NIOS Class 12 Physics Sample Paper-9

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 Spring Constant (Force Constant k) of an elastic spring is identical to the dimensional formula of: **(1)**

(A) Pressure (P)

(B) Coefficient of Viscosity (η)

(C) Modulus of Elasticity (Y)

(D) Surface Tension (T)

Q2. A uniform flywheel of moment of inertia $I = 2.5$ kg m^2 rotating about its fixed geometric axis is subjected to a constant braking torque $\tau = 10$ N m. The magnitude of the angular deceleration (α) produced in the flywheel is: **(1)**

(A) 2.5 rad s^{-2}

(B) 4.0 rad s^{-2}

(C) 25.0 rad s^{-2}

(D) 0.25 rad s^{-2}

Q3. Two spheres of masses m_1 and m_2 undergo a one-dimensional perfectly elastic head-on collision on a smooth horizontal surface. The coefficient of restitution (e) for this collision is: **(1)**

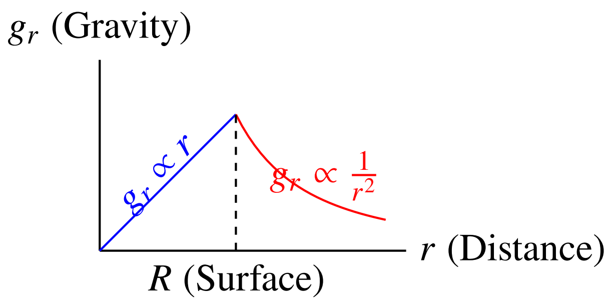
(A) $e = 0$

(B) $e = 0.5$

(C) $e = 1.0$

(D) $e = \infty$

Q4. Let g be the acceleration due to gravity on the surface of a uniform spherical Earth of radius R. As shown in the graph below illustrating the variation of gravitational acceleration g_r with radial distance r from Earth's center, for a small altitude $h \ll R$ above the surface, the value of gravity g_h is approximated by: **(1)**



(A) $g_h = g\left(1 - \frac{2h}{R}\right)$

(B) $g_h = g\left(1 - \frac{h}{R}\right)$

(C) $g_h = g\left(1 + \frac{2h}{R}\right)$

(D) $g_h = g\left(1 + \frac{h}{R}\right)$

Q5. The physical quantity defined as the reciprocal of Bulk Modulus of Elasticity (B) of a material is termed: **(1)**

(A) Poisson's Ratio (σ)

(B) Compressibility (k)

(C) Rigidity Modulus (η)

(D) Young's Modulus (Y)

Q6. According to Mayer's relation in thermodynamics, for one mole of an ideal gas, the difference between its molar specific heat capacity at constant pressure (C_p) and at constant volume (C_v) is equal to: **(1)**

(A) Boltzmann's Constant (k_B)

(B) Universal Gas Constant (R)

(C) Avogadro's Number (N_A)

(D) Mechanical Equivalent of Heat (J)

Q7. A body executing Simple Harmonic Motion (SHM) along a straight line has linear amplitude A and angular frequency ω. The maximum instantaneous velocity (v_{max}) and maximum instantaneous acceleration (a_{max}) attained by the body are respectively: **(1)**

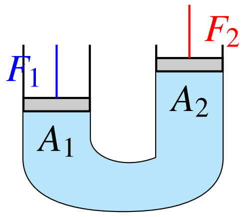
(A) $v_{\text{max}} = A\omega^2, \quad a_{\text{max}} = A\omega$

(B) $v_{\text{max}} = \frac{A}{\omega}, \quad a_{\text{max}} = \frac{A}{\omega^2}$

(C) $v_{\text{max}} = A\omega, \quad a_{\text{max}} = A\omega^2$

(D) $v_{\text{max}} = A^2\omega, \quad a_{\text{max}} = A^2\omega^2$

Q8. In a hydraulic lift operating on Pascal's law as shown below, a downward force F_1 is applied to a small input piston of cross-sectional area $A_1 = 10\text{ cm}^2$. If the large output piston lifting a heavy load has area $A_2 = 200\text{ cm}^2$, the upward lifting force F_2 developed is: **(1)**



(A) $20F_1$

(B) $10F_1$

(C) $\frac{F_1}{20}$

(D) $200F_1$

Q9. Two point charges $+q_1$ and $+q_2$ are separated by a distance r in vacuum. The total electrostatic potential energy (U) of this two-charge system is: **(1)**

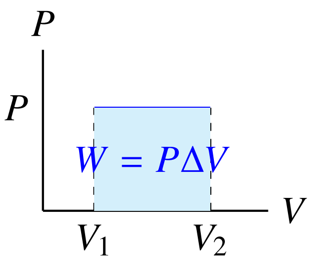
(A) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

(B) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1+q_2}{r}$

(C) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^3}$

(D) $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

Q10. During a reversible isobaric expansion of n moles of an ideal gas at constant pressure P from initial volume V_1 to final volume V_2, the temperature rises from T_1 to T_2. The mechanical work done (W) by the gas is: **(1)**



