NIOS Class 12 Physics Sample Paper-10

Duration: 180 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **43** Questions. The paper is divided into two sections: **Section A – 40** marks, **Section B – 40** marks.
- **Section A** consists of
  - **Q.No. 1 to 16** – Multiple Choice type questions (MCQs) carrying 1 mark each. Select and write the most appropriate option out of the four options given in each of these questions. An internal choice has been provided in some of these questions. You have to attempt only one of the given choices in such questions.
  - **Q. No. 17 to 28** – Objective type questions. Q. No. 17 to 28 carry 02 marks each (with 2 sub- parts of 1 mark each). Attempt these questions as per the instructions given for each of the questions 17 –28.
- **Section B** consists of
  - **Q.No. 29 to 37** – Very Short questions carrying 02 marks each to be answered in the range of 30 to 50 words.
  - **Q.No. 38 to 41** – Short Answer type questions carrying 03 marks each to be answered in the range of 50 to 80 words.
  - **Q.No. 42 and 43** – Long Answer type questions carrying 05 marks each to be answered in the range of 80 to 120 words.
- There is **No Negative marking**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Section: A

Q1. The dimensional formula for Gravitational Potential (V) at a point in a gravitational field is identical to the dimensional formula of: **(1)**

(A) Gravitational force per unit mass (g)

(B) Linear momentum per unit mass (p/m)

(C) Latent heat ($L = Q/m$)

(D) Angular momentum (L)

Q2. The moment of inertia of a uniform circular disc of mass M and radius R about a geometric axis passing perpendicularly through its center of mass is: **(1)**

(A) $\frac{1}{2}MR^2$

(B) $\frac{1}{4}MR^2$

(C) $\frac{5}{4}MR^2$

(D) $\frac{3}{2}MR^2$

Q3. If g is the acceleration due to gravity on the surface of Earth and R is the radius of Earth, the escape velocity (v_e) required to project a body vertically upward so that it permanently escapes Earth's gravitational pull is: **(1)**

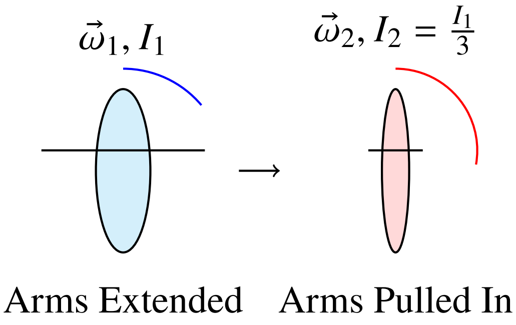
(A) $v_e = \sqrt{gR}$

(B) $v_e = \sqrt{\frac{2g}{R}}$

(C) $v_e = 2\sqrt{gR}$

(D) $v_e = \sqrt{2gR}$

Q4. A figure skater spinning freely on a frictionless horizontal ice surface with her arms extended has moment of inertia I_1 and angular velocity ω_1. When she pulls her arms close to her body as shown below, her moment of inertia decreases to $I_2 = \frac{1}{3}I_1$. Her new angular velocity ω_2 becomes: **(1)**



(A) $\omega_2 = \frac{1}{3}\omega_1$

(B) $\omega_2 = 3\omega_1$

(C) $\omega_2 = 9\omega_1$

(D) $\omega_2 = \sqrt{3}\omega_1$

Q5. The Modulus of Rigidity (Shear Modulus η) of a solid material is defined within its elastic limit as the ratio of: **(1)**

(A) Normal hydraulic stress to volumetric strain

(B) Longitudinal tensile stress to linear tensile strain

(C) Tangential shearing stress to angular shear strain

(D) Lateral compressive strain to longitudinal tensile strain

Q6. For a rigid diatomic ideal gas (such as N_2 or O_2 at room temperature) possessing 5 degrees of freedom (3 translational and 2 rotational), the adiabatic ratio of specific heat capacities ($\gamma = C_p/C_v$) is: **(1)**

(A) $\frac{5}{3} \approx 1.67$

(B) $\frac{7}{5} = 1.40$

(C) $\frac{9}{7} \approx 1.29$

(D) $\frac{4}{3} \approx 1.33$

Q7. A particle executes Simple Harmonic Motion (SHM) along a straight line with a linear displacement frequency f. The frequency with which its instantaneous kinetic energy and instantaneous potential energy oscillate is: **(1)**

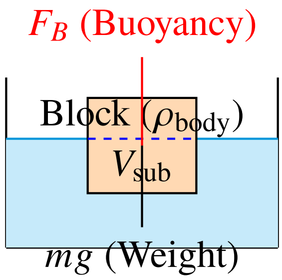
(A) $\frac{f}{2}$

(B) f

(C) $4f$

(D) $2f$

Q8. A uniform solid wooden block of density ρ_{body} floats in a liquid of density ρ_{liquid} ($\rho_{\text{liquid}} > \rho_{\text{body}}$) in static equilibrium as shown below. According to Archimedes' principle, the fraction of the total volume of the block submerged inside the liquid ($V_{\text{sub}}/V_{\text{total}}$) is: **(1)**



(A) $\frac{\rho_{\text{body}}}{\rho_{\text{liquid}}}$

(B) $\frac{\rho_{\text{liquid}}}{\rho_{\text{body}}}$

(C) $1 - \frac{\rho_{\text{body}}}{\rho_{\text{liquid}}}$

(D) $\sqrt{\frac{\rho_{\text{body}}}{\rho_{\text{liquid}}}}$

Q9. A hollow spherical metallic conductor of outer radius R carries a total positive electrostatic charge $+Q$ distributed uniformly over its outer surface. The electric field intensity (E) at any internal point situated at a radial distance $r < R$ from the geometric center is: **(1)**

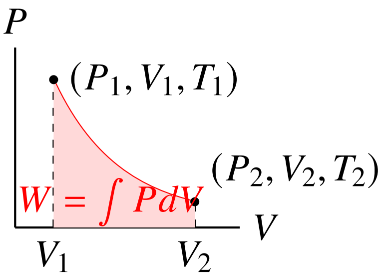
(A) $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

(B) $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

(C) Exactly zero ($E = 0$)

(D) $E = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$

Q10. When n moles of an ideal gas having adiabatic ratio γ undergo a reversible adiabatic expansion ($Q = 0$) from an initial thermodynamic state (P_1, V_1, T_1) to a final state (P_2, V_2, T_2), the external mechanical work done (W) by the gas is: **(1)**



(A) $W = nRT_1 \ln\left(\frac{V_2}{V_1}\right)$

(B) $W = P_1(V_2 - V_1)$

(C) $W = nC_v(T_2 - T_1)$

(D) $W = \frac{nR}{\gamma-1}(T_1 - T_2) = \frac{P_1V_1-P_2V_2}{\gamma-1}$

Q11. The magnitude of magnetic field induction B inside a long, closely wound solenoid having n turns per unit length ($n = N/L$) carrying a steady electric current I is given by: **(1)**

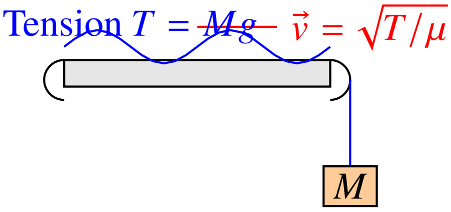
(A) $B = \mu_0 nI$

(B) $B = \frac{\mu_0 nI}{2}$

(C) $B = \frac{\mu_0 I}{2\pi n}$

(D) $B = \mu_0 n^2 I$

Q12. A transverse mechanical wave travels along a stretched vibrating string under tension T. If the mass per unit length (linear mass density) of the string is μ, the speed of propagation (v) of the transverse wave is: **(1)**



(A) $v = \frac{T}{\mu}$

(B) $v = \sqrt{\frac{T}{\mu}}$

(C) $v = \sqrt{\frac{\mu}{T}}$

(D) $v = T\sqrt{\mu}$

Q13. According to Brewster's Law of optical polarization, when unpolarized monochromatic light is incident on a dielectric surface of refractive index μ at the polarizing angle of incidence (i_p), the reflected light is completely plane-polarized. The polarizing angle i_p satisfies: **(1)**

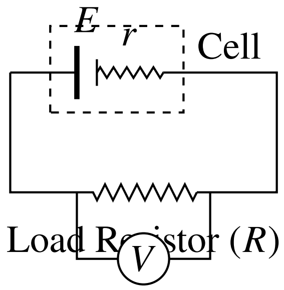
(A) $\tan i_p = \mu$

(B) $\sin i_p = \mu$

(C) $\cos i_p = \frac{1}{\mu}$

(D) $\tan i_p = \frac{1}{\mu}$

Q14. A primary chemical cell of electromotive force E and internal resistance r is connected across an external load resistor R as shown below. When a steady current I flows through the circuit, the terminal potential difference across the load resistor measured by voltmeter V is V. The internal resistance r of the cell is: **(1)**



(A) $r = R\left(\frac{V}{E} - 1\right)$

(B) $r = R\left(\frac{E-V}{E}\right)$

(C) $r = R\left(\frac{E}{V} - 1\right)$

(D) $r = R\left(\frac{V}{E+V}\right)$

Q15. When a parallel beam of monochromatic light of wavelength λ is diffracted by a single narrow slit of width a, a diffraction pattern is observed on a screen. The angular position (θ_n) of the n^{th} secondary dark minimum on either side of the central bright maximum is given by: **(1)**

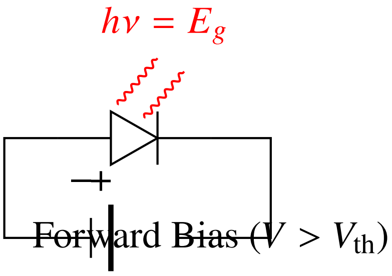
(A) $a\cos\theta_n = n\lambda$

(B) $a\sin\theta_n = (2n-1)\frac{\lambda}{2}$

(C) $a\tan\theta_n = n\lambda$

(D) $a\sin\theta_n = n\lambda \quad (n = 1, 2, 3, \ldots)$

Q16. A Light Emitting Diode (LED) is a specialized optoelectronic p-n junction diode that emits visible or infrared light when electric current flows through it. To achieve photon emission via spontaneous electron-hole recombination across the band gap E_g, the LED must be connected under: **(1)**



(A) Reverse bias exceeding avalanche breakdown voltage

(B) Forward bias exceeding the junction threshold cut-in voltage

(C) Zero bias without any external battery source

(D) Alternating current (AC) high-voltage resonance

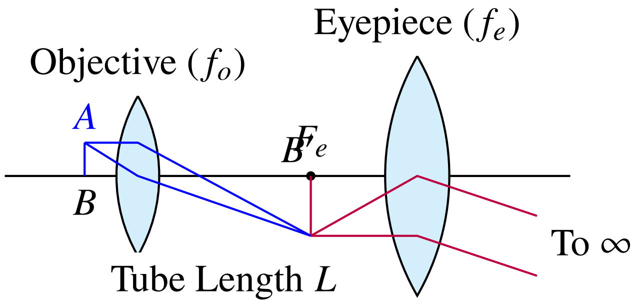
Note: Q. No. 17 to 28 are objective type questions carrying 02 marks each (with 2 sub-parts of 1 mark each).

