NIOS Class 12 Physics Sample Paper-5

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 the Coefficient of Viscosity (η) of a fluid is: **(1)**

(A) $[M^1L^1T^{-1}]$

(B) $[M^1L^{-2}T^{-2}]$

(C) $[\mathrm{M^1L^{-1}T^{-1}}]$

(D) $[\mathrm{M^1L^{-1}T^{-2}}]$

Q2. The moment of inertia of a uniform thin rigid rod of mass M and total length L about a geometric axis passing perpendicularly through its center of mass is: **(1)**

(A) $\frac{1}{12}ML^2$

(B) $\frac{1}{3}ML^2$

(C) $\frac{1}{2}ML^2$

(D) $\frac{1}{6}ML^2$

Q3. A particle moves along the x-axis under the influence of a conservative force field whose potential energy function is given by $U(x)$. The conservative force F_x acting on the particle is related to potential energy $U(x)$ by: **(1)**

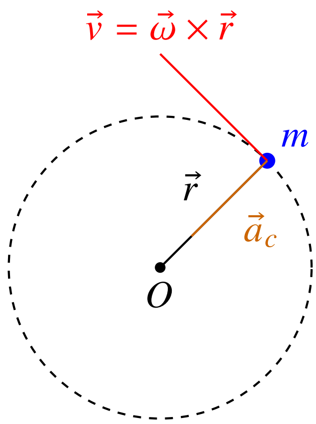
(A) $F_x = \frac{dU}{dx}$

(B) $F_x = \int U(x)dx$

(C) $F_x = -U(x)$

(D) $F_x = -\frac{dU}{dx}$

Q4. A point mass m undergoes uniform circular motion of radius r with a constant angular velocity ω as shown in the diagram below. The magnitude and direction of its instantaneous centripetal acceleration $\vec{a}_c$ are: **(1)**



(A) $a_c = \omega r$ directed tangentially forward

(B) $a_c = \omega^2 r$ directed radially inward toward center O

(C) $a_c = \frac{v^2}{r^2}$ directed radially outward away from center O

(D) $a_c = \omega^2 r^2$ directed along the rotational axis

Q5. When a metallic wire of Young's modulus Y is stretched within its elastic limit by a longitudinal tensile strain, the elastic potential energy stored per unit volume (elastic energy density u) of the wire is: **(1)**

(A) $u = Y \times (\text{strain})^2$

(B) $u = \frac{1}{2}Y \times (\text{stress})^2$

(C) $u = \frac{1}{2}Y \times (\text{strain})^2$

(D) $u = 2Y \times (\text{strain})^2$

Q6. For an ideal monoatomic gas (such as Helium or Argon), the ratio of specific heat capacity at constant pressure to specific heat capacity at constant volume ($\gamma = C_p/C_v$) is: **(1)**

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

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

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

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

Q7. A body of mass m executes Simple Harmonic Motion (SHM) of linear amplitude A and angular frequency ω. The total mechanical energy ($E = K + U$) of the oscillating body is: **(1)**

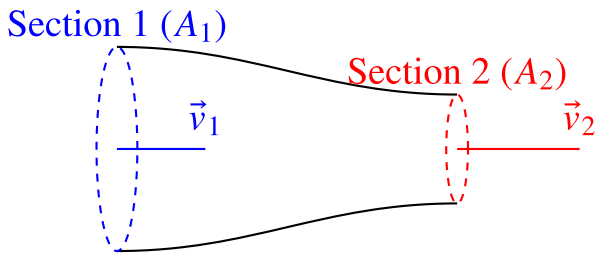
(A) Directly proportional to instantaneous displacement x

(B) Inversely proportional to amplitude squared ($E \propto 1/A^2$)

(C) Directly proportional to frequency ω ($E \propto \omega$)

(D) Directly proportional to amplitude squared ($E \propto A^2$)

Q8. An incompressible, non-viscous fluid flows steadily through a tapering horizontal pipe having cross-sectional area A_1 at entry section 1 and narrower area A_2 at exit section 2 as shown below. According to the Equation of Continuity, the flow velocities v_1 and v_2 satisfy: **(1)**



(A) $A_1 + v_1 = A_2 + v_2$

(B) $A_1 v_1 = A_2 v_2 \implies v_2 > v_1$

(C) $\frac{A_1}{v_1} = \frac{A_2}{v_2} \implies v_1 > v_2$

(D) $A_1 v_1^2 = A_2 v_2^2$

Q9. An electric dipole having dipole moment $\vec{p}$ is placed inside a uniform external electric field $\vec{E}$. The magnitude of the electrostatic torque $\vec{\tau}$ experienced by the dipole is maximum when the angle θ between dipole axis $\vec{p}$ and field $\vec{E}$ is: **(1)**

(A) 0° (Parallel orientation)

(B) 45° ($\pi/4$ radians)

(C) 90° (Perpendicular orientation)

(D) 180° (Antiparallel orientation)

Q10. When n moles of an ideal gas undergo reversible isothermal expansion at constant absolute temperature T from an initial volume V_1 to a final volume V_2, the work done (W) by the gas is given by: **(1)**

(A) $W = nRT \ln\left(\frac{V_2}{V_1}\right) = 2.303nRT \log_{10}\left(\frac{V_2}{V_1}\right)$

(B) $W = nRT\left(\frac{V_2 - V_1}{V_1}\right)$

(C) $W = \frac{nR}{\gamma - 1}(T_1 - T_2)$

(D) $W = P_1 V_1 \ln\left(\frac{V_1}{V_2}\right)$

Q11. Two infinitely long parallel straight conductors separated by a distance d in vacuum carry steady electric currents I_1 and I_2 respectively. The magnetic force per unit length between them is: **(1)**

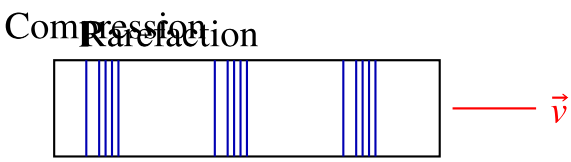
(A) Attractive if the currents flow in opposite (antiparallel) directions

(B) Zero if the conductors carry equal currents ($I_1 = I_2$)

(C) Repulsive if the currents flow in the same (parallel) direction

(D) Attractive if the currents flow in the same (parallel) direction, and repulsive if opposite

Q12. According to Laplace's corrected Newton's formula, the speed of longitudinal sound waves (v) propagating through an ideal gas of density ρ, pressure P, and specific heat ratio γ is: **(1)**



(A) $v = \sqrt{\frac{P}{\rho}}$

(B) $v = \sqrt{\frac{\gamma P}{\rho}}$

(C) $v = \sqrt{\frac{\rho}{\gamma P}}$

(D) $v = \gamma\sqrt{\frac{P}{\rho}}$

Q13. A beam of monochromatic light having vacuum wavelength $\lambda_{vac} = 600$ nm enters a transparent optical medium of absolute refractive index $\mu = 1.5$. The wavelength of this light inside the medium (λ_{med}) is: **(1)**

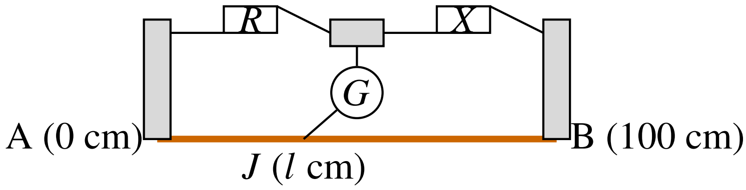
(A) 900 nm

(B) 600 nm

(C) 400 nm

(D) 300 nm

Q14. In a standard Meter Bridge experiment used for determining an unknown resistance X, a known standard resistance R is connected in the left gap and X in the right gap as shown below. If the galvanometer null balance point occurs at length l cm from end A along the 100 cm uniform slide wire AB, the unknown resistance X is given by: **(1)**



(A) $X = R\left(\frac{100-l}{l}\right)$

(B) $X = R\left(\frac{l}{100-l}\right)$

(C) $X = R\left(\frac{100}{l}\right)$

(D) $X = R\left(\frac{l}{100}\right)$

Q15. The theoretical theoretical Resolving Power of an astronomical telescope objective lens of circular aperture diameter D observing light of wavelength λ is: **(1)**

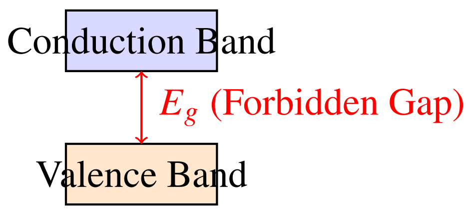
(A) $\frac{1.22\lambda}{D}$

(B) $\frac{D}{\lambda}$

(C) $\frac{1.22D}{\lambda}$

(D) $\frac{D}{1.22\lambda}$

Q16. According to modern solid-state band theory, the forbidden energy band gap (E_g) separating the valence band and conduction band in a typical electrical insulator (such as diamond or fused quartz) at room temperature is: **(1)**