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

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

(C) $W = P(V_2 - V_1) = nR(T_2 - T_1)$

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

Q11. A planar rectangular loop of N turns, area A, carrying a steady current I is suspended in a uniform magnetic field $\vec{B}$. If the normal to the plane of the loop makes an angle θ with the magnetic field direction, the magnitude of the deflecting torque (τ) acting on the loop is: **(1)**

(A) $\tau = NIAB \sin\theta$

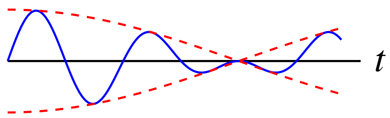
(B) $\tau = NIAB \cos\theta$

(C) $\tau = \frac{NIA}{B} \sin\theta$

(D) $\tau = NIAB \tan\theta$

Q12. When two coherent or slightly overlapping acoustic sound waves of frequencies $f_1 = 500$ Hz and $f_2 = 504$ Hz travel in the same direction, they interfere to produce periodic waxing and waning of sound intensity known as beats. The number of beats heard per second (f_{beat}) is: **(1)**

Beat Envelope ($f_{\text{beat}} = |f_1 - f_2|$)



(A) 4 beats s^{-1}

(B) 1004 beats s^{-1}

(C) 2 beats s^{-1}

(D) 8 beats s^{-1}

Q13. A light ray passing through a rectangular glass slab of thickness t and refractive index μ undergoes refraction at both parallel faces, emerging with a lateral displacement d. Which of the following changes will cause the lateral shift d to strictly decrease? **(1)**

(A) Increasing the thickness t of the glass slab

(B) Increasing the angle of incidence i

(C) Increasing the refractive index μ of the slab material

(D) Decreasing the thickness t of the glass slab

Q14. According to Joule's Law of electrical heating, when a steady current I flows through an ohmic resistor of resistance R for a time duration t, the total electrical heat energy (H) dissipated is: **(1)**

(A) $H = IR^2t$

(B) $H = \frac{I^2R}{t}$

(C) $H = I^2Rt = \frac{V^2t}{R}$

(D) $H = IRt^2$

Q15. The magnifying power (M) of a compound microscope consisting of an objective lens of focal length f_o and an eyepiece of focal length f_e separated by optical tube length L, when the final virtual image is formed at the least distance of distinct vision D, is given by: **(1)**

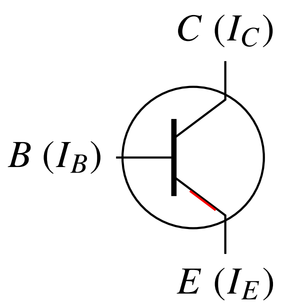
(A) $M = -\frac{f_o}{L}\left(1 + \frac{f_e}{D}\right)$

(B) $M = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$

(C) $M = -\frac{f_o}{f_e}\left(1 + \frac{L}{D}\right)$

(D) $M = -\frac{L}{f_e}\left(1 + \frac{D}{f_o}\right)$

Q16. In an n-p-n Bipolar Junction Transistor (BJT) operating in its active region, let I_E, I_B, and I_C be the emitter current, base current, and collector current respectively. The DC current gain β in Common-Emitter (CE) configuration is defined as: **(1)**



(A) $\beta = \frac{I_C}{I_B}$

(B) $\beta = \frac{I_C}{I_E}$

(C) $\beta = \frac{I_B}{I_E}$

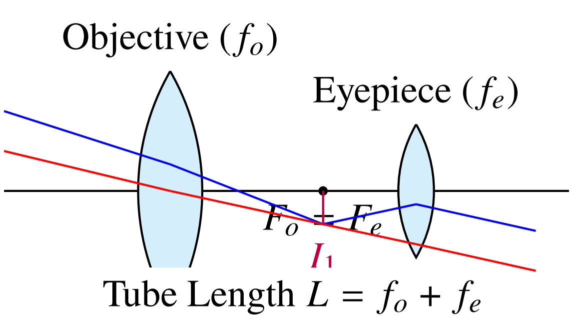
(D) $\beta = \frac{I_E}{I_C}$

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 mechanical energy by filling in the blanks:
(Kilowatt-hour, Joule, Conservative Force, Non-conservative Force) **(2)**

1. The commercial unit of electrical energy consumed in households and industry is the ...., which equals 3.6×10^6 Joules.
2. A force field in which the work done around any closed loop is zero ($\oint \vec{F} \cdot d\vec{r} = 0$) is classified as a ....

Q18. Read the short passage given below regarding optical telescopes and answer the two sub-questions:
An Astronomical Refracting Telescope is an optical instrument used to view distant celestial bodies like stars and planets. It consists of two converging lenses mounted coaxially: a large objective lens of large aperture and long focal length f_o facing the object, and a small eyepiece lens of short focal length f_e facing the eye. When adjusted for normal relaxed eye vision (infinity adjustment), parallel rays from a star form a real inverted image at the joint focus, emerging as parallel rays from the eyepiece. **(2)**



1. Write the formula for the magnifying power (M) of an astronomical telescope in normal adjustment in terms of f_o and f_e.

