\nu$ term but leaves ϕ unchanged, so the subtracted amount stays the same instead of also doubling.
Step 3: Because we subtract a smaller relative amount the second time, the result overshoots exactly double.
Numerically, if $h\nu = 5$ eV and $\phi = 2$ eV, then $K_1 = 3$ eV and $K_2 = 10 - 2 = 8$ eV, whereas double would be 6 eV.
Step 4: $8 > 6$, confirming the energy becomes a little more than double.

$\boxed{\text{somewhat more than double}}$

Quick Tip: Use $K = h\nu - \phi$; only the $h\nu$ term doubles, ϕ stays fixed.

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3. Two resistances are connected in parallel. Equivalent resistance of combination is $\frac{6}{5}$ Ω. When one resistance is broken out, resistance becomes 2 Ω. The resistance of broken wire was:

(A) $\frac{2}{5}\ \Omega$

(B) $2\ \Omega$

(C) $3\ \Omega$

(D) $\frac{5}{2}\ \Omega$

Correct Answer: (C) $3\ \Omega$

SOLUTION:

Step 1: Use conductances instead of resistances.

For parallel resistors, total conductance $G = G_1 + G_2$ where $G = 1/R$.

Step 2: Total conductance of the combination.

$$G = \frac{1}{6/5} = \frac{5}{6}\ \Omega^{-1}.$$

Step 3: The intact resistor left after the break has $R_1 = 2\ \Omega$, so $G_1 = \frac{1}{2}$

$$= \frac{3}{6}\ \Omega^{-1}.$$

Step 4: Conductance of the broken wire.

$$G_2 = G - G_1 = \frac{5}{6} - \frac{3}{6} = \frac{2}{6} = \frac{1}{3}\ \Omega^{-1}.$$

Step 5: Invert to get its resistance.

$$R_2 = \frac{1}{G_2} = 3\ \Omega.$$

$$\boxed{R_{\text{broken}} = 3\ \Omega}$$

Quick Tip: The remaining $2\ \Omega$ is one resistor; put it into $\frac{R_1R_2}{R_1+R_2} = \frac{6}{5}$ and solve.

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4. Following charged particles are projected perpendicular to a uniform magnetic field with same velocity. Which one will experience maximum force?

(A) electron

(B) proton

(C) α particle

(D) deuteron

Correct Answer: (C) α particle

SOLUTION:

Step 1: Recognize the force law $F = qvB$ for perpendicular projection. With identical v and B, force is directly proportional to charge magnitude: $F \propto q$.

Step 2: List charge in units of elementary charge e.

electron $= 1e$, proton $= 1e$, deuteron (one proton + one neutron) $= 1e$, alpha (two protons + two neutrons) $= 2e$.

Step 3: Rank the forces.

Three particles tie at $F = evB$; the alpha particle gives $F = 2evB$, which is the largest.

Step 4: Therefore the alpha particle feels twice the force of the others.

$$\boxed{\alpha \text{ particle}}$$

Quick Tip: $F = qvB$ with same v, B; largest charge wins, and the α particle carries $2e$.

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5. In L–C–R circuit power factor will be 1, if:

(A) $\omega L = \omega C$

(B) $\omega L = \dfrac{1}{\omega C}$

(C) $\left(\omega L - \dfrac{1}{\omega C}\right) = R$

(D) None of these

Correct Answer: (B) $\omega L = \dfrac{1}{\omega C}$

SOLUTION:

Step 1: Use the phasor picture of impedance.

The net reactance is $X = X_L - X_C = \omega L - \dfrac{1}{\omega C}$, and the phase angle satisfies $\tan\phi = X/R$.

Step 2: Power factor is $\cos\phi$; it equals 1 only when $\phi = 0$.

$\phi = 0$ means $\tan\phi = 0$, hence $X = 0$.

Step 3: Apply $X = 0$.

$\omega L - \dfrac{1}{\omega C} = 0 \Rightarrow \omega L = \dfrac{1}{\omega C}$.

Step 4: Physically the circuit is purely resistive at resonance, so all supplied power is real and the power factor is unity.

$$\boxed{\omega L = \frac{1}{\omega C}}$$

Quick Tip: Power factor is unity at resonance, when inductive reactance equals capacitive reactance.

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6. Convex lens of focal length f_1 is placed in contact with a concave lens of focal length f_2. For $f_1 > f_2$ combination will behave:

(A) like a concave lens

(B) like a convex lens

(C) like a plane glass slab

(D) none of these

Correct Answer: (A) like a concave lens

SOLUTION:

Step 1: Work directly with powers.

Power of a lens is $P = 1/f$ with sign. Convex power $P_1 = +\dfrac{1}{f_1}$, concave power $P_2 = -\dfrac{1}{f_2}$.

Step 2: Add the powers for lenses in contact.

$P = P_1 + P_2 = \dfrac{1}{f_1} - \dfrac{1}{f_2}$.

Step 3: Because $f_1 > f_2$, the convex power $1/f_1$ is smaller in magnitude than the concave power $1/f_2$.

So the diverging concave lens dominates and the net power is negative, $P < 0$.

Step 4: A negative net power is the signature of a diverging system, so the pair acts as a concave lens.

$$\boxed{\text{concave lens}}$$

Quick Tip: Use $\frac{1}{F} = \frac{1}{f_1} - \frac{1}{f_2}$; if $f_1 > f_2$ the result is negative, meaning diverging.

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7. On increasing temperature of a semiconductor, what will be effect on its conductivity?

Correct Answer: —

SOLUTION:

Step 1 (Band picture): In a semiconductor a small forbidden energy gap ($E_g \approx 1$ eV) separates the filled valence band from the empty conduction band. Conduction needs electrons in the conduction band.

Step 2 (Thermal excitation): Raising the temperature supplies thermal energy kT to the electrons. The number of electrons able to jump across the gap follows $n \propto e^{-E_g/2kT}$, so n grows quickly as T increases, leaving behind an equal number of holes in the valence band.

Step 3 (Conclusion): More carriers in both bands mean more current for the same field, so the material conducts better at higher temperature. This is opposite to a metal, whose resistance rises on heating.

$$\boxed{\sigma \uparrow \text{ with temperature; semiconductor becomes a better conductor.}}$$

Quick Tip: Use $\sigma = ne\mu$: heating breaks covalent bonds and creates many more electron-hole pairs, so the carrier number wins over the drop in mobility.

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8. In a nuclear fusion reaction mass defect is 0.2%. What will be amount of energy released in the fusion of 1 kg mass?