(A) Exactly zero ($E_g = 0$ eV)

(B) Greater than 3 eV (typically ∼ 6 eV)

(C) Very small, around 0.67 eV to 1.1 eV

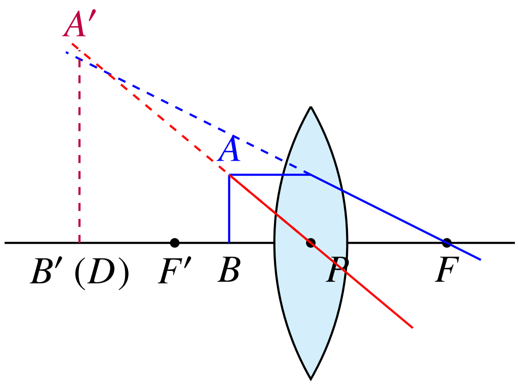
(D) Negative ($E_g < 0$) due to overlapping bands

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 rotational kinematics by filling in the blanks:
(Radius of Gyration, Moment of Inertia, Rotational Kinetic Energy, Angular Acceleration) **(2)**

1. The root-mean-square distance of all constituent mass particles of a rotating body from its axis of rotation, defined as $k = \sqrt{I/M}$, is called the ....
2. The kinetic energy possessed by a rigid body of moment of inertia I rotating with angular velocity ω, given by $K_{\text{rot}} = \frac{1}{2}I\omega^2$, is called its ....

Q18. Read the short passage given below regarding optical magnification and answer the two sub-questions:
A Simple Magnifier (or reading glass) consists of a single thin convex lens of focal length f. When a small object AB is placed between the optical center P and the principal focus F of the lens, it produces an erect, magnified, and virtual image A'B' on the same side of the lens as the object. For maximum visual clarity without straining the eye, the lens is held close to the eye and the virtual image is formed at the least distance of distinct vision ($D \approx 25$ cm). **(2)**



1. Write the mathematical formula for the angular magnifying power (m) of a simple magnifier when the final virtual image is formed at the least distance of distinct vision D.
2. What is the magnifying power (m_∞) when the object is shifted exactly to the focus F, forming the image at infinity (normal relaxed eye accommodation)?

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

According to Ohm's law, at constant physical temperature, the electric current I flowing through a uniform metallic conductor is directly proportional to the potential difference V across its ends ($V = IR$). The electrical resistance R of a wire of length L and uniform cross-sectional area A is given by $R = \rho\frac{L}{A}$, where ρ is the specific electrical resistivity of the material. **(2)**

1. State how the electrical resistance R of a wire changes if its length L is doubled by stretching while its total volume remains constant. (State the factor by which R increases).
2. Does the specific electrical resistivity (ρ) of a copper wire change if its cross-sectional area A is halved? (Answer Yes or No, with a one-sentence reason).

Q20. Read the short passage given below regarding atomic structure and answer the two sub-questions:
In 1911, Ernest Rutherford performed the historic alpha-particle scattering experiment by bombarding a very thin gold foil with energetic alpha (α) particles ($^4_2He^{2+}$). He observed that while most alpha particles passed straight through without deflection, a small fraction deflected at large angles, and about 1 in 8000 rebounded backward ($\theta \approx 180°$). This proved that the entire positive charge and almost all atomic mass are concentrated in a tiny central core called the nucleus. **(2)**

1. Write the formula for the distance of closest approach (r_0) of an alpha particle of charge $q_1 = 2e$ and initial kinetic energy E_k approaching a target nucleus of atomic number Z ($q_2 = Ze$) in a head-on collision.
2. What conclusion did Rutherford draw regarding the size of the nucleus compared to the overall size of the atom from the extreme rarity of 180° back-scattering?

Q21. Match the elastic and fluid properties in Column I with their correct units or defining relations in Column II: **(2)**

Column I	Column II
(a) Young's Modulus (Y)	(i) Ratio of shearing tangential stress to angular shear strain
(b) Bulk Modulus (B)	(ii) Surface energy or work done per unit surface area (J m^{-2})
(c) Shear Modulus (η)	(iii) Ratio of longitudinal tensile stress to longitudinal strain
(d) Surface Tension (T)	(iv) Ratio of normal hydraulic pressure change to volumetric strain

Q22. Match the transistor terminals and parameters in Column I with their correct physical characteristics in Column II: **(2)**

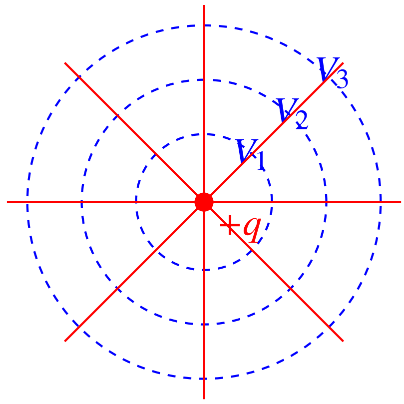
Column I	Column II
(a) Transistor Emitter	(i) Moderately doped terminal having the largest physical size/area for heat dissipation
(b) Transistor Base	(ii) Ratio of collector current to base current ($\beta = I_C/I_B$)
(c) Transistor Collector	(iii) Heavily doped terminal designed to inject majority charge carriers into the base
(d) Current Gain β	(iv) Extremely thin and lightly doped central layer controlling carrier passage

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

1. In a stationary (standing) wave formed on a string, no net transfer of mechanical energy takes place across any node from one segment of the medium to another.
2. All vibrating particles situated within the same loop between two adjacent nodes of a standing wave oscillate with random, continuously varying phase differences relative to one another.

Q24. Read the short passage given below and observe the equipotential diagram:

An equipotential surface is a continuous surface in an electric field over which the electrostatic potential V has a constant value at all points. As illustrated below for a positive point charge $+q$, the equipotential surfaces form concentric spheres centered on the charge. Since $V = \text{const}$ along the surface, the potential difference between any two points on an equipotential surface is strictly zero ($\Delta V = 0$). **(2)**



1. How much electrostatic work W is done in moving a test charge q_0 from one point to another point along the same equipotential surface?
2. What is the geometric angle between the direction of electric field lines ($\vec{E}$) and any equipotential surface at their point of intersection?

Q25. Complete the following statements regarding optical polarization by filling in the blanks:

(Linearly Polarized Light, Unpolarized Light, Malus's Law, Brewster's Law) **(2)**

1. Light waves in which the electric field vectors vibrate symmetrically in all possible directions perpendicular to the direction of wave propagation are called ....
2. Light waves in which the electric field vibrations are confined to a single plane along the direction of propagation are called ....

Q26. Match the nuclear classifications in Column I with their correct atomic definitions in Column II: **(2)**

Column I	Column II
(a) Isotopes	(i) Nuclei having same mass number A but different atomic numbers Z
(b) Isobars	(ii) Nuclei having identical composition (Z, A) but existing in different radioactive energy states
(c) Isotones	(iii) Nuclei having same atomic number Z but different mass numbers A
(d) Nuclear Isomers	(iv) Nuclei having same neutron number $N = A - Z$ but different protons

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

1. The tremendous solar energy continuously radiated by the Sun and stars is generated primarily by thermonuclear Nuclear Fusion reactions (such as the proton-proton cycle).
2. In a commercial nuclear power reactor, controlled nuclear fission is sustained by using cadmium or boron control rods that readily emit high-speed neutrons to multiply the chain reaction.

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

1. In Sky Wave (ionospheric) propagation, High Frequency (HF) radio waves between 3 MHz and 30 MHz are reflected back to Earth by ionospheric plasma layers, enabling long-distance shortwave communication.
2. Ultra-High Frequency (UHF) and microwave signals above 100 MHz easily reflect from the ionosphere and do not require direct line-of-sight space wave propagation between transmitting and receiving antennas.

Section: B

Q29. (i) Define Radius of Gyration (K) of a rotating rigid body about a given rotational axis and write its SI unit. Show mathematically that for a body of mass M and moment of inertia I, $K = \sqrt{I/M}$.

OR

(ii) Define Conservative and Non-Conservative forces in classical mechanics. Give one clear everyday example of each type of force. **(2)**

Q30. State the First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$). Explain clearly why internal energy (U) is classified as a thermodynamic State Function, whereas heat transferred (Q) and work done (W) are Path Functions. **(2)**

Q31. (i) Define Self-Inductance (L) of a single coil and Mutual Inductance (M) between two magnetically coupled coils. State the SI unit of inductance (Henry).