2. Why must the objective lens of an astronomical telescope have a very large circular aperture diameter D? (State two distinct advantages: light gathering and resolution).

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

A Wheatstone Bridge is an electrical network of four resistors R_1, R_2, R_3, R_4 used to measure unknown resistances with high precision. When the bridge is balanced, the potential difference across the galvanometer G is zero ($V_B = V_D$), resulting in zero current deflection ($I_g = 0$). The practical laboratory form of this bridge is the Meter Bridge, which employs a 100 cm uniform manganin wire. **(2)**

1. Write the balanced condition relation connecting the four bridge arms R_1, R_2, R_3, and R_4 when galvanometer current $I_g = 0$.
2. Why is a Wheatstone bridge method considered far more accurate for measuring resistance than using an ordinary voltmeter and ammeter (Ohm's law division V/I)?

Q20. Read the short passage given below regarding nuclear chain reactions and answer the two sub-questions:

When a heavy uranium nucleus $^{235}_{9}2\text{U}$ absorbs a slow thermal neutron, it undergoes Nuclear Fission, splitting into two intermediate radioactive fragments (like Barium and Krypton) alongside emitting 2 to 3 prompt high-speed neutrons and $\sim$ 200 MeV of energy. If these secondary neutrons are slowed down by a moderator, they can trigger fission in adjacent uranium nuclei, propagating a self-sustaining Nuclear Chain Reaction. **(2)**

1. What is meant by the term Critical Mass in a nuclear fission chain reaction?
2. State the primary physical function of: (a) a Moderator (like heavy water or graphite), and (b) Control Rods (like cadmium or boron) in a nuclear power reactor.

Q21. Match the laws and theorems of fluid and solid mechanics in Column I with their correct mathematical formulations or phenomena in Column II: **(2)**

Column I	Column II
(a) Hooke's Law	(i) Viscous drag force $F = 6\pi\eta rv$ on a falling sphere
(b) Stokes' Law	(ii) Speed of efflux of liquid from an orifice $v = \sqrt{2gh}$
(c) Bernoulli's Equation	(iii) Within elastic limit, stress is proportional to strain
(d) Torricelli's Theorem	(iv) Conservation of fluid energy: $P + \frac{1}{2}\rho v^2 + \rho gh =$ const

Q22. Match the digital logic gates in Column I with their Boolean expressions and symbols in Column II: **(2)**

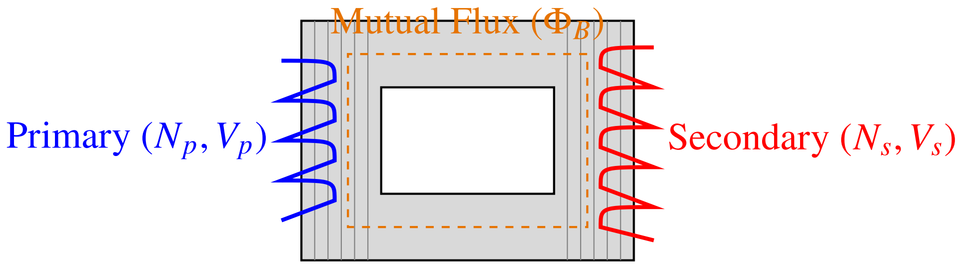
Column I	Column II
(a) OR Gate	(i) Inverter gate: $Y = \overline{A}$ (output is complement of input)
(b) AND Gate	(ii) Universal gate: $Y = \overline{A + B}$ (inverted OR output)
(c) NOT Gate	(iii) Logical addition: $Y = A + B$ (HIGH if any input HIGH)
(d) NOR Gate	(iv) Logical multiplication: $Y = A \cdot B$ (HIGH only if all HIGH)

Q23. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement regarding mechanical oscillations and resonance: **(2)**

1. In a damped simple harmonic oscillator, the mechanical amplitude of vibration decays exponentially over time due to dissipative resistive forces like air drag or friction.
2. When an oscillating system is driven by an external periodic force, the amplitude of forced vibrations reaches an absolute minimum when the driving frequency exactly equals the natural frequency of the system (Resonance).

Q24. Read the short passage given below regarding electromagnetic induction in transformers and observe the diagram:

A transformer is a static electromagnetic device used to step up or step down alternating AC voltages without changing frequency. As shown below, it consists of two insulated copper coils—Primary (N_p turns) and Secondary (N_s turns)—wound around a common laminated soft iron core. When alternating voltage V_p is applied to the primary, changing magnetic flux Φ_B is mutually linked to the secondary, inducing an AC voltage V_s according to Faraday's law: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$. **(2)**



1. What is the turns ratio condition (N_s/N_p) required for a transformer to act as a Step-Up transformer ($V_s > V_p$)?
2. Why can a transformer not step up or step down a steady Direct Current (DC) voltage source?