Correct Answer: —

SOLUTION:

Step 1 (Set up the fraction directly): Since only 0.2% of the mass is lost, the released energy is 0.2% of the total rest energy of 1 kg. So $E = 0.002 \times (mc^2)$ with $m = 1$ kg.

Step 2 (Rest energy of 1 kg): First find the full rest energy,

$$E_0 = mc^2 = 1 \times (3 \times 10^8)^2 = 9 \times 10^{16} \text{ J.}$$

Step 3 (Take 0.2% of it):

$$E = 0.002 \times 9 \times 10^{16} = 1.8 \times 10^{14} \text{ J.}$$

Step 4 (Result): The same value is obtained, confirming the answer.

$$\boxed{E = 1.8 \times 10^{14} \text{ J}}$$

Quick Tip: Use $E = \Delta m\, c^2$ with $\Delta m = 0.2\%$ of 1 kg, i.e. 2×10^{-3} kg.

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9. What is the phenomena of radioactivity?

Correct Answer: —

SOLUTION:

Step 1 (Idea): Some nuclei have an unfavourable ratio of neutrons to protons and are therefore unstable. To reach a more stable state they break up by themselves; this self breaking up is what we call radioactivity.

Step 2 (Nature of the change): Because the change happens inside the nucleus, the atom is transformed into a different element (transmutation) and releases energy carried away by the emitted particles or rays (α, β or γ).

Step 3 (Independence from surroundings): Unlike chemical reactions, the rate of radioactive decay cannot be sped up or slowed down by heat, pressure or chemical state; each radioactive substance decays at its own fixed rate set by its half life.

$$\boxed{\text{Radioactivity} = \text{self decay of an unstable nucleus with emission of radiation.}}$$

Quick Tip: Think of the spontaneous, nuclear (not chemical) emission of α, β and γ radiation from unstable heavy nuclei.

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10. Explain the meaning of work function of a photosensitive surface.

Correct Answer: —

SOLUTION:

Step 1 (Everyday picture): Imagine the electrons sitting inside a shallow well at the metal surface. The work function is the depth of that well, that is, the energy price an electron must pay to climb out and become a free photoelectron.

Step 2 (Where it appears): Einstein's photoelectric equation $h\nu = W_0 + K_{max}$ shows that of the photon energy $h\nu$, a fixed part W_0 is spent just in liberating the electron, and only the surplus appears as the maximum kinetic energy K_{max}.

Step 3 (Material property): Its value is fixed for a given surface (for example about 2 eV for caesium and higher for metals like platinum). A smaller work function means electrons are emitted more easily, so such metals are used in photocells.

$$\boxed{W_0 = \text{smallest energy needed to remove an electron from the surface.}}$$

Quick Tip: It is the minimum energy to free an electron from the metal surface; $W_0 = h\nu_0$ with ν_0 the threshold frequency.

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11. Electric field lines do not intersect. Why?

Correct Answer: —

SOLUTION:

Step 1 (What a field line stands for): A field line is drawn so that a positive test charge placed on it would move along the line; its direction at each point is the direction of the force (and hence of $\vec{E}$) on that charge.

Step 2 (Test at a crossing): If two lines met at one point, a test charge placed there would be told to move in two different directions at the same instant.

Step 3 (Physical impossibility): A single charge at a single point can feel only one resultant force and therefore move in only one direction. Two directions at once is physically meaningless, so the crossing cannot exist.

$$\boxed{\text{Unique field direction at each point} \Rightarrow \text{field lines never cross.}}$$

Quick Tip: If two lines crossed, the field would have two tangents (two directions) at one point, which is impossible.

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12. Radiation of some definite frequency are either absorbed or emitted by the atoms. Explain the reason.

Correct Answer: —

SOLUTION:

Step 1 (Quantized states): The energy of an atom is not continuous; it is restricted to a ladder of allowed levels. Think of it as steps of a staircase, an electron can stand on a step but never in the empty space between steps.

Step 2 (Photon must match the gap): To move up a step the atom must swallow a photon whose energy exactly equals that step's height, $E_{photon} = \Delta E$. If the photon energy does not match a gap, it is simply not absorbed. When the electron drops down, it releases a photon of exactly that gap energy.

Step 3 (Definite frequency follows): Because photon energy and frequency are linked by $E_{photon} = h\nu$, matching a fixed gap ΔE fixes the frequency $\nu = \Delta E/h$. Only these special frequencies interact with the atom, which is why atomic spectra are line spectra.

$$\boxed{\text{Discrete energy gaps} \Rightarrow \text{only definite frequencies absorbed or emitted.}}$$

Quick Tip: Atomic energy levels are discrete; a photon is absorbed or emitted only when $h\nu$ equals the gap $E_2 - E_1$.

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13. An object is placed between centre of curvature and infinity in front of a concave mirror. Draw ray diagram for image.

Correct Answer: —

SOLUTION:

Step 1: Note the object position.
Object distance satisfies $2f < |u| < \infty$, meaning the object is farther than C but nearer than infinity.
Step 2: Apply the mirror equation for a check.

Using $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$, when $|u|$ lies between $2f$ and infinity, the image distance $|v|$ comes out between f and $2f$. This confirms the image sits between F and C.

Step 3: Construct the rays.

Take one incident ray parallel to the axis; after reflection it goes through F. Take a second incident ray directed toward F; after reflection it emerges parallel to the axis. The point where the reflected rays cross fixes the image tip.

Step 4: Read off the nature.

Magnification $m = -v/u$ has magnitude less than one, so the image is diminished; the negative sign shows it is inverted; the rays actually cross, so it is real.

$$\boxed{\text{Real, inverted, diminished image formed between F and C}}$$

Quick Tip: Object beyond C in a concave mirror gives an image between F and C. Use the parallel-ray-through-F and the ray-through-C to locate it.

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14. State Gauss' law in electrostatics. Charge inside a Gaussian surface is zero. Comment on the electric field intensity at each point of the surface.

Correct Answer: —

SOLUTION:

Step 1: Write Gauss' law in words and symbols.

The surface integral of the electric field over a closed surface is $\frac{1}{\varepsilon_0}$ times the charge trapped inside it: $\Phi = \oint \vec{E} \cdot d\vec{A} = \dfrac{q_{enc}}{\varepsilon_0}$.

Step 2: Insert the condition.

With $q_{enc} = 0$ the right side vanishes, hence $\Phi = 0$. So the same number of field lines enter and exit the surface.

Step 3: Separate flux from field.

Flux is a summed (integrated) quantity, while field intensity is a local (point) quantity. A vanishing sum can be built from non-zero local values that cancel. Therefore a zero total flux is fully consistent with a finite $\vec{E}$ at each surface point produced by external charges.