OR

(ii) State Coulomb's Law of electrostatics in vector form. Explain briefly what is meant by the principle of superposition of electrostatic forces among an assembly of multiple point charges. **(2)**

Q32. State Malus's Law of optical polarization relating transmitted intensity I to polarizer-analyzer angle θ ($I = I_0 \cos^2 \theta$). Explain clearly why longitudinal sound waves in air cannot undergo polarization, whereas transverse electromagnetic light waves can be polarized. **(2)**

Q33. What are Eddy Currents (Foucault currents)? State any two practical disadvantages of eddy currents in electromagnetic machinery (such as transformers or electric motors) and explain how they are effectively minimized by using thin laminated iron cores. **(2)**

Q34. The radioactive half-life period of a radon radioisotope is $T_{1/2} = 3.8$ days. Calculate the exact fraction ($\frac{N}{N_0}$) of a pure sample of radon atoms that remains undecayed after an elapsed time of 15.2 days. **(2)**

Q35. Distinguish clearly between optical Interference and optical Diffraction of light by writing any two fundamental differences regarding fringe intensity distribution and fringe width uniformity on an observation screen. **(2)**

Q36. (i) Calculate the nuclear radius (R, in meters and fermis) of a copper nucleus of mass number $A = 64$ using the empirical nuclear radius formula $R = R_0 A^{1/3}$. (Given: Nuclear radius constant $R_0 = 1.2 \times 10^{-15}$ m = 1.2 fm).

OR

(ii) State any two fundamental physical properties of Nuclear Forces operating between nucleons inside an atomic nucleus (such as range, charge dependence, or spin dependence). **(2)**

Q37. (i) Draw the standard logic gate symbol and write the complete truth table for a two-input AND gate. Write its Boolean algebraic expression ($Y = A \cdot B$).

OR

(ii) Explain the primary electrical functions of: (a) a Transducer, and (b) a Repeater station in an electronic communication transmission link. **(2)**

Q38. (i) State Newton's Universal Law of Gravitation. Derive the mathematical expression for acceleration due to gravity (g_d) at a depth d below the surface of a uniform spherical Earth of radius R and surface gravity g. Show that $g_d = g\left(1 - \frac{d}{R}\right)$.

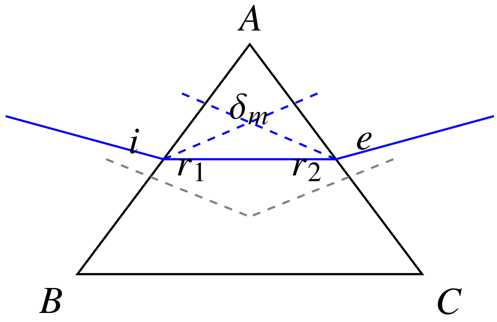
OR

(ii) Derive an expression for the total kinetic energy (K_{total}) of a symmetric rigid body of mass M, radius R, and radius of gyration K rolling without slipping along a horizontal surface with linear center-of-mass velocity v ($K_{\text{total}} = \frac{1}{2}Mv^2[1 + K^2/R^2]$). **(3)**

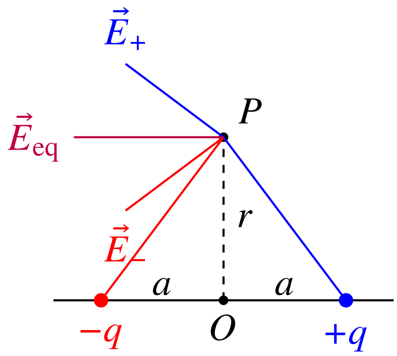
Q39. A projectile is projected vertically upward from the surface of Earth (radius R, surface gravity g) with an initial launch speed equal to exactly half the escape velocity ($u = \frac{1}{2}v_e$). Using conservation of mechanical energy, derive an analytical expression for the maximum vertical altitude h attained by the projectile above the Earth's surface in terms of R. **(3)**

Q40. Derive an expression for the magnetic Lorentz force per unit length ($\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$) acting between two infinitely long, thin, parallel straight conductors carrying steady currents I_1 and I_2 separated by a vacuum distance d. Hence, define the standard SI unit One Ampere of electric current. **(3)**

Q41. A monochromatic light ray passes symmetrically through a refracting glass prism of refracting angle A at the position of minimum deviation δ_m. Using geometric optics and a clean ray diagram, derive the relation connecting refractive index μ, prism angle A, and minimum deviation δ_m: $\mu = \frac{\sin[(A+\delta_m)/2]}{\sin(A/2)}$. **(3)**



Q42. (i) Define an electric dipole and dipole moment $\vec{p}$. Derive an expression for the electric field intensity $\vec{E}_{\text{eq}}$ at a point on the equatorial line (broadside-on position) at distance r from the center of an electric dipole of charge q and length $2a$. Show that for a short dipole ($r \gg a$), $E_{\text{eq}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$.

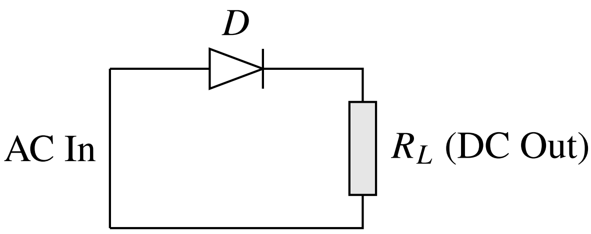


(ii) Write the vector formula for the electrostatic torque $\vec{\tau}$ experienced by an electric dipole placed in a uniform electric field $\vec{E}$. When is this torque maximum?

OR

(iii) Describe the principle, construction, and working of a Moving Coil Galvanometer with a neat labeled diagram. Derive the relation between coil deflection angle θ and current I ($I = \frac{k}{NAB}\theta$). Why is a radial magnetic field used in the air gap? **(5)**

Q43. (i) Describe the construction and working of a Half-Wave Rectifier using a single semiconductor diode (D) with a labeled circuit schematic and input/output voltage waveforms.



(ii) Define ripple factor (γ) of a rectifier. Explain why a full-wave bridge rectifier is significantly more efficient than a single-diode half-wave rectifier.

OR

(iii) Describe the construction and operational principle of a Semiconductor Solar Cell with a labeled structure diagram. Plot its typical I-V characteristic curve in the fourth quadrant, highlighting short-circuit current (I_{sc}) and open-circuit voltage (V_{oc}). Why are Silicon (Si) and Gallium Arsenide (GaAs) preferred semiconductors for solar cell fabrication? **(5)**

Detailed Solutions

Q1.

Solution

Concept: According to Newton's law of viscosity, viscous tangential force between fluid layers is $F = \eta A \frac{dv}{dx}$, hence $\eta = \frac{F}{A(dv/dx)}$.

Step 1 — Substitute dimensional formulas for force $F = [\mathrm{M}^1\mathrm{L}^1\mathrm{T}^{-2}]$, area $A = [\mathrm{L}^2]$, and velocity gradient $\frac{dv}{dx} = [\mathrm{L}^1\mathrm{T}^{-1}]/[\mathrm{L}^1] = [\mathrm{T}^{-1}]$:

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

Why other options are wrong:

- **Option A:** $[\mathrm{M}^1\mathrm{L}^1\mathrm{T}^{-1}]$ represents linear momentum or impulse.
- **Option B:** $[\mathrm{M}^1\mathrm{L}^{-2}\mathrm{T}^{-2}]$ represents pressure gradient or force per unit volume.
- **Option D:** $[\mathrm{M}^1\mathrm{L}^{-1}\mathrm{T}^{-2}]$ represents pressure or stress.

Final Answer: $\boxed{[\mathrm{M}^1\mathrm{L}^{-1}\mathrm{T}^{-1}]}$ (Option C)

Answer: (C) Go Back to Question 1

Q2.

Solution

Concept: For a uniform thin rod of linear mass density $\lambda = M/L$, moment of inertia about its center of mass is found by integrating $x^2 dm$ from $-L/2$ to $+L/2$.

Step 1 — Consider an elemental mass $dm = \lambda dx$ at distance x from the center:

$$I_{\text{cm}} = \int_{-L/2}^{+L/2} x^2(\lambda dx) = \lambda \left[\frac{x^3}{3}\right]_{-L/2}^{+L/2} = \left(\frac{M}{L}\right)\left[\frac{L^3}{24} - \left(-\frac{L^3}{24}\right)\right] = \frac{1}{12}ML^2$$

Why other options are wrong:

- **Option B:** $\frac{1}{3}ML^2$ is the moment of inertia about an axis passing through one end of the rod.
- **Option C:** $\frac{1}{2}ML^2$ is incorrect coefficient scaling.
- **Option D:** $\frac{1}{6}ML^2$ would result from integrating only half the rod without proper bounds.

Final Answer: $\boxed{\frac{1}{12}ML^2}$ (Option A)

Answer: (A) Go Back to Question 2

Q3.

Solution

Concept: For a conservative force field, the work done by the field equals the negative change in potential energy: $dW = F_x dx = -dU$.