Q25. Complete the following statements regarding optical communications by filling in the blanks:
(Total Internal Reflection, Refraction, Core, Cladding) **(2)**

1. In an optical fiber, the central light-transmitting cylinder of high refractive index (μ_1) is called the ., surrounded by an outer layer of lower index (μ_2) called the cladding.
2. The operational principle of transmitting laser pulses along curved optical fibers without optical energy loss is ....

Q26. Match the nuclear radiation particles/photons in Column I with their exact composition in Column II: **(2)**

Column I	Column II
(a) Alpha (α) Particle	(i) High-speed electron ($^{0}_{-1}$e) emitted from nucleus during beta decay
(b) Beta (β^-) Particle	(ii) High-energy neutral electromagnetic photon emitted during de-excitation
(c) Gamma (γ) Photon	(iii) Positively charged antiparticle of electron ($^{0}_{+1}$e or β^+)
(d) Positron (β^+)	(iv) Doubly ionized helium nucleus ($^{4}_{2}$He^{2+}) containing 2 protons and 2 neutrons

Q27. Write TRUE (T) for the correct statement and FALSE (F) for the incorrect statement regarding Bohr's atomic model: **(2)**

1. According to Bohr's postulates, an electron revolving in a stationary circular orbit radiates electromagnetic energy continuously, causing its orbit to spiral into the nucleus.
2. The total mechanical energy ($E_n = K_n + U_n$) of an electron bound to the nucleus in a hydrogen atom is strictly negative ($E_n = -13.6/n^2$ eV), signifying an attractive binding potential well.

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

1. Ground Wave (surface wave) propagation is highly efficient and primarily utilized for transmitting Very High Frequency (VHF) television and microwave radar signals above 100 MHz.
2. Optical fiber communication systems utilize high-frequency infrared and visible laser carrier waves, providing enormous information bandwidth and complete immunity to external electromagnetic interference.

Section: B

Q29. (i) Define the Center of Mass of a system of particles. Write the mathematical formula for the position vector of the center of mass ($\vec{R}_{cm}$) for a system of n

discrete particles of masses $m_1, m_2, \ldots, m_n$.

OR

(ii) Distinguish clearly between Static Friction (f_s) and Kinetic Friction (f_k) between two surfaces in contact. Explain briefly why static friction is referred to as a self-adjusting force up to its limiting threshold. **(2)**

Q30. State Mayer's thermodynamic relation connecting molar specific heat capacities at constant pressure (C_p) and at constant volume (C_v) for an ideal gas ($C_p - C_v = R$). Explain physically why C_p is always strictly greater than C_v for any gas. **(2)**

Q31. (i) Define Magnetic Flux (Φ_B) linking a surface area and state its SI unit (Weber). Specify the exact angles θ between magnetic field induction $\vec{B}$ and normal area vector $\vec{A}$ for which magnetic flux is: (a) Maximum, and (b) Zero.

OR

(ii) Define Electric Dipole Moment ($\vec{p}$) of an electric dipole. Write its mathematical formula ($\vec{p} = q \cdot 2\vec{a}$), specify its orientation direction along the dipole axis, and state its standard SI unit (C m). **(2)**

Q32. What is the Doppler Effect in Light? Define the astronomical terms Redshift and Blueshift in stellar spectroscopy. Explain briefly how redshift is utilized by astronomers to determine the radial recession velocity of distant galaxies. **(2)**

Q33. What is meant by Electrical Resonance in a series LCR AC circuit? Write the condition for resonance ($X_L = X_C$) and the resulting resonant angular frequency ($\omega_0 = 1/\sqrt{LC}$). What are the values of total circuit impedance (Z) and power factor ($\cos\phi$) at resonance? **(2)**

Q34. The radioactivity of a pure sample of radioactive iodine drops to exactly one-eighth ($\frac{1}{8}$) of its initial activity in an elapsed time of 15 hours. Calculate: (a) the Half-Life Period ($T_{1/2}$), and (b) the radioactive Decay Constant (λ) of the isotope. **(2)**

Q35. State the two fundamental physical conditions required for two light sources to act as Coherent Sources and produce a sustained, stable optical interference pattern on an observation screen. **(2)**

Q36. (i) Define Atomic Mass Unit (1 u). Calculate the energy equivalent (in MeV) of a nuclear mass defect of $\Delta m = 0.030$ u. (Given: 1 u $\approx$ 931.5 MeV).

OR

(ii) Distinguish between Natural Radioactivity and Artificial (Induced) Radioactivity by writing two fundamental differences along with one typical nuclear reaction equation for each type. **(2)**

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

OR

(ii) What is meant by Demodulation (Detection) in electronic communication systems? Explain briefly why a simple envelope diode detector circuit is used in radio receivers to recover the low-frequency audio modulating signal from an Amplitude Modulated (AM) carrier wave. **(2)**

Q38. (i) Derive an expression for the velocity of the center of mass ($\vec{v}_{cm}$) of a two-particle system undergoing a collision. Using Newton's second law for a system of particles, prove mathematically that if the net external force acting on the system is zero ($\vec{F}_{ext} = 0$), total linear momentum is strictly conserved.