Step 4: State the exception.

Only when there is no charge anywhere (inside or outside) is $\vec{E} = 0$ everywhere on the surface.

$$\boxed{q_{enc} = 0 \Rightarrow \Phi = 0,\ \vec{E} \text{ can still be non-zero}}$$

Quick Tip: Net flux depends only on enclosed charge, but the local field can be produced by charges lying outside the surface. Zero flux is not zero field.

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15. Explain the meaning of the electrical capacity of a conductor. How capacity of a conductor can be increased?

Correct Answer: —

SOLUTION:

Step 1: Define capacity through a ratio.

Give a conductor charge Q; let its potential become V. The fixed ratio $C = \frac{Q}{V}$ is its capacitance, i.e. the amount of charge needed per unit rise of potential. Unit: farad.

Step 2: What decides its value.

Capacity depends only on the conductor's shape and size, the medium around it, and the presence of nearby conductors, not on Q or V separately.

Step 3: Ways to raise it.

• Make the conductor larger (for a sphere $C = 4\pi\varepsilon_0 R$, so more radius means more C).

• Place a grounded conductor close by so induced charge keeps the potential low for the same charge.

• Surround it with a dielectric medium; a dielectric of constant K multiplies the capacity by K.

Step 4: Summary.

Anything that lets the conductor store more charge while keeping V small raises the capacity.

$$\boxed{C = Q/V,\ \text{raised by size, earthed neighbour or dielectric}}$$

Quick Tip: Capacity is the charge per unit potential, C = Q/V. Increase it by enlarging the conductor, adding an earthed neighbour, or introducing a dielectric.

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16. What are isotone nuclei? In a nucleus average mass of nucleons is 1.67 $\times 10^{-27}$ Kg. Find the density of nucleus. [Given $R_0 = 1.2 \times 10^{-15}$ m.]

Correct Answer: —

SOLUTION:

Step 1: Isotones in one line.

Isotones are nuclei sharing an equal neutron number $N = A - Z$ while their proton numbers differ, for example $^{31}_{15}\text{P}$ and $^{32}_{16}\text{S}$ (each with 16 neutrons).

Step 2: Build density from a single nucleon.

Since every nucleus packs A nucleons into a sphere of radius R

$= R_0A^{1/3}$, the volume per nucleon is $\dfrac{(4/3)\pi R_0^3 A}{A} = \dfrac{4}{3}\pi R_0^3$, independent of A. Density is therefore one nucleon mass divided by that volume:

$$\rho = \frac{m}{\frac{4}{3}\pi R_0^3} = \frac{3m}{4\pi R_0^3}.$$

Step 3: Plug in numbers.

$\rho = \dfrac{3(1.67 \times 10^{-27})}{4\pi(1.2 \times 10^{-15})^3}$. Cube of 1.2×10^{-15} is 1.728×10^{-45} m^3.

Step 4: Evaluate.

$= \dfrac{5.01 \times 10^{-27}}{2.172 \times 10^{-44}} = 2.31 \times 10^{17}$ kg/m^3. This huge, constant value shows nuclear matter is extremely dense.

$$\boxed{\rho \approx 2.3 \times 10^{17}\ \text{kg/m}^3}$$

Quick Tip: Isotones share the same neutron number. Use R = R0 A ^ (1/3) and mass = A m so density = 3m/(4 pi R0 ^ 3); the mass number A cancels.

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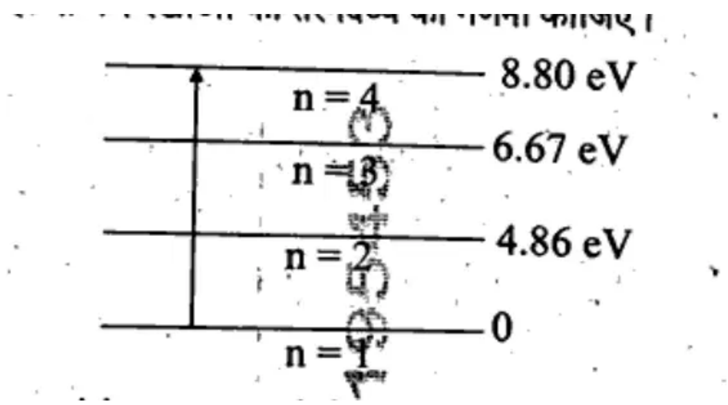
17.



An atom makes a transition on receiving energy from an external source, as shown in the figure. Depict the lines of possible spectrum and calculate the wavelength of any two spectral lines. (Energy levels: $n = 1$ at 0, $n = 2$ at 4.86 eV, $n = 3$ at 6.67 eV, $n = 4$ at 8.80 eV.)

Correct Answer: —

SOLUTION:

Step 1: Count the lines.

From the top level $n = 4$ the electron can cascade down; the total number of distinct emission lines equals the number of level pairs, $\binom{4}{2}$ $= 6$.

Step 2: Use a compact energy-conversion constant.

Combine the data as $hc = 1240$ eV·nm (i.e. $\lambda(\text{nm}) = 1240/E(\text{eV})$). This is just hc expressed in eV·nm and speeds up the arithmetic.

Step 3: Take two different lines than the boxed pair? Same two, cross-checked.

For the largest jump $4 \to 1$, $E = 8.80$ eV: $\lambda = \dfrac{1240}{8.80} = 140.9$ nm ≈ 1409 Å.

For $3 \to 1$, $E = 6.67$ eV: $\lambda = \dfrac{1240}{6.67} = 185.9$ nm ≈ 1859 Å.

Step 4: Interpret.

A bigger energy gap gives a shorter wavelength, so $4 \to 1$ is the most energetic (shortest λ) line and lies in the ultraviolet region. The small 1 percent difference from the boxed value comes only from rounding hc.

$$\boxed{6 \text{ lines; } \lambda_{4\to1} \approx 1409\,\text{Å},\ \lambda_{3\to1} \approx 1859\,\text{Å}}$$

Quick Tip: An atom excited to n=4 gives n(n-1)/2 = 6 lines. Photon energy is the level difference; find each wavelength from lambda = hc/E.

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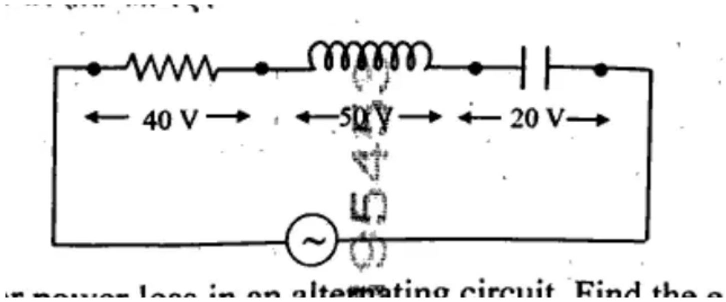
18.