Q17. Complete the following statements regarding frictional forces and circular motion by filling in the blanks:
(Angle of Friction, Angle of Repose, Centripetal Force, Centrifugal Force) **(2)**

1. The angle ϕ which the resultant contact force between two rough surfaces makes with the normal reaction N, related to static friction coefficient by $\tan\phi = \mu_s$, is called the ....
2. The radial inward force $F_c = \frac{mv^2}{r}$ required to keep a particle of mass m moving uniformly along a circular trajectory of radius r is called the ....

Q18. Read the short passage given below regarding optical microscopes and answer the two sub-questions:
A Compound Microscope is an optical instrument utilized for producing high linear magnification of extremely tiny microscopic objects. As shown in the ray diagram below, it mounts two converging lenses at the ends of a coaxial tube: an objective lens of very short focal length f_o and small aperture, and an eyepiece lens of short focal length f_e and larger aperture. In normal adjustment (relaxed eye), the real inverted intermediate image A'B' formed by the objective

lies exactly at the principal focus F_e of the eyepiece, emerging as parallel rays from the eyepiece at infinity. **(2)**



1. Write the formula for the magnifying power (M_∞) of a compound microscope in normal adjustment (infinity focus) in terms of optical tube length L, f_o, f_e, and least distance of distinct vision D.
2. Why must both the objective focal length (f_o) and eyepiece focal length (f_e) be chosen as extremely short as possible to achieve high compounding magnifying power?

Q19. Read the short passage given below regarding electrical power transmission and answer the two sub-questions:

Electric power generated at central power stations is transmitted over long distances to cities via metallic transmission lines. When a steady current I flows through transmission cables of total resistance R, electrical energy is continuously wasted as thermal Joule heating at a rate $P_{\text{loss}} = I^2R$. To minimize this power loss, step-up transformers at generating stations step up the AC voltage to extremely high levels (e.g., 132 kV or 400 kV). **(2)**

1. For a given transmitted electrical power $P = VI$, by what factor does the Joule heating power loss (I^2R) decrease if the transmission voltage V is stepped up by a factor of 10 (ten times)?
2. What is the primary electrical function of a Step-Down transformer installed at city distribution substations before supplying power to domestic households?

Q20. Read the short passage given below regarding Bohr's quantum theory of the hydrogen atom and answer the two sub-questions:

According to Bohr's theory, the total mechanical energy of an electron in the n^{th} stationary orbit of a hydrogen atom is quantized and given by $E_n = -\frac{13.6}{n^2}$ eV. The lowest energy state ($n = 1$, $E_1 = -13.6$ eV) is called the ground state, while states with $n \geq 2$ are called excited states. To lift an electron from a lower state n_i to a higher state n_f, an exact excitation energy $\Delta E = E_{n_f} - E_{n_i}$ must be absorbed. **(2)**

1. What is the numerical value of the first excitation energy (in eV) required to excite a ground-state hydrogen electron ($n = 1$) to the first excited state ($n = 2$)?
2. What is meant by the Ionization Potential of a hydrogen atom? State its exact numerical value in volts (V).

Q21. Match the mechanical fatigue and fluid terms in Column I with their correct defining phenomena in Column II: **(2)**

Column I	**Column II**
(a) Elastic Fatigue	(i) Dimensionless parameter governing transition from streamline to turbulent flow
(b) Elastic After-Effect	(ii) Attractive intermolecular force operating between molecules of the same substance
(c) Reynolds Number (N_R)	(iii) Loss of elastic strength in a material subjected to repeated alternating stresses
(d) Cohesive Force	(iv) Temporary delay exhibited by an elastic body in regaining original shape upon load removal

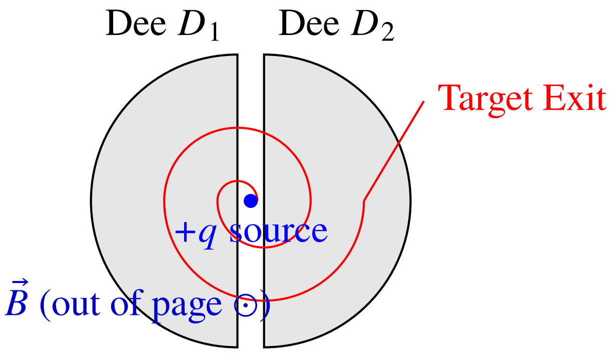
Q22. Match the solid-state semiconductor classifications in Column I with their carrier charge density characteristics in Column II: **(2)**

Column I	**Column II**
(a) Intrinsic Semiconductor	(i) Doped with pentavalent donor impurities (P, As); electron density far exceeds holes ($n_e \gg n_h$)
(b) Extrinsic n-type	(ii) Region near p-n junction devoid of free mobile charge carriers containing immobile ionized atoms
(c) Extrinsic p-type	(iii) Pure semiconductor crystal where conduction electron density strictly equals hole density ($n_e = n_h$)
(d) Depletion Region	(iv) Doped with trivalent acceptor impurities (B, Al); hole density far exceeds electrons ($n_h \gg n_e$)

Q23. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement regarding optical wave superposition: **(2)**

1. The optical phase difference ($\Delta\phi$, in radians) between two coherent light waves arriving at a point on a screen is related to their geometric path difference (Δx) by the formula $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$.
2. Constructive interference (bright fringe formation) occurs at points on a screen where the geometric path difference between two interfering coherent waves is an odd integral multiple of half-wavelength ($\Delta x = [2n - 1]\frac{\lambda}{2}$).

Q24. Read the short passage given below regarding magnetic Lorentz forces and observe the Cyclotron particle trajectory diagram:
When a positively charged particle of charge q and mass m enters a uniform magnetic field $\vec{B}$ perpendicular to its velocity $\vec{v}$ ($\theta = 90°$), it is deflected into a circular trajectory of radius $r = \frac{mv}{qB}$ inside hollow metallic D-shaped dees. As illustrated below in a Cyclotron particle accelerator, the frequency of revolution ($f = \frac{qB}{2\pi m}$) is completely independent of the particle's orbital radius and speed. **(2)**



1. Write the mathematical expression for the kinetic energy (K_{max}) attained by a charged ion of charge q and mass m when it exits the cyclotron at the maximum dee radius R_{max}.
2. Why can a Cyclotron not be used to accelerate light neutral particles (like neutrons) or extremely low-mass electrons to high relativistic speeds?

Q25. Complete the following statements regarding optical interference by filling in the blanks:
(Coherent Sources, Monochromatic Light, Constructive Interference, Destructive Interference) **(2)**

1. In Young's Double Slit Experiment, points on the observation screen where two superposing light waves arrive exactly in phase ($\Delta x = n\lambda$), reinforcing each other to produce bright intensity bands, undergo ....
2. Points on the screen where the two superposing waves arrive exactly out of phase (180° phase opposition, $\Delta x = [2n - 1]\lambda/2$), canceling each other to produce dark zero-intensity bands, undergo ....

Q26. Match the nuclear parameters and laws in Column I with their corresponding algebraic formulas in Column II: **(2)**

Column I	**Column II**
(a) Nuclear Mass Defect (Δm)	(i) Exponential decay formula: $N(t) = N_0 e^{-\lambda t}$
(b) Nuclear Binding Energy (BE)	(ii) Half-life relation with decay constant: $T_{1/2} = \frac{0.693}{\lambda}$
(c) Rutherford-Soddy Decay Law	(iii) Einstein mass-energy equivalence: $BE = \Delta m \times c^2$
(d) Radioactive Half-Life ($T_{1/2}$)	(iv) Mass difference: $\Delta m = [Zm_p + (A - Z)m_n] - M_{\text{nucleus}}$

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement regarding nuclear stability and binding energy: **(2)**

1. In the curve of binding energy per nucleon ($\overline{BE}$) versus mass number A, the maximum stability peak occurs around Iron-56 ($^{56}_{26}\text{Fe}$), which has the highest binding energy per nucleon of approximately 8.75 MeV/nucleon.
2. Heavy nuclei ($A > 200$) can release thermonuclear energy by merging together via nuclear fusion, whereas very light nuclei ($A < 10$) release energy by splitting via nuclear fission.

Q28. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement regarding electronic communication modulation and propagation: **(2)**

1. In Amplitude Modulation (AM), the Modulation Index ($m = A_m/A_c$) is the ratio of peak modulating audio voltage to peak carrier voltage, and must be kept ≤ 1.0 (100%) to prevent waveform distortion and clipping.
2. In Space Wave (line-of-sight) transmission, the maximum line-of-sight communication distance (d) between a transmitting antenna of height h_t and receiving antenna of height h_r over Earth of radius R is $d = \sqrt{2Rh_t} + \sqrt{2Rh_r}$.

Section: B

Q29. (i) Define Gravitational Field Intensity ($\vec{E}_g$) and Gravitational Potential (V) at a point in space due to a massive body. Write their respective SI units (N kg^{-1} and J kg^{-1}).

OR

(ii) Define the Impulse ($\vec{J}$) of a variable force acting on a body over a short time duration Δt. Write its mathematical formula ($\vec{J} = \int \vec{F} dt = \vec{F}_{\text{avg}} \Delta t$) and state the Impulse-Momentum Theorem ($\vec{J} = \Delta \vec{p}$). **(2)**

Q30. State the Second Law of Thermodynamics in its two classical macroscopic formulations: (a) Kelvin-Planck Statement regarding cyclic heat engine efficiency, and (b) Clausius Statement regarding heat transfer from cold to hot bodies. **(2)**

Q31. (i) Define Magnetic Permeability (μ) and Magnetic Susceptibility (χ_m) of a magnetic material. State the fundamental mathematical relation connecting relative permeability (μ_r) and susceptibility ($\mu_r = 1 + \chi_m$).