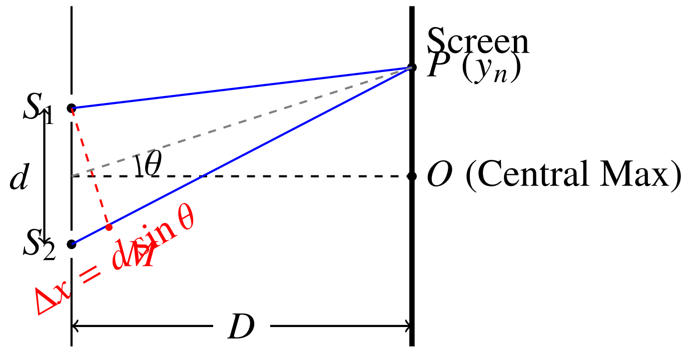
OR

(ii) Derive an expression for the time period of oscillation (T) of a compound (physical) pendulum of total mass m and moment of inertia I suspended from a frictionless pivot located at a distance l from its center of mass ($T = 2\pi\sqrt{I/mgl}$). **(3)**

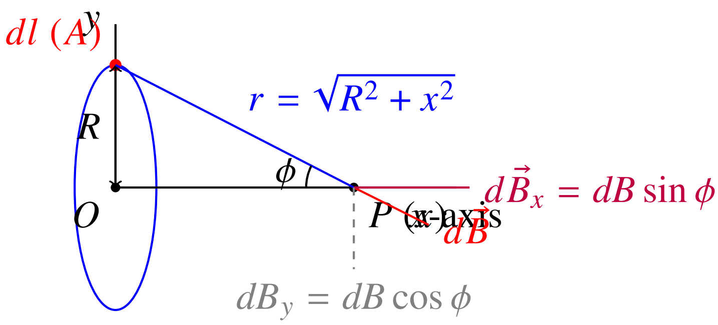
Q39. State Kepler's Three Laws of Planetary Motion: (a) Law of Orbits, (b) Law of Areas, and (c) Law of Periods ($T^2 \propto r^3$). Explain clearly how Isaac Newton utilized Kepler's third law of periods and circular centripetal acceleration to deduce the inverse-square distance dependence ($F \propto 1/r^2$) of universal gravitation. **(3)**

Q40. Derive an expression for the electrostatic potential V at a distance r from an isolated positive point charge $+q$ in vacuum ($V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$) by integrating the work done against Coulomb electrostatic repulsive force in moving a unit positive test charge from infinity up to distance r. **(3)**

Q41. Derive an expression for the fringe width ($\beta = \frac{\lambda D}{d}$) of consecutive bright or dark interference bands formed on an observation screen at distance D from two coherent slits separated by distance d in Young's Double Slit Experiment (YDSE). Include a geometric path difference diagram. **(3)**



Q42. (i) Using Biot-Savart law, derive an expression for the magnetic field induction $\vec{B}$ at a point P located on the axis of a circular current-carrying loop of radius R at a perpendicular distance x from its center: $B = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$. Include a labeled vector resolution diagram.

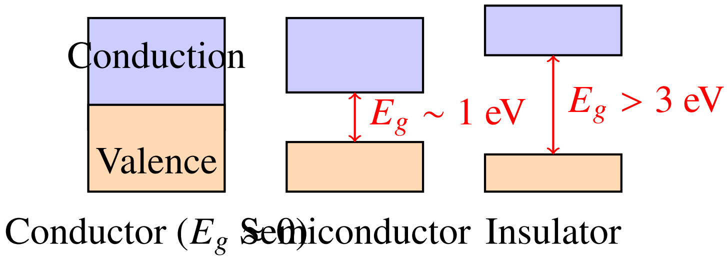


(ii) Show mathematically that at the center of the circular loop ($x = 0$), the axial magnetic field formula reduces to $B = \frac{\mu_0 I}{2R}$.

OR

(iii) Describe the principle, construction, and working of a Van de Graaff Electrostatic Generator with a clean schematic diagram. Explain clearly how it builds up high electrostatic potentials of the order of several million volts using corona discharge and hollow sphere charge transfer. **(5)**

Q43. (i) Explain the physical formation of energy bands in crystalline solids. Distinguish clearly between Conductors, Semiconductors, and Electrical Insulators on the basis of valence band occupancy, conduction band electron availability, and forbidden energy band gap (E_g) with clean comparison diagrams.



(ii) Explain why the electrical conductivity of an intrinsic semiconductor increases exponentially with a rise in temperature, whereas the conductivity of a metallic conductor decreases when heated.