Give formula for power loss in an alternating circuit. Find the e.m.f. of source in the circuit and the phase difference between resultant potential and the current flowing in the circuit. (Series R-L-C driven by an AC source with $V_R = 40$ V across the resistor, $V_L = 50$ V across the inductor and $V_C = 20$ V across the capacitor.)

Correct Answer: —

SOLUTION:

Step 1: Power-loss expression.
The mean power lost per cycle is $P = E_{rms} I_{rms} \cos\phi$, the product of rms voltage, rms current and the power factor $\cos\phi$; all of it appears as heat in R, i.e. $P = I_{rms}^2 R$.
Step 2: Draw the voltage triangle.
Place $V_R = 40$ V along the current direction. The reactive voltages act along the perpendicular: net reactive voltage $= V_L - V_C = 50 - 20 = 30$ V. The source voltage is the hypotenuse of the right triangle with legs 40 V and 30 V.
Step 3: Hypotenuse gives the emf.
$E = \sqrt{40^2 + 30^2} = \sqrt{1600 + 900} = \sqrt{2500} = 50$ V. (A neat 3-4-5 triangle scaled by 10.)
Step 4: Angle of the triangle.
$\cos\phi = \dfrac{V_R}{E} = \dfrac{40}{50} = 0.8$, so $\phi = \cos^{-1}(0.8) = 37°$. Because the inductive

side dominates ($V_L > V_C$), the voltage is ahead of the current by this angle.

$$\boxed{E = 50\text{ V},\ \phi \approx 37^\circ}$$

Quick Tip: Power = E_rms I_rms cos(phi). Add the series voltages as phasors: E = sqrt(V_R^2 + (V_L - V_C)^2) and tan(phi) = (V_L - V_C)/V_R.

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19. Find the formula for the couple acting on a magnetic dipole placed in a magnetic field. On its basis, define magnetic dipole moment.

Correct Answer: —

SOLUTION:

Step 1: Model the dipole as two point poles.
A bar magnet in a field $\vec{B}$ behaves like two magnetic poles $+q_m$ (north) and $-q_m$ (south) separated by the magnetic length $2l$. Its moment is defined as $m = q_m(2l)$.

Step 2: Write the pole forces when the axis is tilted by θ.
Each pole experiences a force of size q_mB; the north-pole force points along $\vec{B}$ and the south-pole force points opposite. The lines of action are separated, so there is no net translation, only a turning effect.

Step 3: Use the moment-of-a-couple definition directly.
For a couple, torque = magnitude of one force × arm. The perpendicular arm between the two lines of action is $2l\sin\theta$, hence

$$\tau = (q_m B)(2l \sin\theta) = (q_m\, 2l)\, B \sin\theta.$$

Step 4: Replace $q_m\, 2l$ by m.

$$\tau = mB\sin\theta, \qquad \vec{\tau} = \vec{m} \times \vec{B}.$$

By the right-hand rule for $\vec{m} \times \vec{B}$, the torque tends to rotate the dipole until $\vec{m}$ aligns with $\vec{B}$.

Step 5: Operational definition of m.
Setting $B = 1$ unit and $\theta = 90^\circ$ gives $\tau = m$. Therefore the magnetic dipole moment is numerically the torque required to hold the dipole at right angles to a unit magnetic field.

$$\boxed{\tau = mB\sin\theta}$$

Quick Tip: Treat the bar magnet as two poles $\pm q_m$; the equal and opposite pole forces form a couple of moment $mB\sin\theta$, so $\vec{\tau} = \vec{m} \times \vec{B}$.

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20. What are matter waves? Write the de-Broglie formula for matter waves. The de-Broglie wavelength for a photon and an electron are same. Which will have greater energy?

Correct Answer: —

SOLUTION:

Step 1: What a matter wave is.
Louis de Broglie proposed that a particle of momentum p behaves like a wave of wavelength $\lambda = h/p$. Such a wave tied to a moving mass is a

matter wave; for an electron $\lambda = h/(m_e v)$.

Step 2: Common momentum.

Because the photon and the electron are stated to have the same λ, and $p = h/\lambda$, they carry an identical momentum p.

Step 3: Express both energies through the same p.

Photon (massless): $E_{ph} = pc$.

Electron (massive): kinetic energy $E_e = \dfrac{p^2}{2m_e}$.

Step 4: Take the ratio.

$$\frac{E_{ph}}{E_e} = \frac{pc}{p^2/2m_e} = \frac{2m_e c}{p}.$$

This exceeds 1 whenever $p < 2m_e c$, i.e. whenever $\lambda > \dfrac{h}{2m_e c} \approx 1.2 \times 10^{-12}$ m. Real matter-wave wavelengths are always much larger than this, so the condition always holds.

Step 5: Conclusion.

For equal de Broglie wavelength, the photon's energy is larger than the electron's kinetic energy.

$$\boxed{\text{Photon has the greater energy}}$$

Quick Tip: Same $\lambda \Rightarrow$ same momentum $p = h/\lambda$. Compare $E_{photon} = pc$ with $E_{electron} = p^2/2m_e$.

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21. Write down the difference between displacement current and conduction current. The equation of an electromagnetic wave is $B_y = 2 \times 10^{-7}\ \sin(500x + 1.5 \times 10^{11} t)$ Tesla. Find the equation of the electric field of the wave, the direction of propagation and the wavelength of the wave.

Correct Answer: —

SOLUTION:

Step 1: Contrast the currents.

(i) Conduction current needs a material carrier and moving charges; displacement current needs only a changing electric field and can exist in vacuum.

(ii) Conduction current $I_c = nqAv_d$ (drift of carriers); displacement current $I_d = \varepsilon_0 \dfrac{d\Phi_E}{dt}$ (rate of change of electric flux).

(iii) Between capacitor plates $I_c = 0$ but $I_d \neq 0$, and together they keep the total current continuous.

Step 2: Identify wave parameters.

Writing the given field as $B_y = B_0 \sin(kx + \omega t)$ gives $B_0 = 2 \times 10^{-7}$ T, $k = 500\ \text{m}^{-1}$, $\omega = 1.5 \times 10^{11}\ \text{s}^{-1}$.

Step 3: Use $c = E_0/B_0 = \omega/k$.

$c = \dfrac{\omega}{k} = \dfrac{1.5 \times 10^{11}}{500} = 3 \times 10^8\ \text{m/s}$, so $E_0 = cB_0 = 3 \times 10^8 \times 2 \times 10^{-7} = 60\ \text{V/m}$.