OR

(ii) Define Capacitance ($C = Q/V$) of an electrical conductor and state its SI unit (Farad). On what three physical factors does the capacitance of a parallel plate capacitor depend? **(2)**

Q32. Distinguish clearly between a Real Image and a Virtual Image in geometrical optics by writing two fundamental physical differences regarding actual ray intersection and projection onto an observation screen. **(2)**

Q33. What is the Power Factor ($\cos\phi$) of an alternating current (AC) circuit? Explain clearly why the average electrical power consumed in an ideal purely inductive or purely capacitive AC circuit is strictly zero (termed Wattless Current). **(2)**

Q34. Calculate the de Broglie wavelength (λ, in meters and angstroms Å) associated with a thermal neutron of mass $m_n = 1.67 \times 10^{-27}$ kg moving with a thermal kinetic energy of $E_k = 0.04$ eV.
(Given: Planck's constant $h = 6.63 \times 10^{-34}$ J s, 1 eV $= 1.6 \times 10^{-19}$ J). **(2)**

Q35. State the basic physical principle of Huygens' Construction of secondary wavelets. Explain clearly how an expanding spherical wavefront propagating in a homogeneous isotropic medium is geometrically constructed over a time interval Δt. **(2)**

Q36. (i) State the Rutherford-Soddy Law of Radioactive Decay ($\frac{dN}{dt} = -\lambda N$). Derive mathematically that the number of undecayed nuclei in a radioactive sample decreases exponentially over time ($N(t) = N_0 e^{-\lambda t}$).

OR

(ii) Define Alpha (α), Beta (β^-), and Gamma (γ) radioactive decays. Write one typical balanced nuclear disintegration equation illustrating each of these three decay types. **(2)**

Q37. (i) Draw the standard logic gate symbol and write the complete truth table for a two-input Exclusive-OR (EX-OR / XOR) gate. Write its Boolean algebraic expression ($Y = A \oplus B = A\overline{B} + \overline{A}B$).

OR

(ii) What is the physical significance of the Modulation Index ($m = A_m/A_c$) in Amplitude Modulation (AM)? Explain clearly why the modulation index must always be maintained strictly less than or equal to unity ($m \leq 1.0$ or $\leq 100\%$) in AM radio broadcasting. **(2)**

Q38. (i) Derive an expression for the gravitational potential energy (U) of an object of mass m situated at an altitude h above the surface of a spherical Earth of radius R and mass M ($U = -\frac{GMm}{R+h}$). Show that for small elevations ($h \ll R$), the gain in potential energy reduces to the linear relation $\Delta U \approx mgh$.

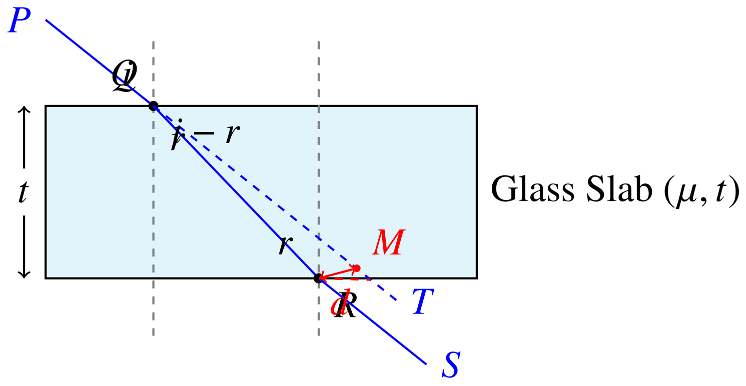
OR

(ii) Derive an expression for the moment of inertia (I) of a uniform solid cylinder of total mass M, geometric radius R, and axial length L about its central longitudinal axis of cylinder symmetry ($I = \frac{1}{2}MR^2$). **(3)**

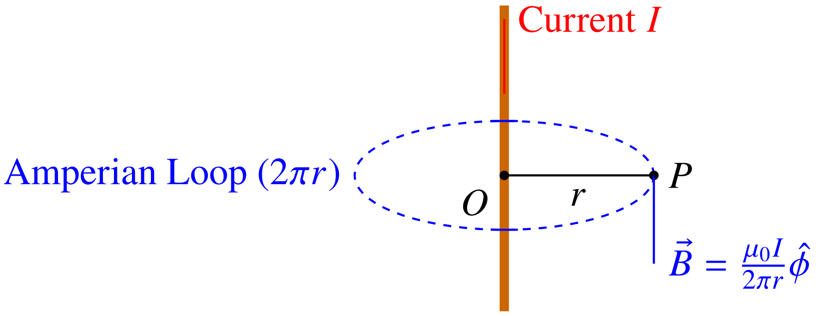
Q39. State the empirical laws of static and kinetic friction. Derive an analytical expression for the linear acceleration (a) of a body of mass m sliding down a rough inclined plane of inclination θ having coefficient of kinetic friction μ_k ($a = g[\sin\theta - \mu_k \cos\theta]$). How is angle of repose (α) related to static friction coefficient ($\tan\alpha = \mu_s$)? **(3)**

Q40. Derive an expression for the electric field intensity $\vec{E}$ at a perpendicular distance r situated outside an infinitely large, uniformly charged thin planar sheet of charge having surface charge density σ using Gauss's law in electrostatics ($E = \frac{\sigma}{2\varepsilon_0}$). Show that the electric field is uniform and independent of distance r. **(3)**

Q41. Derive an expression for the lateral shift (d) of a monochromatic light ray refracted across a parallel-faced rectangular glass slab of thickness t and absolute refractive index μ: $d = \frac{t\sin(i-r)}{\cos r}$. Include a clean labeled geometric ray diagram. **(3)**



Q42. (i) Using Ampere's Circuital Law, derive an expression for the magnetic field induction $\vec{B}$ at a perpendicular distance r from an infinitely long straight conductor carrying a steady electric current I: $B = \frac{\mu_0 I}{2\pi r}$. Include a diagram showing concentric circular magnetic field lines.

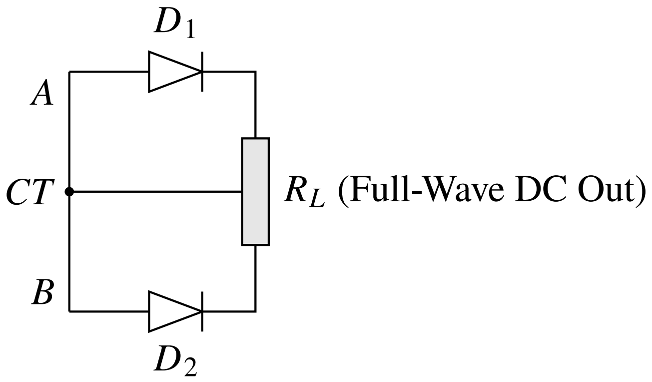


(ii) Using this expression, show mathematically why two parallel straight conductors carrying currents in the same (parallel) direction exert a mutual attractive magnetic force on each other.

OR

(iii) Describe the principle, construction, and working of a static electrical Transformer. Derive the voltage-turn-current transformation ratio $\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$ for an ideal 100% efficient transformer. **(5)**

Q43. (i) Describe the construction and working of a Center-Tapped Full-Wave Rectifier using two semiconductor diodes (D_1, D_2) and a center-tapped transformer secondary with a labeled circuit schematic and input/output voltage waveforms.



(ii) Define rectifying efficiency (η) and ripple factor (γ). Show clearly why full-wave rectification delivers double the fundamental ripple frequency ($2f$) of the input AC supply (f).

OR

(iii) Describe the construction and transistor action of a p-n-p Bipolar Junction Transistor (BJT) operating as a voltage amplifier in Common-Base (CB) configuration. Define DC current amplification factor $\alpha_{\text{dc}} = \frac{I_C}{I_E}$ and derive its mathematical relation with common-emitter gain β_{dc} ($\alpha = \frac{\beta}{1+\beta}$). **(5)**

Detailed Solutions

Q1.

Solution

Concept: Gravitational potential V at a point is work done per unit mass in bringing a body from infinity to that point: $V = \frac{W}{m}$.

Step 1 — Dimensional formula of work $W = [\mathrm{M}^1\mathrm{L}^2\mathrm{T}^{-2}]$ and mass $m = [\mathrm{M}^1]$:

$$[V] = \frac{[\mathrm{M}^1\mathrm{L}^2\mathrm{T}^{-2}]}{[\mathrm{M}^1]} = [\mathrm{M}^0\mathrm{L}^2\mathrm{T}^{-2}]$$

Step 2 — Latent heat L is thermal heat required per unit mass during phase transition: $L = \frac{Q}{m} \implies [L] = \frac{[\mathrm{M}^1\mathrm{L}^2\mathrm{T}^{-2}]}{[\mathrm{M}^1]} = [\mathrm{M}^0\mathrm{L}^2\mathrm{T}^{-2}]$.

Why other options are wrong:

- **Option A:** Gravitational acceleration g is $[\mathrm{M}^0\mathrm{L}^1\mathrm{T}^{-2}]$.
- **Option B:** Linear momentum per unit mass is velocity: $[\mathrm{M}^0\mathrm{L}^1\mathrm{T}^{-1}]$.
- **Option D:** Angular momentum $L = mvr$ is $[\mathrm{M}^1\mathrm{L}^2\mathrm{T}^{-1}]$.

Final Answer: $\boxed{\text{Latent heat } (L = Q/m)}$ (Option C)

$\boxed{\textbf{Answer: (C)}}$ **Go Back to Question 1**

Q2.

Solution

Concept: For a uniform circular disc of mass M and radius R, moment of inertia about its perpendicular central axis is obtained by integrating elemental ring inertias $(dm)r^2$.