Step 1 — Rearranging the differential relation $F_x dx = -dU$:

$$F_x = -\frac{dU}{dx}$$

The conservative force always acts in the direction of the steepest decrease (negative gradient) of potential energy.

Why other options are wrong:

- **Option A:** Missing the negative sign; force would incorrectly point toward higher potential energy.
- **Option B:** Integral of potential energy has no physical force identity.
- **Option C:** Force is the spatial gradient of potential, not simply its negative scalar value.

Final Answer: $\boxed{F_x = -\frac{dU}{dx}}$ (Option D)

Answer: (D) Go Back to Question 3

Q4.

Solution

Concept: In uniform circular motion, velocity magnitude v is constant, but its direction continuously changes, generating a centripetal acceleration directed along the radius toward the center.

Step 1 — Magnitude of centripetal acceleration in terms of linear speed v is $a_c = \frac{v^2}{r}$. Substituting tangential velocity relation $v = \omega r$:

$$a_c = \frac{(\omega r)^2}{r} = \omega^2 r$$

Step 2 — In vector form, $\vec{a}_c = -\omega^2 \vec{r}$, confirming that acceleration is directed radially inward toward center O.

Why other options are wrong:

- **Option A:** ωr is tangential velocity v, not acceleration.
- **Option C:** Centripetal acceleration is inversely proportional to r, not r^2, and points inward.
- **Option D:** Incorrect dimension scaling ($\omega^2 r^2$ is velocity squared).

Final Answer: $\boxed{a_c = \omega^2 r \text{ directed radially inward}}$ (Option B)

Answer: (B) Go Back to Question 4

Q5.

Solution

Concept: Elastic potential energy density (stored energy per unit volume) in a stretched wire is half the product of stress and strain: $u = \frac{1}{2} \times \text{stress} \times \text{strain}$.

Step 1 — From Hooke's law, longitudinal stress = $Y \times$ strain.

Step 2 — Substitute stress into the energy density formula:

$$u = \frac{1}{2} \times (Y \times \text{strain}) \times \text{strain} = \frac{1}{2} Y \times (\text{strain})^2$$

Why other options are wrong:

- **Option A:** Missing the factor of $\frac{1}{2}$ arising from integration of linear restoring force.
- **Option B:** Stress squared requires $2Y$ in the denominator ($u = \text{stress}^2/2Y$).
- **Option D:** Incorrect multiplication factor of 2.

Final Answer: $\boxed{u = \frac{1}{2} Y \times (\text{strain})^2}$ (Option C)

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

Q6.

Solution

Concept: For an ideal monoatomic gas having only 3 translational degrees of freedom ($f = 3$), molar specific heats are $C_v = \frac{3}{2} R$ and $C_p = C_v + R = \frac{5}{2} R$.

Step 1 — Calculate the adiabatic ratio $\gamma = \frac{C_p}{C_v}$:

$$\gamma = \frac{\frac{5}{2} R}{\frac{3}{2} R} = \frac{5}{3} \approx 1.67$$

Why other options are wrong:

- **Option B:** $\frac{7}{5} = 1.40$ is the specific heat ratio for rigid diatomic gases ($f = 5$).
- **Option C:** $\frac{4}{3} \approx 1.33$ applies to non-linear polyatomic gases ($f = 6$).
- **Option D:** $\frac{9}{7} \approx 1.29$ applies to high-temperature diatomic gases vibrating with $f = 7$.

Final Answer: $\boxed{\frac{5}{3} \approx 1.67}$ (Option A)

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

Q7.

Solution

Concept: In SHM, total mechanical energy is the sum of kinetic energy $K = \frac{1}{2}m\omega^2(A^2 - x^2)$ and potential energy $U = \frac{1}{2}m\omega^2x^2$.

Step 1 — Adding kinetic and potential energies eliminates displacement x:

$$E = K + U = \frac{1}{2}m\omega^2(A^2 - x^2) + \frac{1}{2}m\omega^2x^2 = \frac{1}{2}m\omega^2A^2$$

Step 2 — Since mass m and frequency ω are constant, total energy is directly proportional to amplitude squared ($E \propto A^2$).

Why other options are wrong:

- **Option A:** Energy is independent of instantaneous position x; it remains constant.
- **Option B:** Energy increases with amplitude; it is not inversely proportional.
- **Option C:** Energy scales as frequency squared (ω^2), not linearly.

Final Answer: Directly proportional to amplitude squared ($E \propto A^2$) (Option D)

Answer: (D) Go Back to Question 7

Q8.

Solution

Concept: Equation of Continuity expresses conservation of mass in fluid dynamics: volume flow rate entering section 1 equals volume flow rate exiting section 2 ($A_1v_1 = A_2v_2$).

Step 1 — Since $A_1v_1 = A_2v_2$, flow velocity is inversely proportional to cross-sectional area ($v \propto 1/A$).

Step 2 — At the narrower constriction where $A_2 < A_1$, flow speed must strictly increase to conserve volumetric flow rate, resulting in $v_2 > v_1$.

Why other options are wrong:

- **Option A:** Area and velocity are multiplied, not added.
- **Option C:** Inverted proportionality claiming speed decreases at narrow constrictions.
- **Option D:** Velocity is linear, not squared, in volumetric flow rate conservation.

Final Answer: $A_1v_1 = A_2v_2 \implies v_2 > v_1$ (Option B)

Answer: (B) Go Back to Question 8

Q9.

Solution

Concept: A dipole in a uniform electric field experiences two equal and opposite forces creating a restoring couple (torque): $\vec{\tau} = \vec{p} \times \vec{E} \implies \tau = pE\sin\theta$.

Step 1 — Torque magnitude is $\tau = pE\sin\theta$. Since p and E are constant, τ is maximum when $\sin\theta = 1$.

Step 2 — The sine function reaches its maximum value of 1 at angle $\theta = 90^\circ$ ($\pi/2$ radians), perpendicular to the field.

Why other options are wrong:

- **Option A:** At $\theta = 0^\circ$, $\sin 0^\circ = 0$, giving zero torque (stable equilibrium).
- **Option B:** At $\theta = 45^\circ$, $\tau = pE/\sqrt{2} \approx 0.707pE$, which is sub-maximal.
- **Option D:** At $\theta = 180^\circ$, $\sin 180^\circ = 0$, giving zero torque (unstable equilibrium).

Final Answer: $\boxed{90^\circ \text{ (Perpendicular orientation)}}$ (Option C)

Answer: (C) Go Back to Question 9

Q10.

Solution

Concept: In reversible isothermal expansion (T = const), gas pressure varies as $P = nRT/V$. Work done is $W = \int P dV = nRT \int \frac{dV}{V}$.

Step 1 — Evaluating the definite integral from initial volume V_1 to final volume V_2:

$$W = nRT[\ln V]_{V_1}^{V_2} = nRT \ln\left(\frac{V_2}{V_1}\right)$$

Converting natural logarithm to base 10: $W = 2.303nRT \log_{10}\left(\frac{V_2}{V_1}\right)$.

Why other options are wrong:

- **Option B:** Linear volume approximation applies only to isobaric work ($P\Delta V$).
- **Option C:** $\frac{nR}{\gamma-1}(T_1 - T_2)$ is the mechanical work done during an adiabatic process.
- **Option D:** Inverted volume ratio ($\ln(V_1/V_2)$ represents negative isothermal compression work).

Final Answer: $\boxed{W = nRT\ln(V_2/V_1)}$ (Option A)

Answer: (A) Go Back to Question 10

Q11.

Solution

Concept: Conductor 1 creates magnetic field $B_1 = \frac{\mu_0 I_1}{2\pi d}$ at conductor 2. Conductor 2 experiences Lorentz force $F = I_2 L B_1 \sin 90^\circ = \frac{\mu_0 I_1 I_2 L}{2\pi d}$.

Step 1 — By Fleming's left-hand rule (or right-hand cross product $\vec{I}_2 \times \vec{B}_1$), when currents I_1 and I_2 flow in the exact same (parallel) direction, the magnetic force acts inward, pulling the conductors together (**Attraction**).

Step 2 — When currents flow in opposite (antiparallel) directions, the magnetic force acts outward, pushing them apart (**Repulsion**).

Why other options are wrong:

- **Option A:** Reverses force direction; antiparallel currents repel.
- **Option B:** Equal currents produce maximum magnetic interaction force, not zero.
- **Option C:** Reverses force direction; parallel currents attract.

Final Answer: Attractive for parallel currents, repulsive for opposite currents (Option D)

Answer: (D) Go Back to Question 11

Q12.

Solution

Concept: Newton originally assumed sound propagation in air is isothermal ($v = \sqrt{P/\rho} \approx 280 \text{ m s}^{-1}$, too slow). Laplace corrected this by proving rapid acoustic compressions occur adiabatically without heat exchange ($PV^\gamma = \text{const}$).