OR

(iii) Describe the construction and working of an *n*-*p*-*n* Bipolar Junction Transistor as a voltage amplifier in Common-Emitter (CE) configuration. Draw the labeled circuit schematic showing input/output AC voltages and explain why a phase reversal of 180° occurs between input and output amplified signals. **(5)**

Detailed Solutions

Q1.

Solution

Concept: Spring constant k is defined by Hooke's law as restoring force per unit extension: $F = -kx \implies k = \frac{F}{x}$.

Step 1 — Dimensional formula of force $F = [\mathrm{M^1L^1T^{-2}}]$ and extension $x = [\mathrm{L^1}]$:

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

Step 2 — Surface tension T is defined as tangential force per unit length on a liquid surface: $T = \frac{F}{L} \implies [T] = \frac{[\mathrm{M^1L^1T^{-2}}]}{[\mathrm{L^1}]} = [\mathrm{M^1L^0T^{-2}}]$.

Why other options are wrong:

- **Option A:** Pressure is force per unit area: $[\mathrm{M^1L^{-1}T^{-2}}]$.
- **Option B:** Viscosity is $[\mathrm{M^1L^{-1}T^{-1}}]$.
- **Option C:** Modulus of elasticity is stress over strain: $[\mathrm{M^1L^{-1}T^{-2}}]$.

Final Answer: Surface Tension (T) (Option D)

Answer: (D) Go Back to Question 1

Q2.

Solution

Concept: Newton's second law for rotational motion states that net external torque equals moment of inertia times angular acceleration: $\tau = I\alpha$.

Step 1 — Given moment of inertia $I = 2.5$ kg m^2 and braking torque $\tau = 10$ N m.

Step 2 — Solving for angular acceleration α:

$$\alpha = \frac{\tau}{I} = \frac{10 \text{ N m}}{2.5 \text{ kg m}^2} = 4.0 \text{ rad s}^{-2}$$

Why other options are wrong:

- **Option A:** 2.5 rad s^{-2} is just the numerical value of inertia I.
- **Option C:** 25.0 rad s^{-2} results from multiplying torque and inertia (10×2.5).
- **Option D:** 0.25 rad s^{-2} results from dividing inertia by torque ($2.5/10$).

Final Answer: 4.0 rad s^{-2} (Option B)

Answer: (B) Go Back to Question 2

Q3.

Solution

Concept: The coefficient of restitution (e) is defined as the ratio of relative velocity of separation after collision to relative velocity of approach before collision: $e = \frac{v_2 - v_1}{u_1 - u_2}$.

Step 1 — In a perfectly elastic collision, both total linear momentum and total kinetic energy are strictly conserved.

Step 2 — Solving the momentum and kinetic energy conservation equations simultaneously yields $v_2 - v_1 = u_1 - u_2$, making the ratio strictly equal to unity ($e = 1.0$).

Why other options are wrong:

- **Option A:** $e = 0$ corresponds to a perfectly inelastic (plastic) collision where bodies stick together.
- **Option B:** $e = 0.5$ represents a semi-elastic or partially inelastic collision.
- **Option D:** Infinite restitution is physically impossible without explosive energy generation.

Final Answer: $e = 1.0$ (Option C)

Answer: (C) Go Back to Question 3

Q4.

Solution

Concept: Acceleration due to gravity at an altitude h above Earth's surface is $g_h = \frac{GM}{(R+h)^2} = g\left(1+\frac{h}{R}\right)^{-2}$. For $h \ll R$, binomial expansion gives $g_h \approx g\left(1-\frac{2h}{R}\right)$.

Step 1 — Expand $\left(1+\frac{h}{R}\right)^{-2}$ using binomial theorem:

$$g_h = g\left[1 + (-2)\frac{h}{R} + \frac{(-2)(-3)}{2!}\left(\frac{h}{R}\right)^2 + \dots\right]$$

Step 2 — Since $h \ll R$, higher power terms $(h/R)^2 \approx 0$ are negligible. Thus:

$$g_h \approx g\left(1-\frac{2h}{R}\right)$$

Why other options are wrong:

- **Option B:** $g\left(1-\frac{h}{R}\right)$ is the formula for gravity variation with depth d below the surface (g_d).
- **Option C:** Positive sign implies gravity increases with altitude, violating inverse-square law.
- **Option D:** Incorrect positive sign and coefficient.

Final Answer: $\boxed{g_h = g\left(1-\frac{2h}{R}\right)}$ (Option A)

Answer: (A) Go Back to Question 4

Q5.

Solution

Concept: Bulk modulus B measures a material's resistance to uniform hydrostatic compression. Its reciprocal quantifies how fractional volume changes per unit pressure increase.

Step 1 — By definition, the fractional volume reduction per unit increase in hydrostatic pressure is called **Compressibility** (k):

$$k = \frac{1}{B} = -\frac{1}{V}\frac{dV}{dP}$$

Why other options are wrong:

- **Option A:** Poisson's ratio σ is the ratio of lateral strain to longitudinal strain.
- **Option C:** Rigidity modulus η relates shear stress to shear strain.
- **Option D:** Young's modulus Y relates longitudinal stress to linear tensile strain.