Step 1 — By standard integration over concentric rings from radius 0 to R:

$$I_{\text{disc}} = \int_0^R r^2 dm = \int_0^R r^2 \left(\frac{2M}{R^2} r dr\right) = \frac{2M}{R^2}\left[\frac{r^4}{4}\right]_0^R = \frac{1}{2}MR^2$$

Why other options are wrong:

- **Option B:** $\frac{1}{4}MR^2$ is the moment of inertia of the disc about any of its planar diameters ($I_{\text{diameter}} = I_{\text{cm}}/2$).
- **Option C:** $\frac{5}{4}MR^2$ is about a tangential axis lying in the plane of the disc.
- **Option D:** $\frac{3}{2}MR^2$ is about a tangential axis perpendicular to the plane.

Final Answer: $\boxed{\frac{1}{2}MR^2}$ (Option A)

Answer: (A) Go Back to Question 2

Q3.

Solution

Concept: Escape velocity is derived by equating surface kinetic energy $\frac{1}{2}mv_e^2$ to gravitational binding energy $\frac{GMm}{R}$.

Step 1 — Solving for escape velocity: $v_e = \sqrt{\frac{2GM}{R}}$.

Step 2 — Substitute surface gravity relation $g = \frac{GM}{R^2} \implies GM = gR^2$:

$$v_e = \sqrt{\frac{2(gR^2)}{R}} = \sqrt{2gR}$$

Why other options are wrong:

- **Option A:** $\sqrt{gR}$ is the orbital velocity (v_0) of a near-Earth grazing satellite.
- **Option B:** Inverted radius term.
- **Option C:** $2\sqrt{gR}$ places factor 2 outside square root (four times kinetic requirement).

Final Answer: $\boxed{v_e = \sqrt{2gR}}$ (Option D)

Answer: (D) Go Back to Question 3

Q4.

Solution

Concept: Since no external rotational torque acts on the skater ($\tau_{\text{ext}} = 0$), her total angular momentum remains strictly conserved: $L = I_1\omega_1 = I_2\omega_2$.

Step 1 — Equating initial and final angular momentum:

$$I_1\omega_1 = I_2\omega_2$$

Step 2 — Substitute $I_2 = \frac{1}{3}I_1$:

$$I_1\omega_1 = \left(\frac{1}{3}I_1\right)\omega_2 \implies \omega_2 = 3\omega_1$$

When rotational inertia decreases threefold, angular spinning velocity triples.

Why other options are wrong:

- **Option A:** One-third velocity occurs if inertia were tripled.
- **Option C:** Ninefold increase would require kinetic energy conservation rather than momentum conservation.
- **Option D:** $\sqrt{3}\omega_1$ assumes angular velocity scales with square root of inertia.

Final Answer: $\boxed{\omega_2 = 3\omega_1}$ (Option B)

Answer: (B) **Go Back to Question 4**

Q5.

Solution

Concept: Modulus of Rigidity (Shear Modulus η) characterizes a material's elastic resistance to shear deformation (shape distortion without volume change).

Step 1 — By definition within Hooke's elastic limit, shear modulus is the ratio of tangential shearing stress (F_t/A) applied parallel to a surface to the resulting angular shear strain (θ, angle of shear distortion):

$$\eta = \frac{\text{Tangential Shearing Stress}}{\text{Angular Shear Strain}} = \frac{F_t/A}{\theta}$$

Why other options are wrong:

- **Option A:** Normal hydraulic stress to volumetric strain defines Bulk Modulus (B).
- **Option B:** Longitudinal tensile stress to linear tensile strain defines Young's Modulus (Y).
- **Option D:** Lateral strain over longitudinal strain defines Poisson's Ratio (σ).

Final Answer: $\boxed{\text{Tangential shearing stress to angular shear strain}}$ (Option C)

Answer: (C) **Go Back to Question 5**

Q6.

Solution

Concept: By equipartition of energy, each degree of freedom contributes $\frac{1}{2}R$ to molar specific heat. For rigid diatomic gas ($f = 3$ trans + 2 rot = 5), $C_v = \frac{5}{2}R$ and $C_p = \frac{7}{2}R$.

Step 1 — Calculate the ratio of specific heat capacities $\gamma = \frac{C_p}{C_v}$:

$$\gamma = \frac{\frac{7}{2}R}{\frac{5}{2}R} = \frac{7}{5} = 1.40$$

Why other options are wrong:

- **Option A:** $\frac{5}{3} \approx 1.67$ applies to monoatomic ideal gases ($f = 3$).
- **Option C:** $\frac{9}{7} \approx 1.29$ applies to non-rigid vibrating diatomic gases ($f = 7$).
- **Option D:** $\frac{4}{3} \approx 1.33$ applies to non-linear polyatomic gases ($f = 6$).

Final Answer: $\boxed{\frac{7}{5} = 1.40}$ (Option B)

Answer: (B) **Go Back to Question 6**

Q7.

Solution

Concept: In SHM, displacement is $x = A\sin(2\pi f t)$. Kinetic energy is $K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2 A^2 \cos^2(2\pi f t) = \frac{1}{4}m\omega^2 A^2[1 + \cos(4\pi f t)]$.

Step 1 — Since $\cos^2\theta = \frac{1+\cos 2\theta}{2}$, squaring trigonometric harmonic terms doubles the angular frequency from $2\pi f$ to $4\pi f = 2\pi(2f)$.

Step 2 — Therefore, both instantaneous kinetic energy and potential energy oscillate at exactly **double ($2f$)** the frequency of linear displacement.

Why other options are wrong:

- **Option A:** Half frequency occurs in sub-harmonic parametric oscillations.
- **Option B:** Frequency f applies to displacement, velocity, and acceleration.
- **Option C:** $4f$ would require fourth-power displacement dependence.

Final Answer: $\boxed{2f}$ (Option D)

Answer: (D) **Go Back to Question 7**

Q8.

Solution

Concept: In floating equilibrium, upward buoyant force equals downward gravitational weight of the body: $F_B = W \implies V_{\text{sub}}\rho_{\text{liquid}}g = V_{\text{total}}\rho_{\text{body}}g$.

Step 1 — Dividing both sides by $V_{\text{total}}\rho_{\text{liquid}}g$:

$$\frac{V_{\text{sub}}}{V_{\text{total}}} = \frac{\rho_{\text{body}}}{\rho_{\text{liquid}}}$$

Thus, the submerged volume fraction is directly equal to the relative density of the body with respect to the liquid.

Why other options are wrong:

- **Option B:** Inverted density ratio (exceeds unity for floating bodies).
- **Option C:** $1 - \rho_{\text{body}}/\rho_{\text{liquid}}$ represents the fraction of volume exposed above the liquid surface.
- **Option D:** Square root density ratio has no static equilibrium identity.

Final Answer: $\boxed{\frac{\rho_{\text{body}}}{\rho_{\text{liquid}}}}$ (Option A)

Answer: (A) **Go Back to Question 8**

Q9.

Solution

Concept: In static equilibrium, excess electric charge on a conductor resides entirely on its outer surface due to mutual Coulomb repulsion.

Step 1 — Consider a concentric spherical Gaussian surface of radius $r < R$ inside the hollow conductor. Since no charge is enclosed inside ($Q_{\text{enc}} = 0$), Gauss's law gives:

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0} = 0 \implies E(4\pi r^2) = 0 \implies E = 0$$

Step 2 — Therefore, electric field intensity is **strictly zero** everywhere inside the shell (electrostatic shielding).

Why other options are wrong:

- **Option A:** $Q/4\pi\varepsilon_0 r^2$ holds for external points ($r > R$).
- **Option B:** $Q/4\pi\varepsilon_0 R^2$ is the field just outside the surface ($r = R$).
- **Option D:** Linear radial field occurs inside uniformly charged insulating solid spheres.

Final Answer: $\boxed{\text{Exactly zero } (E = 0)}$ (Option C)

$\boxed{\textbf{Answer: (C)}}$ **Go Back to Question 9**

Q10.

Solution

Concept: In an adiabatic process ($PV^\gamma = \text{const}$), no heat enters or leaves ($Q = 0$). By first law ($\Delta U = -W$), work done equals loss of internal energy: $W = -\Delta U = nC_v(T_1 - T_2)$.

Step 1 — Since $C_v = \frac{R}{\gamma-1}$, substitute for specific heat:

$$W = n\left(\frac{R}{\gamma - 1}\right)(T_1 - T_2) = \frac{nR(T_1 - T_2)}{\gamma - 1} = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

Why other options are wrong:

- **Option A:** Isothermal work formula ($T = \text{const}$).
- **Option B:** Isobaric work formula ($P = \text{const}$).
- **Option C:** $nC_v(T_2 - T_1)$ is the internal energy gain ($\Delta U = -W$), opposite in sign to expansion work.

Final Answer: $\boxed{W = \frac{nR}{\gamma - 1}(T_1 - T_2)}$ (Option D)

Answer: (D) **Go Back to Question 10**

Q11.

Solution

Concept: By Ampere's circuital law around a rectangular loop threading a long solenoid of turn density $n = N/L$, axial magnetic field is uniform and parallel to the axis.

Step 1 — Equating line integral $\oint \vec{B} \cdot d\vec{l} = Bl$ to enclosed current $\mu_0(nlI)$:

$$Bl = \mu_0 nlI \implies B = \mu_0 nI$$

The internal field depends strictly on turn density n and current I, being completely uniform and independent of solenoid cross-sectional area.

Why other options are wrong:

- **Option B:** $\frac{1}{2}\mu_0 nI$ is the magnetic field exactly at the open ends of a long solenoid.
- **Option C:** $\frac{\mu_0 I}{2\pi n}$ corresponds to field around a straight wire at distance n.
- **Option D:** Incorrect turn density scaling (n^2).

Final Answer: $\boxed{B = \mu_0 nI}$ (Option A)

Answer: (A) **Go Back to Question 11**

Q12.

Solution

Concept: Transverse mechanical wave propagation along a flexible string is governed by restoring tension force T and inertial linear mass density $\mu = M/L$.

Step 1 — By dimensional analysis or applying Newton's second law to an oscillating string segment, propagation velocity v is proportional to $\sqrt{T/\mu}$:

$$v = \sqrt{\frac{T}{\mu}}$$

Higher tension T increases restoring acceleration, while higher linear density μ increases inertia, slowing propagation.

Why other options are wrong:

- **Option A:** T/μ has dimensions of velocity squared ($\mathrm{m^2 s^{-2}}$).
- **Option C:** Inverted square root ($\sqrt{\mu/T}$ has dimensions of inverse speed $\mathrm{s\,m^{-1}}$).
- **Option D:** Product square root lacks velocity dimensions.