Step 1 — For adiabatic acoustic propagation, bulk modulus of elasticity is $B_{\text{adia}} = \gamma P$.

Step 2 — Substituting adiabatic bulk modulus into general wave speed formula $v = \sqrt{B/\rho}$:

$$v = \sqrt{\frac{\gamma P}{\rho}} \approx \sqrt{1.4 \times \frac{1.013 \times 10^5}{1.29}} \approx 331 \text{ m s}^{-1}$$

which perfectly matches experimental measurements.

Why other options are wrong:

- **Option A:** Uncorrected isothermal formula of Newton.
- **Option C:** Inverted density and pressure terms.
- **Option D:** Specific heat ratio γ must be inside the square root.

Final Answer: $\boxed{v = \sqrt{\frac{\gamma P}{\rho}}}$ (Option B)

Answer: (B) Go Back to Question 12

Q13.

Solution

Concept: When light enters an optically denser medium, its frequency ν remains strictly constant (being an intrinsic source property), but its propagation speed decreases to $v = c/\mu$.

Step 1 — Since wave speed is $v = \nu\lambda$, wavelength inside the medium scales directly with speed:

$$\lambda_{\text{med}} = \frac{v}{\nu} = \frac{c/\mu}{\nu} = \frac{\lambda_{\text{vac}}}{\mu}$$

Step 2 — Substitute $\lambda_{\text{vac}} = 600$ nm and $\mu = 1.5$:

$$\lambda_{\text{med}} = \frac{600 \text{ nm}}{1.5} = 400 \text{ nm}$$

Why other options are wrong:

- **Option A:** 900 nm results from multiplying by μ (600×1.5).
- **Option B:** 600 nm assumes wavelength is unchanged in denser media.
- **Option D:** 300 nm would require a refractive index of $\mu = 2.0$.

Final Answer: 400 nm (Option C)

Answer: (C) Go Back to Question 13

Q14.

Solution

Concept: A meter bridge works on the Wheatstone bridge null deflection principle: $\frac{R}{X} = \frac{R_{\text{wire}(0 \text{ to } l)}}{R_{\text{wire}(l \text{ to } 100)}}$.

Step 1 — Since slide wire AB is uniform, resistance of wire segment of length l cm is proportional to l, and resistance of remaining $(100 - l)$ cm segment is proportional to $(100 - l)$.

Step 2 — Equating bridge arm resistance ratios at null balance:

$$\frac{R}{X} = \frac{l}{100 - l} \implies X = R\left(\frac{100 - l}{l}\right)$$

Why other options are wrong:

- **Option B:** Inverted ratio giving left-hand resistance if unknown were in the left gap.
- **Option C:** Ignores the remaining wire segment length $(100 - l)$.
- **Option D:** Simple percentage scaling without balance equation.

Final Answer: $\boxed{X = R\left(\frac{100 - l}{l}\right)}$ (Option A)

Answer: (A) Go Back to Question 14

Q15.

Solution

Concept: According to Airy's diffraction criterion, two distant point stars are just resolved by a circular telescope aperture of diameter D when the angular separation between them is $\theta_{\text{min}} = \frac{1.22\lambda}{D}$.

Step 1 — Resolving Power (R.P.) is defined as the reciprocal of the minimum limit of resolution (θ_{min}):

$$\text{R.P.} = \frac{1}{\theta_{\text{min}}} = \frac{D}{1.22\lambda}$$

A larger aperture diameter D significantly increases resolving power, allowing telescopes to distinguish fine astronomical details.

Why other options are wrong:

- **Option A:** $\frac{1.22\lambda}{D}$ is the angular limit of resolution (θ_{min}), not its reciprocal resolving power.
- **Option B:** Missing Airy's circular aperture diffraction factor of 1.22.
- **Option C:** Inverts factor 1.22 into the numerator alongside aperture diameter.

Final Answer: $\boxed{\frac{D}{1.22\lambda}}$ (Option D)

Answer: (D) Go Back to Question 15

Q16.

Solution

Concept: In solid-state physics, electrical conductivity depends on the width of the forbidden energy band gap E_g separating valence and conduction bands.

Step 1 — In metals (conductors), valence and conduction bands overlap ($E_g \approx 0$), providing abundant free electrons.

Step 2 — In semiconductors (Si, Ge), the band gap is narrow ($E_g \sim 0.7$ eV to 1.1 eV), allowing thermal excitation at room temperature.

Step 3 — In electrical insulators (diamond, quartz), the forbidden band gap is extremely wide, always strictly **greater than** 3 **eV** (e.g., diamond $E_g \approx 6$ eV), preventing thermal excitation of electrons across the gap.

Why other options are wrong:

- **Option A:** Exactly zero corresponds to overlapping metallic conductors.
- **Option C:** 0.67 eV to 1.1 eV corresponds to Ge and Si semiconductors.
- **Option D:** Negative band gap refers to semi-metals or theoretical degenerate states.

Final Answer: $\boxed{\text{Greater than 3 eV (typically } \sim 6 \text{ eV)}}$ (Option B)

Answer: (B) Go Back to Question 16

Q17.

Solution

Concept: Radius of gyration and rotational kinetic energy characterize rigid body rotational mechanics.

Step 1 — The radial distance k from the axis at which the entire mass M of a body could be concentrated without altering its moment of inertia ($I = Mk^2 \implies k = \sqrt{I/M}$) is called the **Radius of Gyration**.

Step 2 — The mechanical energy possessed by a body due to its rotational motion about an axis, formulated as $K_{\text{rot}} = \frac{1}{2}I\omega^2$, is called its **Rotational Kinetic Energy**.

Final Answer: $\boxed{\text{1. Radius of Gyration} \quad \text{2. Rotational Kinetic Energy}}$

Answer: (See above) Go Back to Question 17

Q18.

Solution

Concept: A simple magnifier achieves angular magnification by allowing the eye to view a close virtual image at large visual angles.

Step 1 — When the virtual image is formed at the least distance of distinct vision D (maximum visual magnification), the angular magnifying power is:

$$m = 1 + \frac{D}{f}$$

Step 2 — When the object is placed at focus F, parallel emergent rays form the image at infinity (∞). The magnifying power for relaxed eye accommodation (m_∞) is:

$$m_\infty = \frac{D}{f}$$

Final Answer: $\boxed{1.\ m = 1 + \frac{D}{f} \quad 2.\ m_\infty = \frac{D}{f}}$

Answer: (See above) Go Back to Question 18

Q19.

Solution

Concept: Resistance depends on geometry ($R = \rho L/A$), whereas specific resistivity ρ is an intrinsic material constant at a given temperature.

Step 1 — Since volume $V = AL =$ const, when length is stretched to $L' = 2L$, area halves to $A' = A/2$. New resistance is:

$$R' = \rho\frac{L'}{A'} = \rho\frac{2L}{A/2} = 4\left(\rho\frac{L}{A}\right) = 4R$$

Thus, resistance increases by a factor of **4 (four times)**.

Step 2 — No. Specific electrical resistivity (ρ) is an intrinsic material property depending only on atomic structure and temperature; it does not change with physical dimensions or cross-sectional area.

Final Answer: $\boxed{1.\ \text{Increases 4 times } (4R) \quad 2.\ \text{No, } \rho \text{ is an intrinsic material constant}}$

Answer: (See above) Go Back to Question 19

Q20.

Solution

Concept: At distance of closest approach r_0, alpha particle kinetic energy converts entirely into electrostatic potential energy.

Step 1 — Equating initial kinetic energy E_k to Coulomb electrostatic potential energy at head-on distance r_0:

$$E_k = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r_0} \implies r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_k}$$

Step 2 — From the rarity of large-angle deflections ($\sim$ 1 in 8000), Rutherford concluded that the nuclear radius ($\sim 10^{-15}$ m = 1 fm) is extremely tiny—about **10,000 to 100,000 times smaller** than the atomic radius ($\sim 10^{-10}$ m = 1 Å), meaning the atom is mostly empty space.

Final Answer: 1. $r_0 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{E_k}$ 2. Nucleus is $\sim 10^4$ to 10^5 times smaller than atom

Answer: (See above) Go Back to Question 20

Q21.

Solution

Concept: Matching elastic moduli and surface energy definitions with their ratios.

Step 1 — Young's Modulus (Y) is the ratio of longitudinal tensile stress to longitudinal strain, so (a) matches (iii).

Step 2 — Bulk Modulus (B) is the ratio of normal hydraulic pressure change to volumetric strain, so (b) matches (iv).

Step 3 — Shear Modulus (η) is the ratio of shearing tangential stress to angular shear strain, so (c) matches (i).

Step 4 — Surface Tension (T) equals surface energy or work done per unit surface area ($\mathrm{J\,m^{-2}}$), so (d) matches (ii).