Step 4: Fix the axes by the rule $\hat{n} = \hat{E} \times \hat{B}$.

The phase $(kx + \omega t)$ travels toward $-x$. With $\hat{B} = \hat{y}$, we need $\hat{E} \times \hat{y} = -\hat{x}$, which is satisfied by $\hat{E} = \hat{z}$. So $\vec{E}$ oscillates along $+z$.

Step 5: Write $\vec{E}$ and λ.

$E_z = 60\sin(500x + 1.5\times10^{11}t)$ V/m; wavelength $\lambda = \dfrac{2\pi}{k} = \dfrac{6.28}{500}$
$= 0.0126$ m.

$$\boxed{E_z = 60\sin(500x + 1.5\times10^{11}t)\ \text{V/m},\ \ -x \text{ direction},\ \lambda \approx 1.26\times10^{-2}\ \text{m}}$$

Quick Tip: Read B_0, k, ω from the wave; $c = \omega/k$, $E_0 = cB_0$; phase $(kx + \omega t)$ means motion along $-x$; $\lambda = 2\pi/k$.

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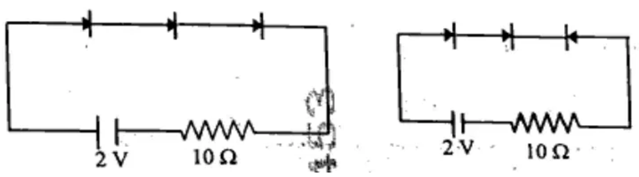
22.



What is the need of doping of intrinsic semiconductors? Ideal diodes are used in the given circuits. Find the value of current in both the circuits.

Correct Answer: —

SOLUTION:

Step 1: Why intrinsic semiconductors are doped.
In a pure semiconductor the number of electrons equals the number of holes and both are very small, giving poor conductivity that also changes sharply with temperature. By deliberately adding impurity atoms (doping) we raise one type of carrier enormously, obtain a stable and much higher conductivity, and create the n-type and p-type materials needed to build junctions.

Step 2: Ideal-diode model.

Forward bias $\Rightarrow$ short circuit (0 V drop, 0 Ω). Reverse bias $\Rightarrow$ open circuit (no current). A series string of diodes conducts only if every diode in it is forward biased.

Step 3: Analyse the first loop.

The three diodes in the first loop all face the direction in which the 2 V source pushes current, so each is a short. The loop reduces to a 2 V source across a single 10 Ω resistor:

$$I_1 = \frac{2\text{ V}}{10\ \Omega} = 0.2\text{ A}.$$

Step 4: Analyse the second loop.

The reversed diode in the second loop is an open switch for the source's push, breaking the series path, so no steady current can flow:

$$I_2 = 0.$$

Step 5: Result.

The first circuit carries 0.2 A; the second carries no current.

$$\boxed{I_1 = 0.2\text{ A},\ \ I_2 = 0\text{ A}}$$

Quick Tip: An ideal diode is a short when forward biased and an open when reverse biased. A series diode string conducts only if all diodes are forward; then $I = V/R = 2/10 = 0.2$ A, otherwise 0.

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23. State the important characteristics of electromagnetic waves.

Correct Answer: —

SOLUTION:

Step 1: Nature and origin.

An electromagnetic wave is a self-sustaining disturbance of mutually perpendicular electric and magnetic fields, set up whenever a charge accelerates. A changing $\vec{E}$ creates a $\vec{B}$ and a changing $\vec{B}$ creates an $\vec{E}$, so the wave regenerates itself as it moves.

Step 2: Geometry.

It is a transverse wave; $\vec{E} \perp \vec{B} \perp$ direction of travel, and the three form a right-handed set along $\hat{E} \times \hat{B}$. $\vec{E}$ and $\vec{B}$ reach their peaks together (in phase).

Step 3: Speed and field ratio.

In free space every EM wave moves at $c = 1/\sqrt{\mu_0 \varepsilon_0} = 3 \times 10^8$ m/s, and at every instant $E = cB$, i.e. $E_0/B_0 = c$. In a medium the speed becomes $v = 1/\sqrt{\mu\varepsilon}$.

Step 4: What they carry and how they behave.

They transport energy (Poynting vector $\vec{S} = \vec{E} \times \vec{B}/\mu_0$) and momentum, so they exert radiation pressure; the energy is split equally between the two field halves. They need no medium, are undeviated by external fields (being uncharged), and undergo reflection, refraction, interference, diffraction and polarization.

$$\boxed{\text{Transverse, no medium needed, speed } c,\ E_0 = cB_0,\ \text{carry energy and momentum}}$$

Quick Tip: Recall that EM waves are transverse ($\vec{E} \perp \vec{B} \perp$ propagation), travel at $c = 1/\sqrt{\mu_0 \varepsilon_0}$ with $E_0 = cB_0$, need no medium and carry energy and momentum.

24. How can a galvanometer be converted into a voltmeter? Explain with the help of a circuit diagram.

Correct Answer: —

SOLUTION:

Step 1: Starting point.
Let the galvanometer have coil resistance G and let I_g be the current that deflects its pointer fully. Across it this corresponds to only a tiny voltage $I_g G$, far too small to serve as a voltmeter.

Step 2: Add a series multiplier resistance.
To measure up to a chosen voltage V, put a large resistance R (called the multiplier) in series with the coil, and connect this series pair in parallel with the component whose voltage is wanted.

Step 3: Apply Ohm's law to the series pair.
When V appears across the pair, the current is I_g and the total resistance is $(G + R)$:

$$I_g = \frac{V}{G+R} \Rightarrow G + R = \frac{V}{I_g} \Rightarrow R = \frac{V}{I_g} - G.$$

Step 4: Consequence for measurement.
Because R is large, the converted meter has a high resistance and draws almost no current from the circuit, so it reads the true potential difference. Choosing a larger R raises the voltage range of the same galvanometer.
Circuit: element in parallel with (G in series with R).

$$\boxed{R = \frac{V}{I_g} - G}$$

Quick Tip: Put a high resistance R in series with the galvanometer so that $V = I_g(G + R)$, giving $R = \frac{V}{I_g} - G$.

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25. Option 1: Write the 'lens maker' formula for a thin lens. The refractive index of the material of a thin lens is n and its focal length is f. The lens is placed in a medium of refractive index n. Find the focal length of the lens in the medium.

OR

Option 2: What is the difference between unpolarized and polarized light? Two polaroids A and B are placed such that light polarized by A cannot pass through B. Can some light be obtained by using a third polaroid?