Final Answer: $\boxed{v = \sqrt{\frac{T}{\mu}}}$ (Option B)

Answer: (B) **Go Back to Question 12**

Q13.

Solution

Concept: Brewster's law states that at polarizing incidence angle i_p, reflected and refracted rays are perpendicular ($i_p + r = 90^\circ \implies \sin r = \cos i_p$).

Step 1 — Applying Snell's law at incidence angle i_p:

$$\mu = \frac{\sin i_p}{\sin r} = \frac{\sin i_p}{\cos i_p} = \tan i_p$$

Why other options are wrong:

- **Option B:** $\sin i_p = \mu$ is impossible since $\mu > 1$ and sine cannot exceed 1.
- **Option C:** $\cos i_p = 1/\mu$ is the cosine complement of critical angle.
- **Option D:** $\tan i_p = 1/\mu$ gives the polarizing angle for internal reflection from denser to rarer medium.

Final Answer: $\boxed{\tan i_p = \mu}$ (Option A)

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: In a closed circuit carrying current I, EMF equals terminal voltage plus internal drop: $E = V + Ir$. By Ohm's law, external current is $I = \frac{V}{R}$.

Step 1 — Substitute current $I = V/R$ into internal drop relation:

$$E = V + \left(\frac{V}{R}\right) r \implies \left(\frac{V}{R}\right) r = E - V$$

Step 2 — Solving for internal resistance r:

$$r = R\left(\frac{E-V}{V}\right) = R\left(\frac{E}{V} - 1\right)$$

Why other options are wrong:

- **Option A:** Inverted ratio ($V/E - 1 < 0$, giving negative resistance).
- **Option B:** Divides difference by total EMF E instead of terminal voltage V.
- **Option D:** Sum denominator scaling lacks voltage balance identity.

Final Answer: $\boxed{r = R\left(\frac{E}{V} - 1\right)}$ (Option C)

Answer: (C) **Go Back to Question 14**

Q15.

Solution

Concept: In single-slit Fraunhofer diffraction of slit width a, destructive interference occurs when path difference between top and bottom rays is $a \sin\theta = n\lambda$.

Step 1 — Dividing the slit into $2n$ equal zones of width $a/2n$, rays from adjacent zones cancel in pairs with path difference $\lambda/2$, giving secondary dark minimum condition:

$$a \sin\theta_n = n\lambda \quad \text{where } n = 1, 2, 3, \ldots$$

Why other options are wrong:

- **Option A:** Uses cosine instead of sine projection.
- **Option B:** $(2n - 1)\lambda/2$ represents the approximate condition for secondary bright maxima.
- **Option C:** Tangent relation does not correspond to geometric path difference projections.

Final Answer: $\boxed{a \sin\theta_n = n\lambda}$ (Option D)

Answer: (D)

Go Back to Question 15

Q16.

Solution

Concept: An LED emits light via spontaneous radiative recombination of injected conduction electrons and valence holes across the forbidden band gap E_g.

Step 1 — To inject majority carriers across the junction potential barrier into opposite regions, the LED must be connected under **Forward Bias** exceeding the threshold cut-in voltage ($V > V_{\text{th}}$).

Step 2 — As injected electrons recombine with holes, their excess band-gap energy is released directly as visible or infrared photons ($h\nu = E_g$).

Why other options are wrong:

- **Option A:** Reverse breakdown avalanche applies to Zener diodes and avalanche photodiodes.
- **Option C:** Zero bias cannot inject charge carriers across the potential barrier.
- **Option D:** High-voltage AC resonance destroys semiconductor junctions via excessive reverse breakdown dissipation.

Final Answer: $\boxed{\text{Forward bias exceeding cut-in voltage}}$ (Option B)

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: Angle of friction relates normal reaction to limiting static friction ($\tan\phi = \mu_s$); centripetal force deflects velocity without changing speed.

Step 1 — The angle ϕ between resultant contact force $\vec{R} = \vec{N} + \vec{f_s}$ and normal reaction $\vec{N}$ at the point of impending slipping ($\tan\phi = f_{s,\max}/N = \mu_s$) is called the **Angle of Friction**.

Step 2 — The radial inward force $F_c = \frac{mv^2}{r} = m\omega^2 r$ required to maintain uniform circular motion is called the **Centripetal Force**.

Final Answer: $\boxed{\text{1. Angle of Friction} \quad \text{2. Centripetal Force}}$

Answer: (See above) **Go Back to Question 17**

Q18.

Solution

Concept: Microscope magnification multiplies objective magnification $m_o = -L/f_o$ by eyepiece infinity magnification $m_e = D/f_e$.

Step 1 — When the final virtual image is formed at infinity (relaxed eye adjustment), the magnifying power formula is:

$$M_\infty = m_o \times m_{\infty,e} = -\left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$$

Step 2 — Why Short Focal Lengths: Since both f_o and f_e appear strictly in the denominators of the magnification formula ($M \propto \frac{1}{f_o f_e}$), choosing extremely small focal lengths for both lenses exponentially multiplies total magnifying power, enabling high resolution of cellular structures.

Final Answer: $\boxed{\text{1. } M_\infty = -\frac{L}{f_o}\frac{D}{f_e} \quad \text{2. } f_o, f_e \text{ in denominator; small focal lengths maximize magnification}}$

Answer: (See above) **Go Back to Question 18**

Q19.

Solution

Concept: Step-up transformers reduce line current ($I = P/V$), cutting Joule heating (I^2R) by the square of voltage gain. Step-down transformers ensure domestic safety.

Step 1 — Since current $I = P/V$, stepping up voltage by a factor of 10 ($V' = 10V$) reduces transmission line current by a factor of 10 ($I' = I/10$). Joule heating power loss scales as current squared:

$$P'_{\text{loss}} = (I')^2R = \left(\frac{I}{10}\right)^2 R = \frac{1}{100}(I^2R) = \frac{1}{100}P_{\text{loss}}$$

Thus, power loss decreases by a factor of **100 (one hundred times)**.

Step 2 — The primary function of a Step-Down transformer at city substations is to safely lower the dangerous transmission voltage (132 kV) down to standard domestic consumer voltage (220 V / 240 V).

Final Answer: 1. Decreases by factor of 100 ($1/100$) 2. Step down to safe domestic 220 V

Answer: (See above) **Go Back to Question 19**

Q20.

Solution

Concept: Excitation energy lifts bound electrons to higher orbits ($\Delta E = E_f - E_i$); ionization potential is energy required to remove an electron to infinity ($n = \infty$).

Step 1 — Calculate first excitation energy ($\Delta E_{1\to2}$) from ground state $n = 1$ ($E_1 = -13.6$ eV) to first excited state $n = 2$ ($E_2 = -13.6/4 = -3.4$ eV):

$$\Delta E_{1\to2} = E_2 - E_1 = -3.4\text{ eV} - (-13.6\text{ eV}) = 10.2\text{ eV}$$

Step 2 — Ionization Potential is the minimum accelerating potential difference through which a ground-state hydrogen electron must fall to acquire sufficient kinetic energy ($E_{\text{ion}} = E_\infty - E_1 = 0 - [-13.6] = 13.6$ eV) to permanently detach from the atom ($n = \infty$). Its value is exactly 13.6 **V**.

Final Answer: 1. 10.2 eV 2. Potential to detach electron to $n = \infty$; value: 13.6 V

Answer: (See above) **Go Back to Question 20**

Q21.

Solution

Concept: Matching mechanical fatigue and fluid flow phenomena with definitions.

Step 1 — Elastic Fatigue is the temporary loss of elastic strength due to repeated cyclic stressing, so (a) matches (iii).

Step 2 — Elastic After-Effect is the time delay exhibited by an elastic body in regaining original shape after load removal, so (b) matches (iv).

Step 3 — Reynolds Number ($N_R = \rho v D/\eta$) determines whether fluid flow is laminar ($N_R < 2000$) or turbulent ($N_R > 3000$), so (c) matches (i).

Step 4 — Cohesive Force is the intermolecular attraction between like molecules of the same substance, so (d) matches (ii).

Final Answer: $\boxed{\text{(a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)}}$

$\boxed{\textbf{Answer: (See above)}}$ **Go Back to Question 21**

Q22.

Solution

Concept: Matching semiconductor doping and junction depletion parameters.

Step 1 — Intrinsic Semiconductor is a pure crystal where thermal electron density equals hole density ($n_e = n_h$), so (a) matches (iii).

Step 2 — Extrinsic n-type is doped with pentavalent donor impurities (P, As), giving majority electrons ($n_e \gg n_h$), so (b) matches (i).

Step 3 — Extrinsic p-type is doped with trivalent acceptor impurities (B, Al), giving majority holes ($n_h \gg n_e$), so (c) matches (iv).

Step 4 — Depletion Region is the junction zone devoid of free mobile carriers containing immobile ionized atoms, so (d) matches (ii).

Final Answer: $\boxed{\text{(a)-(iii), (b)-(i), (c)-(iv), (d)-(ii)}}$

$\boxed{\textbf{Answer: (See above)}}$ **Go Back to Question 22**

Q23.

Solution

Concept: Wave phase difference scales as $\frac{2\pi}{\lambda}\Delta x$; constructive interference requires even half-wavelength multiples ($\Delta x = n\lambda = 2n\frac{\lambda}{2}$).

Step 1 — Statement 1 is **TRUE (T)**. Since a full wavelength λ corresponds to a complete 2π radian cycle, phase difference is directly proportional to path difference: $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$.

Step 2 — Statement 2 is **FALSE (F)**. Odd integral multiples of half-wavelength ($\Delta x = [2n-1]\frac{\lambda}{2}$) produce 180° phase opposition, causing **destructive interference (dark minimum)**. Constructive bright maxima require even multiples: $\Delta x = n\lambda$.

Final Answer: $\boxed{\text{1. T} \quad \text{2. F}}$

Answer: (See above) Go Back to Question 23

Q24.

Solution

Concept: Cyclotrons accelerate charged ions via synchronized magnetic deflection ($r = mv/qB$) and alternating electric dee voltage; maximum energy occurs at dee radius $R_{\max}$.