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

Answer: (See above) Go Back to Question 21

Q22.

Solution

Concept: Matching BJT transistor physical terminal design with electrical functions.

Step 1 — Transistor Emitter is heavily doped to inject majority carriers into the base, so (a) matches (iii).

Step 2 — Transistor Base is extremely thin and lightly doped to minimize recombination, so (b) matches (iv).

Step 3 — Transistor Collector is moderately doped and physically largest to dissipate power and collect carriers, so (c) matches (i).

Step 4 — Current Gain β is defined as collector current divided by base current (I_C/I_B), so (d) matches (ii).

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

Answer: (See above) **Go Back to Question 22**

Q23.

Solution

Concept: Standing waves localize mechanical energy within loops; medium particles within the same loop vibrate in unison.

Step 1 — Statement 1 is **TRUE (T)**. In a stationary standing wave, equal energy flows in opposite directions simultaneously, resulting in zero net transmission of mechanical energy across any stationary node.

Step 2 — Statement 2 is **FALSE (F)**. All vibrating particles located within the same loop between two adjacent nodes oscillate strictly **in phase** with one another (reaching peak displacement simultaneously), differing only in vibration amplitude.

Final Answer: 1. T 2. F

Answer: (See above) **Go Back to Question 23**

Q24.

Solution

Concept: Electric potential difference along an equipotential surface is zero ($\Delta V = 0$), requiring field lines to be perpendicular to the surface.

Step 1 — Electrostatic work done in moving test charge q_0 between two points on the same equipotential surface is $W = q_0 \Delta V$. Since $V_1 = V_2 \implies \Delta V = 0$, the work done is strictly **Zero** ($W = 0$).

Step 2 — Since $dW = \vec{E} \cdot d\vec{l} = E dl \cos\theta = 0$ for any displacement dl along the surface, $\cos\theta = 0$. Hence, the geometric angle between electric field lines and the equipotential surface is exactly 90° ($\pi/2$ **radians, perpendicular**).

Final Answer: 1. Zero ($W = 0$) 2. 90° ($\pi/2$ rad, perpendicular)

Answer: (See above) Go Back to Question 24

Q25.

Solution

Concept: Defining optical polarization states based on electric vector vibration symmetry.

Step 1 — Light waves emitted by ordinary incandescent or solar sources have electric field vectors vibrating symmetrically in all possible transverse directions perpendicular to propagation, called **Unpolarized Light**.

Step 2 — When light passes through a polaroid filter, electric field vibrations are restricted to a single preferred plane containing the direction of propagation, called **Linearly Polarized Light**.

Final Answer: 1. Unpolarized Light 2. Linearly Polarized Light

Answer: (See above) Go Back to Question 25

Q26.

Solution

Concept: Matching nuclear classifications based on atomic number Z, mass number A, and neutron number N.

Step 1 — Isotopes have the same atomic number Z but different mass numbers A, so (a) matches (iii).

Step 2 — Isobars have the same mass number A but different atomic numbers Z, so (b) matches (i).

Step 3 — Isotones have the same number of neutrons ($N = A - Z$) with different proton counts, so (c) matches (iv).

Step 4 — Nuclear Isomers have identical atomic composition (Z, A) but exist in different internal radioactive energy states, so (d) matches (ii).

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

Answer: (See above) **Go Back to Question 26**

Q27.

Solution

Concept: Stellar energy originates from fusion; nuclear reactors control fission using neutron-absorbing control rods.

Step 1 — Statement 1 is **TRUE (T)**. Solar and stellar luminosity is sustained by thermonuclear fusion, primarily the proton-proton cycle merging four hydrogen nuclei into helium with massive mass-defect energy release.

Step 2 — Statement 2 is **FALSE (F)**. Cadmium and boron control rods are used in fission reactors because they strongly **absorb** (capture) thermal neutrons without fissioning, thereby preventing runaway chain reactions.

Final Answer: 1. T 2. F

Answer: (See above) **Go Back to Question 27**

Q28.

Solution

Concept: Ionospheric reflection enables HF shortwave communication; UHF/microwaves penetrate ionosphere requiring line-of-sight propagation.

Step 1 — Statement 1 is **TRUE (T)**. In Sky Wave propagation, HF signals (3 to 30 MHz) undergo total internal reflection from ionospheric plasma layers, enabling global shortwave broadcasting.

Step 2 — Statement 2 is **FALSE (F)**. UHF and microwave signals (> 100 MHz) penetrate straight through the ionosphere without reflecting. Hence, they strictly require **line-of-sight Space Wave propagation** between elevated antennas or relay satellites.

Final Answer: 1. T 2. F

Answer: (See above) Go Back to Question 28

Q29.

Solution

Concept: Radius of gyration measures effective root-mean-square mass distribution; conservative forces store reversible potential energy without mechanical dissipation.

Step 1 — Alternative (i) - Radius of Gyration (K): The radial distance from an axis at which the entire mass M of a rigid body can be concentrated such that its rotational inertia equals its actual moment of inertia I is called Radius of Gyration (K). SI unit: **meter** (m).

Step 2 — Proof: By definition, $I = MK^2$. Dividing by total mass M and taking square root gives:

$$K = \sqrt{\frac{I}{M}}$$

Step 3 — Alternative (ii) - Conservative vs Non-Conservative:

Conservative Force	**Non-Conservative Force**
1. Work done depends solely on initial and final positions, independent of path taken.	1. Work done depends strongly on the specific length and trajectory of the path taken.
2. Work done around any closed loop is strictly zero ($\oint \vec{F} \cdot d\vec{r} = 0$).	2. Work done around a closed loop is non-zero, dissipating mechanical energy as heat.
Example: Gravitational force or Electrostatic Coulomb force.	Example: Kinetic frictional force or Viscous fluid drag force.

Final Answer: $K = \sqrt{I/M}$ (in m); or Conservative/Non-conservative forces table

Answer: (See above) Go Back to Question 29

Q30.

Solution

Concept: The First Law of Thermodynamics expresses conservation of energy for thermal systems: heat added equals internal energy change plus external work performed ($\Delta Q = \Delta U + \Delta W$).

Step 1 — State Function (U): Internal energy U depends purely on the instantaneous equilibrium state of the system (determined by macroscopic coordinates P, V, T). When a system changes from state A to state B, $\Delta U = U_B - U_A$ is identical for all possible intermediate processes.

Step 2 — Path Functions (Q and W): Heat absorbed Q and work done $W = \int PdV$ depend directly on the geometric process curve connecting state A to state B on an indicator diagram. Different curves enclose different areas (W) and require different heat transfers (Q).

Step 3 — However, their difference $\Delta Q - \Delta W = \Delta U$ is strictly path-independent, confirming energy conservation.

Final Answer: $\Delta Q = \Delta U + \Delta W$; U depends only on state coordinates, while Q and W depend on process trajectory

Answer: (See above) Go Back to Question 30

Q31.

Solution

Concept: Inductance characterizes magnetic flux linkage per unit current; Coulomb's law governs inverse-square electrostatic forces between point charges.

Step 1 — Alternative (i): Self-Inductance (L) is the electromagnetic property of a single coil by which it opposes any change in its own current by inducing a back EMF: $\Phi_B = LI \implies E = -L\frac{dI}{dt}$.

Step 2 — Mutual Inductance (M) is the property of two magnetically coupled coils where changing current in the primary coil induces an EMF across the secondary coil: $\Phi_2 = MI_1 \implies E_2 = -M\frac{dI_1}{dt}$. SI unit of inductance is **Henry** (H).

Step 3 — Alternative (ii): Coulomb's Law in vector form states that the electrostatic force $\vec{F}_{12}$ exerted by point charge q_1 on charge q_2 separated by vector $\vec{r}_{12}$ in vacuum is:

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

Step 4 — Superposition Principle: The net electrostatic force on any point charge due to an assembly of multiple charges is the vector sum of all individual Coulomb forces exerted by each surrounding charge independently ($\vec{F}_{\text{net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots$).

Final Answer: $\Phi = LI,\ \Phi_2 = MI_1$ (in H); or $\vec{F} = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}\hat{r}$ with vector sum

Answer: (See above) Go Back to Question 31

Q32.

Solution

Concept: Malus's law quantifies analyzer transmission; polarization requires transverse vector vibrations perpendicular to propagation.

Step 1 — Malus's Law: When linearly polarized light of intensity I_0 passes through an analyzer, the transmitted intensity I varies directly as the square of the cosine of angle θ between the transmission axes of polarizer and analyzer:

$$I = I_0 \cos^2 \theta$$

Step 2 — Why Longitudinal Sound Cannot Polarize: In longitudinal sound waves, air molecules vibrate strictly back and forth along the line of wave propagation. Since there are no transverse vibration components perpendicular to propagation, passing through a slit or polarizer cannot restrict or select any transverse orientation.