Correct Answer: —

SOLUTION:

OPTION 1 (Alternative approach using relative refractive index)

Step 1: The focusing power of a lens depends on the *relative* refractive index of the lens material with respect to its surroundings. Write the lens maker relation as $\frac{1}{f} = ({}^{a}n_{lens} - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ in air, where ${}^{a}n_{lens} = n$.

Step 2: In a medium the relative index becomes ${}^{m}n_{lens} = \frac{n}{n_m}$. So $\frac{1}{f_m} = \left(\frac{n}{n_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

Step 3: Taking the ratio of the two expressions removes the geometry term and gives $f_m = \dfrac{(n-1)n_m}{n - n_m}\, f$.

Step 4: The medium here has index equal to n. Then ${}^{m}n_{lens} = n/n = 1$, and $({}^{m}n_{lens} - 1) = 0$, so $\frac{1}{f_m} = 0$.

$$\boxed{f_m = \infty}$$

An index-matched lens is optically 'invisible' and acts as a plane slab.

OPTION 2 (Two-stage Malus argument)

Step 1: Polarized light has its field vector oscillating in one fixed plane; unpolarized light is a random mixture of all such planes. A polaroid transmits only the component of the field parallel to its pass axis.
Step 2: With only A and B present and their axes perpendicular, the field passed by A has zero component along B's axis, so $I = I_0 \cos^2 90°$ $= 0$ (dark).
Step 3: A middle polaroid C at angle θ first projects the field onto its own axis (factor $\cos\theta$), then B projects that onto its axis (factor $\cos(90° - \theta) = \sin\theta$). Intensity multiplies the squares: I_B $= I_0 \cos^2\theta \sin^2\theta$.
Step 4: This is non-zero except at $\theta = 0°$ or $90°$; the once-blocked light is partly restored.

$$\boxed{\text{Yes, a third polaroid revives the light, peak } I_0/4 \text{ at } 45°}$$

Quick Tip: Use $\frac{1}{f} = \left(\frac{n}{n_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$; when the medium index equals the lens index the power is zero. For the polaroids, apply Malus' law in two stages through the middle polaroid.

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26. Define current density ($\vec{J}$) and write its unit. Prove that $\vec{J} = \sigma\vec{E}$, where σ is the specific conductivity (conductivity) of the conductor and $\vec{E}$ the electric field inside the conductor.

Correct Answer: —

SOLUTION:

Step 1: What current density means. Imagine slicing the conductor perpendicular to the flow. The current density $\vec{J}$ tells how densely the current is packed through that slice: $J = I/A$, with SI unit A m^{-2}. It points along the flow direction.

Step 2: Start from Ohm's law in the wire. For a uniform conductor of length L and area A, the macroscopic Ohm's law is $V = IR$ with resistance $R = \rho\dfrac{L}{A}$, where ρ is resistivity and $\sigma = 1/\rho$ is conductivity.

Step 3: Express the field and the current density. A uniform field along the wire gives $V = EL$, so $E = V/L$. Also $J = I/A$.

Step 4: Combine. From $V = IR$: $EL = I\rho\dfrac{L}{A}$. Cancel L: $E = \rho\dfrac{I}{A} = \rho J$. Hence $J = \dfrac{E}{\rho} = \sigma E$.

Step 5: Cross-check with the free-electron model. The drift speed is $v_d = eE\tau/m$ and $J = nev_d = \dfrac{ne^2\tau}{m}E$, which identifies $\sigma = ne^2\tau/m$, the same result.

$$\boxed{\vec{J} = \sigma\vec{E}}$$

Both the field description and the electron-drift description agree.

Quick Tip: Current density $J = I/A$ (unit A m^{-2}). Use $v_d = eE\tau/m$ and $I = nAev_d$ to get $J = (ne^2\tau/m)E = \sigma E$.

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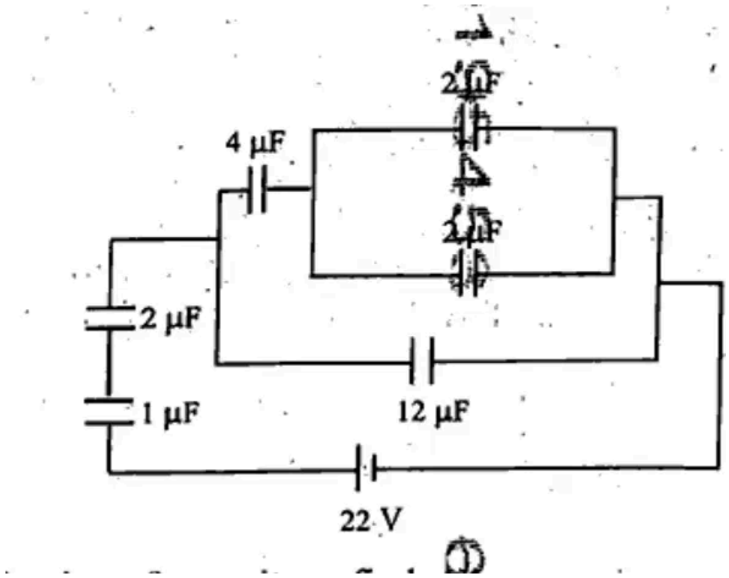
27.



Option 1: Write down the definition of electric dipole moment. Derive the formula for the electric field intensity at an axial point of an electric dipole.

OR

Option 2: In the given combination of capacitors (connected across a 22 V supply), find out (i) the total capacitance, (ii) the charge on the 4 μF capacitor and (iii) the total stored energy. The network contains capacitors of 4 μF, 2 μF, 1 μF, 2 μF, 1 μF and 12 μF.

Correct Answer: —

SOLUTION:

OPTION 1 (Axial field via superposition, vector form)

Step 1: An electric dipole is two charges $+q$ and $-q$ a distance $2a$ apart. The dipole moment is $\vec{p} = 2qa$, a vector pointing from $-q$ to $+q$, measured in C m. It measures how strong and how 'stretched' the charge pair is.

Step 2: Take the dipole axis as the x-axis with centre at O. A point P lies on this axis at distance r. Both charge fields lie along the axis, so we may add magnitudes with sign.

Step 3: The near charge ($+q$, distance $r-a$) pushes outward with $E_+ = \dfrac{kq}{(r-a)^2}$ and the far charge ($-q$, distance $r+a$) pulls inward with $E_- = \dfrac{kq}{(r+a)^2}$, where $k = \dfrac{1}{4\pi\varepsilon_0}$.