Step 1 — At maximum exit radius $r = R_{\max}$, ion velocity is $v_{\max} = \frac{qBR_{\max}}{m}$. Maximum kinetic energy attained is:

$$K_{\max} = \frac{1}{2}mv_{\max}^2 = \frac{1}{2}m\left(\frac{qBR_{\max}}{m}\right)^2 = \frac{q^2B^2R_{\max}^2}{2m}$$

Step 2 — Why Neutrons & Electrons Fail: (1) **Neutrons:** Having zero electric charge ($q = 0$), they experience zero electric acceleration force ($F = qE = 0$) across dee gaps and zero magnetic deflecting force. (2) **Electrons:** Due to their extremely tiny mass (9.1×10^{-31} kg), electrons reach relativistic velocities ($v \approx c$) almost instantly at low voltages. By relativistic mass increase ($m = m_0/\sqrt{1 - v^2/c^2}$), cyclotron frequency $f = qB/2\pi m$ drops rapidly, destroying resonance synchronization with the alternating dee oscillator.

Final Answer: $\boxed{\text{1. } K_{\max} = \frac{q^2B^2R_{\max}^2}{2m} \quad \text{2. Neutrons uncharged; electrons become relativistic}}$

Answer: (See above) Go Back to Question 24

Q25.

Solution

Concept: Supersuperposition of coherent waves produces constructive reinforcement in phase and destructive cancellation in phase opposition.

Step 1 — Where waves arrive in phase ($\Delta x = n\lambda$), amplitudes add ($A = a_1 + a_2$), producing bright bands via **Constructive Interference**.

Step 2 — Where waves arrive out of phase ($\Delta x = [2n-1]\lambda/2$), amplitudes subtract ($A = a_1 - a_2$), producing dark zero-intensity bands via **Destructive Interference**.

Final Answer: 1. Constructive Interference 2. Destructive Interference

Answer: (See above)

Go Back to Question 25

Q26.

Solution

Concept: Matching nuclear parameters with defining formulas and decay laws.

Step 1 — Nuclear Mass Defect is mass difference $\Delta m = [Zm_p + (A - Z)m_n] - M_{\text{nuc}}$, so (a) matches (iv).

Step 2 — Nuclear Binding Energy is Einstein mass equivalent $BE = \Delta m \times c^2$, so (b) matches (iii).

Step 3 — Rutherford-Soddy Decay Law governs exponential decay $N(t) = N_0 e^{-\lambda t}$, so (c) matches (i).

Step 4 — Radioactive Half-Life is inversely proportional to decay constant $T_{1/2} = \frac{0.693}{\lambda}$, so (d) matches (ii).

Final Answer: (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii)

Answer: (See above)

Go Back to Question 26

Q27.

Solution

Concept: Binding energy curve peaks at Iron-56 (^{56}Fe); fusion of light nuclei ($A < 10$) and fission of heavy nuclei ($A > 200$) release energy by moving toward the iron stability peak.

Step 1 — Statement 1 is **TRUE (T)**. The nuclear binding energy per nucleon curve reaches its absolute maximum stability peak at Iron-56 ($^{56}_{26}$Fe) with $\overline{BE} \approx 8.75$ MeV/nucleon.

Step 2 — Statement 2 is **FALSE (F)**. Reverses nuclear processes: heavy nuclei ($A > 200$) release energy by splitting into lighter fragments via **Nuclear Fission**, whereas light nuclei ($A < 10$) release energy by combining into heavier nuclei via **Nuclear Fusion**.

Final Answer: 1. T 2. F

Answer: (See above)

Go Back to Question 27

Q28.

Solution

Concept: Over-modulation ($m > 1$) causes severe waveform clipping; space wave horizon distance scales as $\sqrt{2Rh}$.

Step 1 — Statement 1 is **TRUE (T)**. In Amplitude Modulation, modulation index $m = A_m/A_c$ must be maintained ≤ 1.0 (100%). If $m > 1$ (over-modulation), the carrier wave envelope is cut off at zero voltage during negative cycles, causing severe audio distortion.

Step 2 — Statement 2 is **TRUE (T)**. In line-of-sight space wave propagation over Earth of radius R, geometric radio horizon distance is $d_t = \sqrt{2Rh_t}$ for transmitter and $d_r = \sqrt{2Rh_r}$ for receiver, giving total communication range $d = \sqrt{2Rh_t} + \sqrt{2Rh_r}$.

Final Answer: $\boxed{\text{1. T} \quad \text{2. T}}$

Answer: (See above) **Go Back to Question 28**

Q29.

Solution

Concept: Gravitational field intensity measures force per unit mass; impulse is the time integral of force equal to total momentum change.

Step 1 — Alternative (i) - Gravitational Field & Potential: Gravitational Field Intensity ($\vec{E}_g$) at a point is the gravitational force experienced by a unit test mass placed at that point: $\vec{E}_g = \frac{\vec{F}}{m_0} = -\frac{GM}{r^2}\hat{r}$. SI unit: N kg^{-1} or m s^{-2}. Gravitational Potential (V) is the amount of work done per unit mass by an external agent in bringing a test body from infinity to that point without acceleration: $V = \frac{W}{m_0} = -\frac{GM}{r}$. SI unit: J kg^{-1}.

Step 2 — Alternative (ii) - Impulse & Theorem: Impulse ($\vec{J}$) of a variable force $\vec{F}(t)$ is the total cumulative effect of the force acting over a time interval $\Delta t = t_2 - t_1$:

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}\,dt = \vec{F}_{\text{avg}}\Delta t$$

Step 3 — Impulse-Momentum Theorem: By Newton's second law, $\vec{F} = \frac{d\vec{p}}{dt} \implies \vec{F}dt = d\vec{p}$. Integrating over time:

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}\,dt = \int_{\vec{p}_1}^{\vec{p}_2} d\vec{p} = \vec{p}_2 - \vec{p}_1 = \Delta\vec{p}$$

The impulse of a force acting on a body is exactly equal to the change in its linear momentum ($\vec{J} = \Delta\vec{p}$).

Final Answer: $\boxed{E_g = F/m \text{ (N/kg)}, V = W/m \text{ (J/kg); or } \vec{J} = \int \vec{F}dt = \Delta\vec{p} \text{ (Impulse-Momentum theorem)}}$

Answer: (See above) **Go Back to Question 29**

Q30.

Solution

Concept: The Second Law of Thermodynamics affirms the unidirectional nature of spontaneous thermodynamic processes and rules out 100% efficiency.

Step 1 — Kelvin-Planck Statement (Heat Engines): It is impossible to construct a cyclic heat engine whose sole physical effect is to absorb continuous heat energy from a single thermal reservoir at temperature T_1 and convert it completely into an equal amount of useful mechanical work ($W = Q_1$) without rejecting any heat to a lower-temperature sink (T_2). Thus, no heat engine can ever have 100% thermal efficiency ($\eta < 100\%$).

Step 2 — Clausius Statement (Refrigerators/Heat Pumps): It is impossible to construct a cyclic thermodynamic device whose sole physical effect is to transfer heat energy from a colder body at temperature T_2 to a hotter body at temperature T_1 without the expenditure of mechanical work by an external agent. Heat cannot flow spontaneously from cold to hot.

Final Answer: $\boxed{\text{Kelvin-Planck: No heat engine can be 100\% efficient; Clausius: Heat cannot flow spontaneously from cold to hot without external work}}$

$\boxed{\textbf{Answer: (See above)}}$ **Go Back to Question 30**

Q31.

Solution

Concept: Permeability and susceptibility measure magnetic induction within materials; capacitance quantifies charge storage capacity per unit potential.

Step 1 — Alternative (i) - Permeability & Susceptibility: Magnetic Permeability (μ) of a material is the degree to which it permits magnetic field lines to pass through its volume ($\mu = B/H$). Magnetic Susceptibility (χ_m) is the ratio of induced magnetization M to magnetizing field intensity H ($\chi_m = M/H$).

Step 2 — Relation: Total magnetic field in a material is $B = \mu_0(H + M) = \mu_0 H(1 + M/H) = \mu_0 H(1 + \chi_m)$. Since $\mu = B/H$ and relative permeability is $\mu_r = \mu/\mu_0$:

$$\mu_r = 1 + \chi_m$$

Step 3 — Alternative (ii) - Capacitance: The ratio of electrostatic charge Q given to an isolated conductor to the resulting rise in its electrical potential V is called Capacitance ($C = \frac{Q}{V}$). SI unit is **Farad** (F).

Step 4 — Factors for Parallel Plate Capacitor ($C = \frac{K\varepsilon_0 A}{d}$): Depends on: (1) Area of plates (A, directly proportional), (2) Separation between plates (d, inversely proportional), and (3) Dielectric constant (K) of insulating medium between plates.

Final Answer: $\boxed{\mu_r = 1 + \chi_m\text{; or } C = Q/V \text{ (F), depends on plate area } A\text{, separation } d\text{, and dielectric } K}$

Answer: (See above)

Go Back to Question 31

Q32.

Solution

Concept: Real images are formed by convergent light rays and can be displayed on screens; virtual images are formed by divergent rays and cannot be projected.

Step 1 — Comparison Table:

Real Image	Virtual Image
1. Formed at points where light rays reflected or refracted from an optical system **actually intersect in physical space**.	1. Formed at points where divergent reflected or refracted rays **appear to diverge from** when produced backward geometrically.
2. Can be physically projected and captured onto a viewing screen placed at the intersection plane.	2. Cannot be projected or captured onto a viewing screen; visible only when looking directly into the optical instrument.
3. Always inverted relative to the object orientation.	3. Always erect (upright) relative to the object orientation.

Final Answer: Real vs Virtual Image comparison table above

Answer: (See above) **Go Back to Question 32**

Q33.

Solution

Concept: Power factor ($\cos\phi$) determines the fraction of apparent AC power converted to useful true power; phase shifts of ±90° yield zero true power.

Step 1 — Power Factor: In an AC circuit with voltage $V = V_0 \sin\omega t$ and current $I = I_0 \sin(\omega t - \phi)$, the true average power consumed is $P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi$. The term $\cos\phi$ (cosine of the phase difference between voltage and current) is called the **Power Factor**.

Step 2 — Why Inductive/Capacitive Circuits Consume Zero Power: (1) In a purely inductive AC circuit, alternating current lags behind applied voltage by exactly 90° ($\phi = +90^\circ$). (2) In a purely capacitive AC circuit, alternating current leads applied voltage by exactly 90° ($\phi = -90^\circ$).