Final Answer: $\boxed{\text{Compressibility } (k)}$ (Option B)

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

Q6.

Solution

Concept: When heat is supplied at constant volume, all energy increases internal energy ($\Delta Q_v = \Delta U = nC_v\Delta T$). At constant pressure, heat must also do external expansion work ($\Delta Q_p = \Delta U + P\Delta V = nC_p\Delta T$).

Step 1 — By ideal gas equation, $P\Delta V = nR\Delta T$.

Step 2 — Equating heat at constant pressure: $nC_p\Delta T = nC_v\Delta T + nR\Delta T$. Dividing by $n\Delta T$:

$$C_p - C_v = R$$

where R is the universal gas constant (8.314 J mol^{-1} K^{-1}).

Why other options are wrong:

- **Option A:** Boltzmann's constant $k_B = R/N_A$ applies to a single molecule ($c_p - c_v = k_B$).
- **Option C:** Avogadro's number N_A is particle count per mole.
- **Option D:** Mechanical equivalent of heat $J = 4.186$ J/cal is a unit conversion factor.

Final Answer: $\boxed{\text{Universal Gas Constant } (R)}$ (Option B)

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

Q7.

Solution

Concept: In SHM, displacement is $x(t) = A\sin(\omega t)$. Velocity is $v(t) = A\omega\cos(\omega t)$ and acceleration is $a(t) = -A\omega^2\sin(\omega t)$.

Step 1 — Maximum instantaneous velocity occurs at the mean position ($x = 0$) when $\cos(\omega t) = \pm 1$:

$$v_{\max} = A\omega$$

Step 2 — Maximum instantaneous acceleration occurs at the extreme turning points ($x = \pm A$) when $\sin(\omega t) = \pm 1$:

$$a_{\max} = A\omega^2$$

Why other options are wrong:

- **Option A:** Inverted frequency powers ($v_{\max} = A\omega^2$ is dimensionally acceleration).
- **Option B:** Dividing by frequency corresponds to time-integrated terms.
- **Option D:** Amplitude squared (A^2) appears in mechanical energy, not velocity or acceleration.

Final Answer: $\boxed{v_{\max} = A\omega, \quad a_{\max} = A\omega^2}$ (Option C)

Answer: (C) Go Back to Question 7

Q8.

Solution

Concept: According to Pascal's law, external static pressure applied to an enclosed incompressible fluid is transmitted undiminished throughout the liquid volume: $P_1 = P_2 \implies \frac{F_1}{A_1} = \frac{F_2}{A_2}$.

Step 1 — Solving the pressure equilibrium equation for output lifting force F_2:

$$F_2 = F_1 \left(\frac{A_2}{A_1}\right)$$

Step 2 — Substitute area values $A_1 = 10\ \text{cm}^2$ and $A_2 = 200\ \text{cm}^2$:

$$F_2 = F_1 \left(\frac{200\ \text{cm}^2}{10\ \text{cm}^2}\right) = 20F_1$$

Thus, the hydraulic lift magnifies the applied force by a factor of 20.

Why other options are wrong:

- **Option B:** $10F_1$ results from incorrect area ratio calculation.
- **Option C:** $F_1/20$ corresponds to force reduction if pushing on the larger piston.
- **Option D:** $200F_1$ is the numerical value of output area alone without division by A_1.

Final Answer: $\boxed{20F_1}$ (Option A)

Answer: (A) Go Back to Question 8

Q9.

Solution

Concept: Electrostatic potential energy of a two-charge system equals the work done against Coulomb forces in bringing the charges from infinity to separation r: $U = \int_{\infty}^{r} -F dr = \int_{\infty}^{r} -\frac{q_1 q_2}{4\pi\varepsilon_0 x^2} dx$.

Step 1 — Evaluating the integral:

$$U = \frac{q_1 q_2}{4\pi\varepsilon_0}\left[\frac{1}{x}\right]_{\infty}^{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$

Why other options are wrong:

- **Option A:** Inverse square $(1/r^2)$ represents Coulomb force F, not potential energy.
- **Option B:** Addition of charges $(q_1 + q_2)$ is mathematically incorrect for interaction energy.
- **Option C:** Inverse cube $(1/r^3)$ represents electric field gradient of a dipole.

Final Answer: $\boxed{U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}}$ (Option D)

Answer: (D) Go Back to Question 9

Q10.

Solution

Concept: In an isobaric process, pressure P remains strictly constant. Mechanical work done is the area under the horizontal P-V line: $W = \int P dV = P \int_{V_1}^{V_2} dV = P(V_2 - V_1)$.

Step 1 — From the ideal gas law at constant pressure, initial state is $PV_1 = nRT_1$ and final state is $PV_2 = nRT_2$.