Step 3 — In contrast, transverse light waves vibrate in 360-degree planes perpendicular to propagation, allowing polarizers to isolate a single vibration plane.

Final Answer: $I = I_0 \cos^2 \theta$; longitudinal sound lacks transverse perpendicular vibrations to isolate

Answer: (See above) Go Back to Question 32

Q33.

Solution

Concept: Eddy currents are circulating induced currents in bulk conductors; core lamination interrupts circulation loops, reducing Joule heating.

Step 1 — Definition: When a bulk metallic conductor is subjected to a changing magnetic flux, closed circulating induced currents swirl inside the volume of the metal like water eddies, called **Eddy Currents (Foucault currents)**.

Step 2 — Practical Disadvantages: (1) **Thermal Energy Loss:** Eddy currents cause severe Joule heating (I^2R loss) in transformer and motor iron cores, wasting electrical power. (2) **Magnetic Damping:** By Lenz's law, eddy currents generate opposing magnetic drag forces that impede rotational mechanical motion in motors and dynamos.

Step 3 — Minimization by Lamination: Iron cores are built from thin iron sheets (laminations) electrically insulated from one another by varnish layers oriented parallel to the magnetic field. This slicing breaks up wide conduction loops into narrow paths of high electrical resistance, suppressing eddy current magnitude ($P_{\text{loss}} \propto t^2$, where t is lamination thickness).

Final Answer: Eddy currents cause Joule heating & damping; thin insulated laminations increase path resistance

Answer: (See above) Go Back to Question 33

Q34.

Solution

Concept: Radioactive decay reduces undecayed nuclei exponentially: $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$, where $n = \frac{t}{T_{1/2}}$ is the number of half-lives.

Step 1 — Given half-life period $T_{1/2} = 3.8$ days and total elapsed decay time $t = 15.2$ days.

Step 2 — Calculate the number of elapsed half-lives (n):

$$n = \frac{t}{T_{1/2}} = \frac{15.2 \text{ days}}{3.8 \text{ days}} = 4$$

Step 3 — Calculate the fraction of undecayed radon nuclei remaining:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^4 = \frac{1}{16} = 0.0625 \text{ (or } 6.25\%\text{)}$$

Final Answer: $\boxed{\frac{N}{N_0} = \frac{1}{16} = 0.0625\ (6.25\%)}$

Answer: (See above) Go Back to Question 34

Q35.

Solution

Concept: Interference arises from superposition of distinct wavefronts from two coherent slits; diffraction arises from interference among secondary wavelets originating from different parts of a single wavefront.

Step 1 — Fundamental Differences Table:

Optical Interference	Optical Diffraction
1. All bright interference fringes have exactly the same uniform optical intensity.	1. Central maximum has overwhelming peak intensity; secondary maxima degrade rapidly in intensity.
2. Fringe width $\beta = \frac{\lambda D}{d}$ is strictly identical for all bright and dark bands.	2. Central maximum is twice as wide ($2\lambda D/a$) as all secondary diffraction fringes ($\lambda D/a$).
3. Dark fringes are nearly perfectly black with zero light intensity.	3. Dark diffraction minima are never perfectly zero in intensity.

Final Answer: Interference vs Diffraction comparison table above

Answer: (See above) Go Back to Question 35

Q36.

Solution

Concept: Nuclear radius scales with the cube root of nucleon number ($R = R_0 A^{1/3}$); nuclear forces are the strongest short-range attractive forces in nature.

Step 1 — Alternative (i) - Nuclear Radius: Given mass number $A = 64$ and constant $R_0 = 1.2 \times 10^{-15}$ m.

$$R = R_0 A^{1/3} = (1.2 \times 10^{-15} \text{ m}) \times (64)^{1/3} = (1.2 \times 10^{-15} \text{ m}) \times 4 = 4.8 \times 10^{-15} \text{ m}$$

In fermi units (1 fm = 10^{-15} m), the nuclear radius is $R = 4.8$ fm.

Step 2 — Alternative (ii) - Nuclear Force Properties: (1) **Short-Range Nature:** Nuclear forces are extremely short-range ($\sim$ 2 to 3 fm); beyond 3 fm, their strength drops to zero, unlike infinite-range electromagnetic forces. (2) **Charge Independence:** The nuclear attractive force between two protons (p-p) is strictly identical in magnitude to the force between two neutrons (n-n) or between a proton and neutron (p-n).

Final Answer: $R = 4.8 \times 10^{-15}$ m (4.8 fm); or Short-range & charge-independent

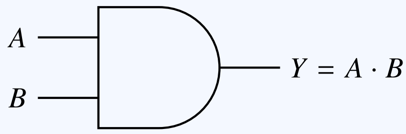
Answer: (See above) Go Back to Question 36

Q37.

Solution

Concept: AND gate performs logical multiplication; transducers and repeaters ensure long-distance electronic signal integrity.

Step 1 — Alternative (i) - AND Gate: Symbol has straight flat input face and rounded D-shaped tip. Boolean expression: $Y = A \cdot B$.



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

Step 2 — Alternative (ii) - Transducer & Repeater: (a) **Transducer:** An electronic device that converts one form of energy into another. In communication, a microphone converts sound waves into electrical voltage signals, and a loudspeaker converts electrical signals back into acoustic sound. (b) **Repeater Station:** A combination of receiver, amplifier, and transmitter placed at intervals along a transmission line. It receives attenuated signals, amplifies them to original power, and retransmits them to overcome attenuation over long distances.

Final Answer: AND symbol & truth table; or Transducer energy conversion & Repeater amplification

Answer: (See above) Go Back to Question 37

Q38.

Solution

Concept: Gravitational field inside a uniform sphere decreases linearly toward zero at center; rolling kinetic energy combines translational and rotational motion ($v = \omega R$).

Step 1 — Alternative (i) - Variation of g with Depth: Newton's Law of Gravitation gives surface gravity $g = \frac{GM}{R^3}R = \frac{4}{3}\pi G\rho R$ for uniform Earth density ρ.

Step 2 — At depth d below surface, distance from Earth's center is $r = R - d$. Only the inner sphere of radius $(R - d)$ and mass $M' = \frac{4}{3}\pi(R - d)^3\rho$ exerts net gravitational pull:

$$g_d = \frac{GM'}{(R-d)^2} = \frac{G\left[\frac{4}{3}\pi(R-d)^3\rho\right]}{(R-d)^2} = \frac{4}{3}\pi G\rho(R-d)$$

Step 3 — Dividing g_d by surface gravity g:

$$\frac{g_d}{g} = \frac{\frac{4}{3}\pi G\rho(R-d)}{\frac{4}{3}\pi G\rho R} = \frac{R-d}{R} = 1 - \frac{d}{R} \implies g_d = g\left(1 - \frac{d}{R}\right)$$

Step 4 — Alternative (ii) - Rolling Kinetic Energy: A rolling body of mass M and radius of gyration K executes simultaneous translational motion of center of mass with speed v and rotational motion with angular speed $\omega = v/R$:

$$K_{\text{total}} = K_{\text{trans}} + K_{\text{rot}} = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}Mv^2 + \frac{1}{2}(MK^2)\left(\frac{v^2}{R^2}\right) = \frac{1}{2}Mv^2\left[1 + \frac{K^2}{R^2}\right]$$

Final Answer: $\boxed{g_d = g\left(1 - \frac{d}{R}\right);\ \text{or Rolling } K_{\text{total}} = \frac{1}{2}Mv^2\left[1 + \frac{K^2}{R^2}\right]}$

Answer: (See above) Go Back to Question 38

Q39.

Solution

Concept: Conservation of mechanical energy equates initial kinetic energy plus surface gravitational potential energy to potential energy at maximum altitude h ($v_{\text{top}} = 0$).

Step 1 — Escape velocity from Earth's surface is $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$. Initial projection speed is $u = \frac{1}{2}v_e = \frac{1}{2}\sqrt{\frac{2GM}{R}}$. Initial kinetic energy is:

$$K_i = \frac{1}{2}mu^2 = \frac{1}{2}m\left(\frac{1}{4}\frac{2GM}{R}\right) = \frac{GMm}{4R}$$

Step 2 — Initial gravitational potential energy at Earth's surface is $U_i = -\frac{GMm}{R}$. Total initial mechanical energy is:

$$E_i = K_i + U_i = \frac{GMm}{4R} - \frac{GMm}{R} = -\frac{3GMm}{4R}$$

Step 3 — At maximum altitude h, velocity becomes zero ($K_f = 0$), so total final energy is purely potential energy at distance $(R + h)$ from Earth's center:

$$E_f = U_f = -\frac{GMm}{R + h}$$

Step 4 — Equating initial and final mechanical energy ($E_i = E_f$):

$$-\frac{3GMm}{4R} = -\frac{GMm}{R + h} \implies \frac{3}{4R} = \frac{1}{R + h} \implies 3(R + h) = 4R \implies 3h = R \implies h = \frac{R}{3}$$

Thus, the projectile attains a maximum height equal to one-third of Earth's radius above the surface.