Step 3 — In both cases, $\cos\phi = \cos(\pm 90^\circ) = 0$. Substituting into power equation:

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos(\pm 90^\circ) = V_{\text{rms}} I_{\text{rms}} \times 0 = 0$$

Thus, although significant alternating current flows through the reactance, **zero net average energy** is consumed over a full cycle (called **Wattless Current**).

Final Answer: Power factor = $\cos\phi$; in pure L or C, phase shift
$\phi = \pm 90^\circ \implies \cos\phi = 0 \implies P_{\text{avg}} = 0$

Answer: (See above) **Go Back to Question 33**

Q34.

Solution

Concept: The de Broglie wavelength of a moving particle of kinetic energy E_k is $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m_n E_k}}$.

Step 1 — Given mass of neutron $m_n = 1.67 \times 10^{-27}$ kg and thermal kinetic energy $E_k = 0.04$ eV. Convert E_k to Joules:

$$E_k = 0.04\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J/eV} = 6.4 \times 10^{-21}\ \text{J}$$

Step 2 — Calculate linear momentum $p = \sqrt{2m_n E_k}$:

$$p = \sqrt{2(1.67 \times 10^{-27}\ \text{kg})(6.4 \times 10^{-21}\ \text{J})} = \sqrt{2.1376 \times 10^{-47}} \approx 4.623 \times 10^{-24}\ \text{kg m s}^{-1}$$

Step 3 — Apply de Broglie's formula $\lambda = \frac{h}{p}$:

$$\lambda = \frac{6.63 \times 10^{-34}\ \text{J s}}{4.623 \times 10^{-24}\ \text{kg m s}^{-1}} \approx 1.434 \times 10^{-10}\ \text{m} = 0.1434\ \text{nm} = 1.434\ \text{Å}$$

Final Answer: $\boxed{\lambda \approx 1.434 \times 10^{-10}\ \text{m}\ (1.434\ \text{Å})}$

Answer: (See above) **Go Back to Question 34**

Q35.

Solution

Concept: Huygens' principle postulates that every wavefront point acts as a secondary source emitting spherical wavelets that build the advancing wavefront.

Step 1 — Huygens' Principle: (1) Every point on a given primary wavefront acts as a fresh source of secondary optical disturbances, emitting spherical wavelets that spread out in all directions with the speed of light v in that medium. (2) The common forward envelope (tangential surface) touching all these secondary wavelets at any later time interval Δt gives the new geometric position and shape of the advancing wavefront.

Step 2 — Construction of Spherical Wavefront: Let AB be a section of a primary spherical wavefront expanding from point source O at time $t = 0$. To find its shape at time Δt:

Step 3 — Choose several points P_1, P_2, P_3 along primary wavefront AB. Taking each point as a center, draw spheres (wavelets) of radius $r = v\Delta t$.

Step 4 — Draw the smooth forward tangential envelope A'B' touching the front surfaces of all these wavelets. A'B' is a concentric sphere of radius $(R + v\Delta t)$, representing the newly expanded spherical wavefront at time Δt.

Final Answer: Wavefront points emit secondary wavelets of radius $v\Delta t$; forward tangent envelope forms new wavefront

Answer: (See above) Go Back to Question 35

Q36.

Solution

Concept: Spontaneous nuclear disintegration rate is proportional to instantaneous undecayed nuclei count ($\frac{dN}{dt} = -\lambda N$); radioactive decays alter atomic number Z and mass number A.

Step 1 — Alternative (i) - Decay Law Derivation: Rutherford-Soddy law states: $\frac{dN}{dt} = -\lambda N$. Separating variables:

$$\frac{dN}{N} = -\lambda dt$$

Step 2 — Integrating from $t = 0$ (when $N = N_0$) to time t (when $N = N(t)$):

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt \implies [\ln N]_{N_0}^{N} = -\lambda t \implies \ln\left(\frac{N}{N_0}\right) = -\lambda t$$

Taking exponential on both sides gives the exponential decay law:

$$N(t) = N_0 e^{-\lambda t}$$

Step 3 — Alternative (ii) - Alpha, Beta, Gamma Decays: (1) **Alpha (α) Decay:** Emission of helium nucleus ($^4_2$He), decreasing Z by 2 and A by 4:

$$^{238}_{92}\text{U} \rightarrow ^{234}_{90}\text{Th} + ^{4}_{2}\text{He} + \text{Q}$$

(2) **Beta (β^-) Decay:** Neutron transforms to proton, emitting electron ($^{0}_{-1}$e) and antineutrino, increasing Z by 1:

$$^{14}_{6}\text{C} \rightarrow ^{14}_{7}\text{N} + ^{0}_{-1}\text{e} + \bar{\nu}_e + \text{Q}$$

(3) **Gamma (γ) Decay:** Excited nucleus transitions to ground state emitting high-energy photon without changing Z or A:

$$^{60}_{28}\text{Ni}^* \rightarrow ^{60}_{28}\text{Ni} + \gamma + \text{Q}$$

Final Answer: $\boxed{N(t) = N_0 e^{-\lambda t};\ \text{or } \alpha, \beta, \gamma \text{ decay equations above}}$

Answer: (See above)

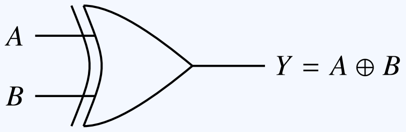
Go Back to Question 36

Q37.

Solution

Concept: EX-OR gate outputs HIGH only when inputs differ; AM modulation index must be ≤ 1.0 to prevent envelope clipping distortion.

Step 1 — Alternative (i) - Exclusive-OR (XOR) Gate: Symbol is an OR gate with an additional curved shield at the input face. Boolean expression: $Y = A \oplus B = A\overline{B} + \overline{A}B$.



Truth Table: $(A = 0, B = 0 \implies Y = 0)$; $(0, 1 \implies 1)$; $(1, 0 \implies 1)$; $(1, 1 \implies 0)$. Output is HIGH when inputs are unequal.

Step 2 — Alternative (ii) - Modulation Index (m): In AM, modulation index $m = \frac{A_m}{A_c}$ measures the extent to which the carrier amplitude A_c is modulated by audio amplitude A_m.

Step 3 — Why $m \leq 1.0$ is Mandatory: If $A_m > A_c$ ($m > 1.0$, called over-modulation), the negative trough of the modulating signal forces the total carrier amplitude $(A_c + A_m \sin \omega_m t)$ below zero. Since RF amplitude cannot become negative, the transmitted carrier envelope is sharply cut off (clipped to zero) for portions of the cycle.

Step 4 — When this clipped envelope is demodulated by a radio receiver, the recovered audio waveform is severely distorted and corrupted, generating false harmonic frequencies and unintelligible sound.

Final Answer: $\boxed{\text{XOR symbol \& truth table; or Over-modulation } (m > 1) \text{ causes envelope clipping \& audio distortion}}$

Answer: (See above) **Go Back to Question 37**

Q38.

Solution

Concept: Gravitational potential energy integrates work done against attractive Coulomb/Newtonian gravity; cylinder inertia integrates concentric cylindrical shell elements.

Step 1 — Alternative (i) - Gravitational Potential Energy (U): The gravitational force on mass m at distance x from Earth's center is $F = \frac{GMm}{x^2}$ directed inward. Work done against gravity in bringing mass m from infinity up to distance $r = R + h$ from Earth's center is:

$$U = \int_{\infty}^{R+h} \frac{GMm}{x^2} dx = GMm\left[-\frac{1}{x}\right]_{\infty}^{R+h} = -\frac{GMm}{R+h}$$

Step 2 — Gain in Potential Energy (ΔU): At Earth's surface ($h = 0$), $U_0 = -\frac{GMm}{R}$. The gain in potential energy in raising mass m to height h is:

$$\Delta U = U_h - U_0 = -\frac{GMm}{R+h} - \left(-\frac{GMm}{R}\right) = \frac{GMm}{R}\left(1 - \frac{1}{1+h/R}\right) = \frac{GMm}{R}\left[1 - \left(1 + \frac{h}{R}\right)^{-1}\right]$$

Step 3 — For small elevations ($h \ll R$), binomial expansion gives $(1 + h/R)^{-1} \approx 1 - h/R$. Substituting this:

$$\Delta U \approx \frac{GMm}{R}\left[1 - \left(1 - \frac{h}{R}\right)\right] = \frac{GMm}{R}\left(\frac{h}{R}\right) = \left(\frac{GM}{R^2}\right)mh$$

Since surface gravity is $g = \frac{GM}{R^2}$, we obtain $\Delta U \approx mgh$.

Step 4 — Alternative (ii) - Cylinder Moment of Inertia: A uniform solid cylinder of mass M, radius R, length L, density $\rho = \frac{M}{\pi R^2 L}$ can be divided into thin coaxial cylindrical shells of radius r, thickness dr, volume $dV = (2\pi r dr)L$, and mass $dm = \rho dV = \frac{2M}{R^2} r dr$.

Step 5 — Since every element of this shell is at exact perpendicular distance r from central axis, total inertia is:

$$I = \int_0^R r^2 dm = \int_0^R r^2\left(\frac{2M}{R^2} r dr\right) = \frac{2M}{R^2}\int_0^R r^3 dr = \frac{2M}{R^2}\left[\frac{r^4}{4}\right]_0^R = \frac{1}{2}MR^2$$

Final Answer: $\boxed{U = -\frac{GMm}{R+h},\ \Delta U \approx mgh;\ \text{or Cylinder } I = \frac{1}{2}MR^2}$

Answer: (See above) **Go Back to Question 38**

Q39.

Solution

Concept: Frictional force opposes impending or actual relative motion; along a rough incline, net accelerating force down the slope is $mg\sin\theta - \mu_k N$.

Step 1 — Laws of Friction: (1) Frictional force is directly proportional to normal reaction N. (2) It acts tangential to the contact surfaces opposing relative motion, independent of contact surface area within elastic limits.

Step 2 — Acceleration down Rough Incline: Consider body of mass m sliding down plane inclined at angle θ. Resolving forces perpendicular to slope: normal reaction $N = mg\cos\theta$.