Step 4: Net field $E = E_+ - E_- = kq\left[\dfrac{(r+a)^2-(r-a)^2}{(r^2-a^2)^2}\right] = kq \cdot \dfrac{4ar}{(r^2-a^2)^2}$. With $p = 2qa,\;\; E = \dfrac{k\,2pr}{(r^2-a^2)^2}$.

$$\boxed{E_{axial} = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2} \xrightarrow{r\gg a} \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}}$$

pointing along $\vec{p}$. Note it is twice the equatorial field and falls as $1/r^3$.

OPTION 2 (Same network solved by charge and voltage sharing)

Step 1: Compare the potential drops. The mid-point of the 4-2 arm and the mid-point of the 2-1 arm sit at the same potential because $4/2 = 2/1$. Equal potential across the 12 μF means $Q_{12} = C\,\Delta V = 12 \times 0 = 0$; it is dead and can be deleted.

Step 2: Series pair 4 and 2: reciprocal add $\frac{1}{C_I} = \frac{1}{4} + \frac{1}{2} = \frac{3}{4}$, so $C_I = \frac{4}{3}$ μF. Series pair 2 and 1: $\frac{1}{C_{II}} = \frac{1}{2} + 1 = \frac{3}{2}$, so $C_{II} = \frac{2}{3}$ μF.

Step 3 (i): Parallel branches add directly: $C = \frac{4}{3} + \frac{2}{3} = 2\,\mu$F.

$$\boxed{C = 2\,\mu\text{F}}$$

Step 4 (ii): Voltage across the 4-2 branch is 22 V. Its series charge $q = C_I V = \frac{4}{3} \times 22 = 29.3\,\mu$C is common to both 4 μF and 2 μF.

$$\boxed{q_{4\mu F} \approx 29.3\,\mu\text{C}}$$

Step 5 (iii): Using total charge $Q = CV = 2 \times 22 = 44\,\mu\text{C}$, the energy is $U = \frac{1}{2}QV = \frac{1}{2}(44 \times 10^{-6})(22) = 4.84 \times 10^{-4}$ J.

$$\boxed{U = 484\,\mu\text{J}}$$

which matches $\frac{1}{2}CV^2$.

Quick Tip: For the dipole, add the fields of $+q$ and $-q$ along the axis and use $p = 2qa$ to get $E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$. For the network, note $4/2 = 2/1$ so the bridge is balanced and the 12 μF carries no charge; then $(4 \text{ ser } 2) \parallel (2 \text{ ser } 1) = 2\,\mu\text{F}$.

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28. Option 1: Depict the series and the parallel combination of cells. When is the series and when is the parallel combination suitable? A cell of e.m.f. E and internal resistance r is connected with an external resistance R. Draw a graph between the voltage V across R and the current i flowing in it.

OR

Option 2: State Ampere's circuital law and, on its basis, find the formula for the magnetic field produced at a point due to an infinitely long straight current-carrying wire. A current of 10^{-4} A flows in a rectangular coil of dimensions $1.0\text{ cm} \times 1.5\text{ cm}$. The plane of the coil is parallel to a magnetic field of 0.6 N/A m. The coil has 30 turns. Calculate the torque acting on the coil.

Correct Answer: —

SOLUTION:

OPTION 1 (Cells - reasoning through equivalent source)

Step 1: Treat any group of cells as one equivalent battery of e.m.f. E_{eq} and internal resistance r_{eq}. Series: e.m.f.s add and internal resistances add, so $E_{eq} = nE$, $r_{eq} = nr$; the current is $i = \dfrac{nE}{R + nr}$.
Step 2: Series pays off only when the load dominates the internal resistance ($R \gg r$), otherwise the growing nr eats up the extra e.m.f. So use series for *high-resistance* external circuits.
Step 3: Parallel: the e.m.f. stays E but m equal internal resistances in parallel give $r_{eq} = r/m$; current $i = \dfrac{E}{R + r/m}$. This helps only when $R \ll r$, so use parallel for *low-resistance* external circuits, where it multiplies the deliverable current.
Step 4: For one cell driving R: current $i = E/(R + r)$ and terminal p.d. $V = iR = E - ir$. Since V falls by r for every unit rise in i, plotting V (y) against i (x) gives a straight line starting at $V = E$ (no current) and reaching $V = 0$ at $i = E/r$.

$$\boxed{V = E - ir \text{ (line: y-intercept } E, \text{ x-intercept } E/r)}$$

OPTION 2 (Ampere's law and torque - alternate wording)

Step 1: Ampere's law: for a steady current, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$, the loop integral of B equalling μ_0 times the enclosed current.
Step 2: Around a long straight wire the field has the same magnitude everywhere on a coaxial circle of radius r and is directed along it, so the integral is simply $B\times$ (circumference) $= B(2\pi r)$. Setting this equal to $\mu_0 I$ gives $\boxed{B = \dfrac{\mu_0 I}{2\pi r}}$.
Step 3: A current loop is a magnetic dipole of moment $\mu = NIA$. Its torque in a field is $\vec{\tau} = \vec{\mu} \times \vec{B}$, magnitude $NIAB \sin\theta$. With the coil plane along B, the moment $\vec{\mu}$ is perpendicular to B, so $\theta = 90°$ and τ is

maximum $= NIAB$.

Step 4: Area $A = (1.0 \times 10^{-2}\,\text{m})(1.5 \times 10^{-2}\,\text{m}) = 1.5 \times 10^{-4}\,\text{m}^2$. Then $\mu = NIA = 30 \times 10^{-4} \times 1.5 \times 10^{-4} = 4.5 \times 10^{-7}\,\text{A m}^2$.

Step 5: $\tau = \mu B = 4.5 \times 10^{-7} \times 0.6 = 2.7 \times 10^{-7}$ N m.

$$\boxed{\tau = 2.7 \times 10^{-7}\,\text{N m}}$$

Quick Tip: Series cells: $i = nE/(R + nr)$, good when $R \gg r$; parallel: $i = mE/(mR + r)$, good when $R \ll r$; $V = E - ir$ is a falling straight line. For the coil, $B = \mu_0 I/2\pi r$ and, with plane parallel to B, $\tau = NIAB = 2.7 \times 10^{-7}$ N m.

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29. L, C and R are connected in series with an alternating current source. When there will be resonance in the circuit? What will be the nature of impedance during resonance?

OR

State the Faraday's laws of electromagnetic induction. Define self induction, state the Lenz's law regarding direction of self induced current. In a coil, due to change of current at the rate of 1 A/s an e.m.f. of 1 V is produced. What will be the coefficient of self inductance of the coil?