Final Answer: $\boxed{h = \frac{R}{3}}$

Answer: (See above) Go Back to Question 39

Q40.

Solution

Concept: A current-carrying conductor creates a circumferential magnetic field that exerts a Lorentz force on a second parallel current-carrying conductor.

Step 1 — Let two long parallel conductors 1 and 2 separated by distance d in vacuum carry steady currents I_1 and I_2. Conductor 1 establishes a magnetic field induction B_1 at the position of conductor 2 given by Ampere's circuital law:

$$B_1 = \frac{\mu_0 I_1}{2\pi d}$$

Step 2 — Since conductor 2 lies perpendicular to magnetic field lines $\vec{B}_1$ ($\theta = 90°$), a segment of length L of conductor 2 experiences a magnetic Lorentz force:

$$F = I_2 L B_1 \sin 90° = I_2 L \left(\frac{\mu_0 I_1}{2\pi d}\right) = \frac{\mu_0 I_1 I_2 L}{2\pi d}$$

Therefore, magnetic force per unit length between the conductors is:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

Step 3 — Definition of One Ampere: Let $I_1 = I_2 = 1$ A and separation $d = 1$ m in vacuum. Using $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}:

$$\frac{F}{L} = \frac{(4\pi \times 10^{-7})(1)(1)}{2\pi(1)} = 2 \times 10^{-7} \text{ N m}^{-1}$$

One Ampere is defined as that constant electric current which, if maintained in two infinitely long, thin parallel straight conductors placed one meter apart in vacuum, produces between them a mutual magnetic force of exactly 2×10^{-7} Newtons per meter of length.

Final Answer: $\boxed{\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}; \quad 1 \text{ A produces } 2 \times 10^{-7} \text{ N/m force at 1 m}}$

Answer: (See above) **Go Back to Question 40**

Q41.

Solution

Concept: When prism deviation is minimum ($\delta = \delta_m$), the light ray passes symmetrically through the prism, making incidence angle equal emergence angle ($i = e$) and internal refraction angles equal ($r_1 = r_2 = r$).

Step 1 — In the prism geometry shown in the diagram, the sum of internal refraction angles equals the prism refracting angle A:

$$r_1 + r_2 = A$$

At minimum deviation symmetry ($r_1 = r_2 = r$):

$$2r = A \implies r = \frac{A}{2} \quad \text{— (Eq. 1)}$$

Step 2 — The total deviation angle δ across both faces is given by exterior angle geometry:

$$\delta = (i - r_1) + (e - r_2) = i + e - (r_1 + r_2) = i + e - A$$

Step 3 — At the position of minimum deviation ($\delta = \delta_m$), symmetry mandates angle of incidence equals angle of emergence ($i = e$):

$$\delta_m = 2i - A \implies 2i = A + \delta_m \implies i = \frac{A + \delta_m}{2} \quad \text{— (Eq. 2)}$$

Step 4 — According to Snell's law of refraction at the first air-glass interface, absolute refractive index μ of the prism material is:

$$\mu = \frac{\sin i}{\sin r}$$

Substituting Eq. 1 and Eq. 2 into Snell's law yields the Prism Formula:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Final Answer: $\boxed{\mu = \dfrac{\sin[(A + \delta_m)/2]}{\sin(A/2)}}$

Answer: (See above) Go Back to Question 41

Q42.

Solution

Concept: Electric dipole equatorial field resolves vertical components while horizontal components add up antiparallel to $\vec{p}$; moving coil galvanometer utilizes radial magnetic field to ensure uniform deflecting torque $\tau = NIAB$.

Step 1 — Part (i) - Dipole Equatorial Field: An electric dipole consists of two equal and opposite point charges $+q$ and $-q$ separated by a small distance $2a$, having dipole moment $\vec{p} = q(2\vec{a})$ directed from $-q$ to $+q$. Consider point P on the equatorial line at perpendicular distance r from center O.

Step 2 — Distance of P from either charge is $\sqrt{r^2 + a^2}$. The magnitudes of electric field at P due to $+q$ and $-q$ are identical:

$$E_+ = E_- = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2 + a^2}$$

Step 3 — Resolving field vectors along and perpendicular to dipole axis: vertical components ($E_+ \sin\theta$ and $E_- \sin\theta$) cancel out. Horizontal components ($E_+ \cos\theta$ and $E_- \cos\theta$) add up parallel to the line joining $+q$ to $-q$ (antiparallel to $\vec{p}$).

$$E_{eq} = 2E_+ \cos\theta = 2\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2 + a^2}\right)\left(\frac{a}{\sqrt{r^2 + a^2}}\right) = \frac{1}{4\pi\varepsilon_0}\frac{q(2a)}{(r^2 + a^2)^{3/2}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2 + a^2)^{3/2}}$$

For a short dipole ($r \gg a$), a^2 is negligible compared to r^2: $\vec{E}_{eq} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$.

Step 4 — Part (ii) - Dipole Torque: When placed in uniform electric field $\vec{E}$, torque is $\vec{\tau} = \vec{p} \times \vec{E} \implies \tau = pE\sin\theta$. Torque is maximum when $\theta = 90^\circ$ ($\tau_{max} = pE$).

Step 5 — Alternative (iii) - Moving Coil Galvanometer: When a rectangular coil of N turns, area A, carrying current I suspended inside a magnetic field B rotates, deflecting torque is $\tau_d = NIAB\sin\alpha$.

Step 6 — Using cylindrical concave pole pieces and a soft iron core creates a **Radial Magnetic Field** where field lines are always parallel to the coil plane ($\alpha = 90^\circ \implies \sin 90^\circ = 1$), giving constant deflecting torque $\tau_d = NIAB$. Equating to suspension phosphor-bronze wire restoring torque $\tau_r = k\theta$:

$$k\theta = NIAB \implies I = \left(\frac{k}{NAB}\right)\theta$$

Final Answer: $E_{eq} = \dfrac{p}{4\pi\varepsilon_0 r^3}$, $\tau_{max} = pE$; or Galvanometer $I = \dfrac{k}{NAB}\theta$

Answer: (See above) Go Back to Question 42

Q43.

Solution

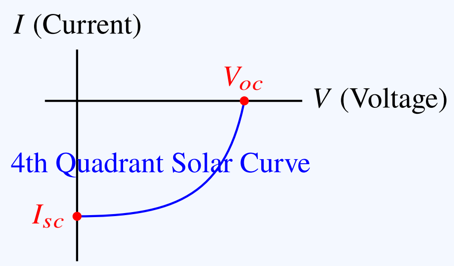
Concept: Half-wave rectifier conducts only during positive AC half-cycles (50% conduction); solar cells generate photovoltaic EMF without external batteries when photons ($h\nu > E_g$) excite electron-hole pairs across p-n junctions.

Step 1 — Part (i) - Half-Wave Rectifier Working: A single semiconductor diode D is connected in series with secondary transformer winding and load resistor R_L.

Step 2 — Positive Half-Cycle: Diode anode is positive, making D forward-biased. It conducts current through R_L, producing output voltage pulse V_0. **Negative Half-Cycle:** Anode is negative, making D reverse-biased. It blocks current flow ($I \approx 0$), resulting in zero output voltage.

Step 3 — Part (ii) - Ripple Factor & Efficiency: Ripple factor (γ) is the ratio of root-mean-square value of AC ripple voltage to DC component voltage in rectifier output ($\gamma = V_{\text{ac}}/V_{\text{dc}}$). For half-wave, $\gamma = 1.21$ (high ripple, max efficiency 40.6%). A full-wave bridge rectifier is far more efficient ($\gamma = 0.48$, max efficiency 81.2%) because it utilizes both AC half-cycles, delivering double DC power with smoother waveforms.

Step 4 — Alternative (iii) - Solar Cell Principle: A solar cell is a p-n junction with a very thin transparent top p-layer. When illuminated by solar photons having energy $h\nu > E_g$, electron-hole pairs are generated inside the depletion region.



Step 5 — The junction electric field sweeps electrons to n-side and holes to p-side, establishing short-circuit photocurrent I_{sc} and open-circuit voltage V_{oc}. Silicon ($E_g \approx 1.1$ eV) and GaAs ($E_g \approx 1.43$ eV) are preferred because their band gaps perfectly match the peak solar irradiance energy spectrum (~ 1.5 eV), maximizing optical absorption and photovoltaic conversion efficiency.

Final Answer: Half-Wave Rectifier working & ripple factor; or Solar cell IV curve & Si/GaAs band gap matching

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	A	7	D	8	B	9	C	10	A
11	D	12	B	13	C	14	A	15	D
16	B								