Step 3 — Forces acting along the slope: downward gravitational pull $F_g = mg\sin\theta$, opposed by upward kinetic frictional drag $f_k = \mu_k N = \mu_k mg\cos\theta$. Net accelerating force is:

$$F_{\text{net}} = ma = mg\sin\theta - \mu_k mg\cos\theta$$

Dividing by mass m gives linear acceleration:

$$a = g(\sin\theta - \mu_k\cos\theta)$$

Step 4 — Angle of Repose (α): The minimum angle of inclination α of a rough plane for which a body placed on it just begins to slide down under gravity without initial pushing. At angle α, downward pull just overcomes limiting static friction ($a = 0$):

$$mg\sin\alpha = f_{s,\max} = \mu_s N = \mu_s mg\cos\alpha \implies \frac{\sin\alpha}{\cos\alpha} = \mu_s \implies \tan\alpha = \mu_s$$

Thus, the tangent of angle of repose equals the coefficient of limiting static friction.

Final Answer: $\boxed{a = g(\sin\theta - \mu_k\cos\theta), \quad \tan\alpha = \mu_s}$

Answer: (See above) **Go Back to Question 39**

Q40.

Solution

Concept: Using Gauss's law for a cylindrical pillbox penetrating a uniformly charged infinite plane sheet: net outward flux through the two circular end caps equals enclosed charge over ε_0.

Step 1 — Let an infinitely large planar sheet carry uniform positive surface charge density $\sigma = \frac{Q}{A}$. By symmetry, electric field $\vec{E}$ is directed normally outward away from both faces of the sheet.

Step 2 — Construct a Gaussian cylindrical pillbox of cross-sectional area A and length $2r$ piercing perpendicularly through the sheet, with its two flat circular caps parallel to the sheet at equal distances on either side.

Step 3 — Evaluate electric flux $\Phi_E = \oint \vec{E} \cdot d\vec{A}$ over the three surfaces of the cylinder: (1) **Curved Lateral Surface:** Field $\vec{E}$ is parallel to surface ($\vec{E} \perp d\vec{A} \implies \theta = 90°$), giving zero flux ($\Phi_{\text{lateral}} = 0$). (2) **Left and Right End Caps:** Field $\vec{E}$ is parallel to normal vector $d\vec{A}$ ($\theta = 0°$) at both circular ends of area A, giving:

$$\Phi_{\text{total}} = \int_{\text{left}} E dA + \int_{\text{right}} E dA + 0 = EA + EA = 2EA$$

Step 4 — Total charge enclosed inside the cylindrical pillbox is $Q_{\text{enc}} = \sigma A$. Equating total flux to Gauss's law ($\Phi_E = \frac{Q_{\text{enc}}}{\varepsilon_0}$):

$$2EA = \frac{\sigma A}{\varepsilon_0} \implies E = \frac{\sigma}{2\varepsilon_0}$$

Step 5 — Since distance r does not appear in the final formula, the electric field intensity outside an infinite charged sheet is **strictly uniform** and completely independent of distance from the sheet.

Final Answer: $\boxed{E = \frac{\sigma}{2\varepsilon_0} \text{ (Uniform field, independent of distance } r\text{)}}$

$\boxed{\textbf{Answer: (See above)}}$ Go Back to Question 40

Q41.

Solution

Concept: A light ray traversing a rectangular glass slab undergoes two equal opposite refractions, emerging parallel to incidence ($i = e$) with a perpendicular lateral displacement d.

Step 1 — In the glass slab geometry shown in the diagram, ray PQ strikes the top face at incidence angle i, refracting along QR inside glass of thickness t at angle r. At bottom face, it refracts into air along RS.

Step 2 — Extend incident ray PQ forward along dotted line QT. The emergent ray RS is strictly parallel to QT ($i = e$). Drop perpendicular RM from exit point R onto forward projection QT. The perpendicular length RM represents the lateral shift d.

Step 3 — In right-angled triangle $\triangle QRM$, the angle between refracted ray QR and forward projection QT is $\angle MQR = (i - r)$. Therefore:

$$\sin(i - r) = \frac{RM}{QR} = \frac{d}{QR} \implies d = QR \sin(i - r) \quad \text{— (Eq. 1)}$$

Step 4 — To express hypotenuse QR in terms of slab thickness t, consider right-angled triangle formed by normal inside the slab where vertical depth is t:

$$\cos r = \frac{\text{Thickness } t}{QR} \implies QR = \frac{t}{\cos r} \quad \text{— (Eq. 2)}$$

Step 5 — Substitute Eq. 2 into Eq. 1 to obtain the Lateral Shift formula:

$$d = \left(\frac{t}{\cos r}\right) \sin(i - r) = \frac{t \sin(i - r)}{\cos r}$$

Final Answer: $\boxed{d = \frac{t \sin(i - r)}{\cos r}}$

Answer: (See above) **Go Back to Question 41**

Q42.

Solution

Concept: Ampere's circuital law evaluates magnetic induction around symmetric current distributions; transformers transform AC voltages and currents via mutual electromagnetic induction without changing power or frequency.

Step 1 — Part (i) - Straight Conductor Magnetic Field: Let an infinitely long straight wire along the vertical z-axis carry a steady current I. To find magnetic field induction $\vec{B}$ at point P at perpendicular distance r, construct a coaxial circular Amperian loop of radius r passing through P in the horizontal xy-plane.

Step 2 — By cylindrical symmetry and Oersted's right-hand thumb rule, magnetic field lines form concentric circles around the wire. Therefore, field vector $\vec{B}$ is everywhere tangential to the circular Amperian loop ($\vec{B} \parallel d\vec{l} \implies \theta = 0^\circ \implies \cos 0^\circ = 1$), and its magnitude B is constant at all points on the loop.

Step 3 — Evaluate line integral around circular circumference $2\pi r$:

$$\oint \vec{B} \cdot d\vec{l} = \oint B dl \cos 0^\circ = B \oint dl = B(2\pi r)$$

Step 4 — Total conduction current enclosed by the circular Amperian loop is $I_{\text{enc}} = I$. By Ampere's Circuital Law ($\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enc}}$):

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

Step 5 — Part (ii) - Why Parallel Currents Attract: Let conductor 1 carry upward current I_1. It establishes magnetic field $B_1 = \frac{\mu_0 I_1}{2\pi d}$ directed perpendicularly into the page ($\otimes$) at the location of parallel conductor 2 carrying upward current I_2. By Fleming's left-hand rule (or cross product $\vec{I}_2 \times \vec{B}_1$), current I_2 moving upward across inward magnetic field experiences a Lorentz force directed horizontally to the left, pulling conductor 2 directly toward conductor 1 (**Mutual Attraction**).

Step 6 — Alternative (iii) - Transformer Transformation Ratio: An ideal transformer has two magnetically coupled coils (N_p and N_s turns) on a closed laminated core. When alternating voltage V_p is applied to primary, changing mutual flux Φ_B links both coils. By Faraday's law:

$$V_p = -N_p \frac{d\Phi_B}{dt} \quad \text{and} \quad V_s = -N_s \frac{d\Phi_B}{dt} \implies \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

For an ideal 100% efficient transformer, output power equals input power ($P_{\text{out}} = P_{\text{in}} \implies V_s I_s = V_p I_p$). Rearranging gives the complete transformation ratio:

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

Final Answer: $\boxed{B = \frac{\mu_0 I}{2\pi r} \text{ (parallel currents attract); or Transformer } \frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}}$

$\boxed{\textbf{Answer: (See above)}}$

Go to Question 42

Q43.

Solution

Concept: A center-tapped full-wave rectifier utilizes two diodes conducting alternately during opposite AC half-cycles, doubling ripple frequency; a CB transistor amplifier achieves high voltage gain without current amplification ($\alpha < 1$).

Step 1 — Part (i) - Center-Tapped Full-Wave Rectifier Working: The circuit employs two diodes D_1 and D_2 connected to opposite ends A and B of a center-tapped transformer secondary winding, with load resistor R_L connected between the common diode cathode junction and the central ground tap CT.

Step 2 — Positive Half-Cycle: Terminal A becomes positive and B becomes negative with respect to center tap CT. Diode D_1 is forward-biased and conducts current through R_L from right to left toward CT. Diode D_2 is reverse-biased and open-circuited.

Step 3 — Negative Half-Cycle: Terminal B becomes positive and A becomes negative with respect to CT. Diode D_2 becomes forward-biased and conducts current through R_L in the exact same direction (right to left toward CT), while D_1 is reverse-biased. Thus, continuous unidirectional DC voltage pulses are delivered to R_L during both half-cycles.

Step 4 — Part (ii) - Efficiency, Ripple, Double Frequency ($2f$): Rectifying efficiency ($\eta = P_{\mathrm{dc}}/P_{\mathrm{ac}}$) reaches 81.2%, and ripple factor ($\gamma = V_{\mathrm{ac}}/V_{\mathrm{dc}}$) drops to 0.48. Since each full 360° AC input cycle (f) produces **two identical output DC current pulses** (one from D_1, one from D_2), the fundamental ripple frequency of the output waveform is strictly doubled to **$2f$** (e.g., 100 Hz ripple for 50 Hz supply).

Step 5 — Alternative (iii) - *p*-*n*-*p* BJT in CB Configuration: In Common-Base amplifier, input signal is applied across forward-biased emitter-base junction and output is taken across reverse-biased collector-base junction. Emitter holes injected into thin *n*-base mostly ($\sim 95\%$) diffuse through to collector: $I_E = I_B + I_C$.

Step 6 — Common-base DC current gain is $\alpha = \frac{I_C}{I_E}$ ($\alpha \approx 0.95$ to 0.99) and common-emitter current gain is $\beta = \frac{I_C}{I_B}$. Substituting $I_E = I_B + I_C$:

$$\alpha = \frac{I_C}{I_B + I_C} = \frac{I_C/I_B}{1 + (I_C/I_B)} = \frac{\beta}{1 + \beta}$$

Final Answer: $\boxed{\text{Center-Tapped Rectifier working, } \eta = 81.2\%\text{, ripple frequency} = 2f\text{; or BJT CB amplifier action \& } \alpha = \frac{\beta}{1+\beta}}$

Answer: (See above)

Go Back to Question 43

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	A	3	D	4	B	5	C
6	B	7	D	8	A	9	C	10	D
11	A	12	B	13	A	14	C	15	D
16	B								