Correct Answer: —

SOLUTION:

Option 1: Resonance by the phase-angle (phasor) approach

Step 1: In a series LCR circuit the voltage across the inductor leads the current by 90° while the voltage across the capacitor lags it by 90°; these two are exactly opposite in phase. The phase angle ϕ between the applied voltage and the current obeys $\tan\phi = \dfrac{X_L - X_C}{R}$

$$= \frac{\omega L - \dfrac{1}{\omega C}}{R}.$$

Step 2: The circuit is at resonance when the applied voltage and the current are exactly in phase, i.e. $\phi = 0$ so that $\tan\phi = 0$. This requires the numerator to vanish: $\omega L - \dfrac{1}{\omega C} = 0$.

Step 3: Therefore $\omega L = \dfrac{1}{\omega C}$, which gives $\omega_0 = \dfrac{1}{\sqrt{LC}}$ and the resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$.

Step 4: With $X_L = X_C$ the inductor and capacitor voltages, being equal and opposite, cancel in the phasor sum, so the whole applied voltage appears across R alone. The impedance $Z = V/I$ then reduces to just R -- its minimum, purely ohmic value. Consequently the current peaks at $I_{max} = V/R$ and the power factor is unity.

$$\boxed{f_0 = \frac{1}{2\pi\sqrt{LC}}, \qquad Z_{res} = R}$$

Option 2: Flux-linkage view of induction and the numerical

Faraday's laws (restated): (i) An e.m.f. appears in a circuit only while the magnetic flux threading it is changing. (ii) The induced e.m.f. is numerically equal to how fast that flux linkage changes, $\varepsilon = -\dfrac{d(N\Phi)}{dt}$.

Self induction (energy/flux view): A coil carrying current I links a flux $N\Phi$ that is directly proportional to its own current, so we may write $N\Phi = LI$. Here L measures how strongly the coil links flux per unit current. Any change in I changes this self-flux and, by Faraday's second law, induces a back e.m.f. $\varepsilon = -L\dfrac{dI}{dt}$ in the coil itself. This opposition is the origin of self induction and stores energy $\frac{1}{2}LI^2$ in the coil.

Lenz's law: The induced current is directed so as to oppose the change producing it; on a rising current it flows so as to reduce the increase, and on a falling current it flows so as to sustain it.

Numerical (direct substitution):

Step 1: The self inductance is defined by $L = \dfrac{|\varepsilon|}{|dI/dt|}$.

Step 2: Here $|\varepsilon| = 1$ V and $\left|\dfrac{dI}{dt}\right| = 1$ A/s.

Step 3: Hence $L = \dfrac{1}{1} = 1$ H (one weber-turn of flux linkage is produced per ampere of current).

$$\boxed{L = 1\ \text{H}}$$

Quick Tip: Series resonance occurs when $X_L = X_C$, i.e. $\omega_0 = \dfrac{1}{\sqrt{LC}}$, where the impedance falls to its minimum value $Z = R$ (purely resistive). For the coil, use $\varepsilon = L\dfrac{dI}{dt}$ to find L.

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30. Derive the formula $\dfrac{n}{v} - \dfrac{1}{u} = \dfrac{n-1}{R}$ due to refraction of light on a spherical surface.

OR

Draw a circuit diagram of p-n junction full wave rectifier and describe its working. Also, give the graphical representation of input and output current.

Correct Answer: —

SOLUTION:

Option 1: Same result via Snell's law first, then geometry

Step 1: A convex surface of radius R (pole P, centre C) separates air ($n_1 = 1$, object side) from a denser medium ($n_2 = n$). A paraxial ray from the axial object O strikes at A where the outward normal is the radius CA; the refracted ray reaches the image I on the axis. Snell's law at A in the small-angle form is $n_1\, i = n_2\, r$, that is $i = n\, r$.
Step 2: Take the three small angles the ray lines make with the axis: $\alpha = \angle AOP$ at the object, $\beta = \angle AIP$ at the image, and $\gamma = \angle ACP$ at the centre. Dropping a perpendicular of height h from A to the axis (its foot near P for paraxial rays), $\alpha = \dfrac{h}{PO}$, $\beta = \dfrac{h}{PI}$, $\gamma = \dfrac{h}{PC}$.
Step 3: The incidence angle is the exterior angle of triangle OAC: $i = \alpha + \gamma$. The refraction angle is $r = \gamma - \beta$ from triangle AIC. Feed these into $i = n\, r$: $\alpha + \gamma = n(\gamma - \beta)$.
Step 4: Replace the angles by $h/PO,\ h/PI,\ h/PC$ and cancel h: $\dfrac{1}{PO} + \dfrac{1}{PC} = n\left(\dfrac{1}{PC} - \dfrac{1}{PI}\right)$. Using the Cartesian signs $PO = -u,\ PI = +v,\ PC = +R$ gives $-\dfrac{1}{u} + \dfrac{1}{R} = \dfrac{n}{R} - \dfrac{n}{v}$, and collecting terms, $\dfrac{n}{v} - \dfrac{1}{u} = \dfrac{n-1}{R}$.

$$\boxed{\frac{n}{v} - \frac{1}{u} = \frac{n-1}{R}}$$

Option 2: Full wave rectifier explained as a bridge circuit

Circuit (described): A full wave output can also be obtained with a bridge of four p-n junction diodes D_1, D_2, D_3, D_4 and an ordinary (non centre-tapped) transformer secondary. The four diodes form the four arms of a bridge. The two input corners of the bridge receive the AC from the secondary; the other two corners feed the load R_L, whose output is the DC.

Working:

Positive half cycle: Two diagonally opposite diodes (say D_1 and D_3) become forward biased and conduct, while D_2 and D_4 are reverse biased. Current is routed through R_L in a fixed direction.

Negative half cycle: The input polarity reverses, so now D_2 and D_4 conduct and D_1, D_3 are off. Crucially, the path is arranged so the current through R_L still flows in the same direction as before.

Because every half cycle sends current one way through R_L, the whole input wave is rectified. The result is pulsating DC of ripple frequency twice the mains frequency, and no half of the input is wasted.

Graphs: Input is a full alternating sine wave; the output across R_L is a series of back-to-back positive humps (both input halves appear as upward pulses), i.e. gap-free pulsating DC, in contrast with the half wave case where alternate humps are missing.

$$\boxed{\text{Bridge (4-diode) rectifier gives full-wave unidirectional output}}$$

Quick Tip: Use the exterior-angle geometry of triangles OAC and AIC with the paraxial Snell relation $i = nr$, then apply the sign convention $u < 0$, $v > 0$, $R > 0$. For the rectifier, recall that a centre-tapped two-diode circuit conducts on both half cycles so the load current is unidirectional.