Step 2 — Subtracting the two ideal gas equations gives $P(V_2 - V_1) = nR(T_2 - T_1)$. Therefore, work done can be written as:

$$W = P(V_2 - V_1) = nR(T_2 - T_1)$$

Why other options are wrong:

- **Option A:** $nC_v(T_2 - T_1)$ is the change in internal energy (ΔU), not external work.
- **Option B:** $\frac{nR}{\gamma-1}(T_1 - T_2)$ is work done during an adiabatic process ($Q = 0$).
- **Option D:** $nRT_1 \ln(V_2/V_1)$ is work done during an isothermal expansion (T = const).

Final Answer: $\boxed{W = P(V_2 - V_1) = nR(T_2 - T_1)}$ (Option C)

Answer: (C) Go Back to Question 10

Q11.

Solution

Concept: A current loop in a magnetic field experiences a deflecting torque due to equal and opposite Lorentz forces on parallel arms: $\vec{\tau} = \vec{M} \times \vec{B}$, where magnetic dipole moment $\vec{M} = NI\vec{A}$.

Step 1 — The magnitude of vector cross product $\vec{\tau} = (NI\vec{A}) \times \vec{B}$ is:

$$\tau = NIAB \sin\theta$$

where θ is the angle between the area normal vector $\vec{A}$ and magnetic field $\vec{B}$.

Why other options are wrong:

- **Option B:** Cosine term applies if angle α is measured between the coil plane and magnetic field ($\alpha = 90° - \theta$).
- **Option C:** Inverted magnetic field term in denominator.
- **Option D:** Tangent relation has no rotational force identity.

Final Answer: $\boxed{\tau = NIAB \sin\theta}$ (Option A)

Answer: (A) Go Back to Question 11

Q12.

Solution

Concept: When two sound waves of slightly different frequencies f_1 and f_2 travel in the same direction, their superposition causes periodic constructive and destructive interference, creating beats.

Step 1 — The number of beats heard per second (f_{beat}) equals the absolute difference between the two interfering frequencies:

$$f_{beat} = |f_1 - f_2|$$

Step 2 — Substitute given frequencies $f_1 = 500$ Hz and $f_2 = 504$ Hz:

$$f_{beat} = |500 - 504| = 4 \text{ beats s}^{-1}$$

Why other options are wrong:

- **Option B:** 1004 beats s^{-1} is the additive sum of frequencies ($f_1 + f_2$).
- **Option C:** 2 beats s^{-1} is half the beat frequency.
- **Option D:** 8 beats s^{-1} is double the beat frequency.

Final Answer: $\boxed{4 \text{ beats s}^{-1}}$ (Option A)

Answer: (A) Go Back to Question 12

Q13.

Solution

Concept: The lateral displacement d of a ray through a rectangular refracting slab is $d = \frac{t\sin(i-r)}{\cos r}$.

Step 1 — Since lateral shift d is directly proportional to slab thickness t ($d \propto t$), decreasing the thickness t of the glass slab directly decreases the lateral shift d.

Step 2 — Conversely, increasing incidence angle i or increasing refractive index μ increases the internal refraction bending $(i - r)$, which increases lateral shift.

Why other options are wrong:

- **Option A:** Increasing thickness t increases lateral shift linearly.
- **Option B:** Increasing incidence angle i increases lateral shift.
- **Option C:** Increasing index μ decreases refraction angle r, increasing $(i - r)$ and lateral shift.

Final Answer: Decreasing the thickness t of the glass slab (Option D)

Answer: (D) Go Back to Question 13

Q14.

Solution

Concept: When electric current I flows through a resistor R, electrical potential energy is converted into thermal Joule heat at rate $P = VI = I^2R$.

Step 1 — Total heat energy produced in time t is $H = P \times t = I^2Rt$.

Step 2 — Using Ohm's law ($I = V/R$), substitute for current:

$$H = \left(\frac{V}{R}\right)^2 Rt = \frac{V^2t}{R}$$

Thus, $H = I^2Rt = \frac{V^2t}{R}$ represents the exact formulations of Joule's heating law.

Why other options are wrong:

- **Option A:** IR^2t has incorrect power on resistance (R^2).
- **Option B:** I^2R/t divides by time, which would mean heat decreases with longer conduction.
- **Option D:** IRt^2 squares time instead of current.

Final Answer: $H = I^2Rt = \frac{V^2t}{R}$ (Option C)

Answer: (C) Go Back to Question 14

Q15.

Solution

Concept: A compound microscope multiplies the linear magnification of the objective lens ($m_o \approx -L/f_o$) by the angular magnification of the eyepiece ($m_e = 1 + D/f_e$ at near point).

Step 1 — Multiplying objective and eyepiece magnifications gives total magnifying power:

$$M = m_o \times m_e = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)$$

where L is optical tube length and D is least distance of distinct vision (25 cm).

Why other options are wrong:

- **Option A:** Inverted objective ratio (f_o/L) and eyepiece ratio (f_e/D).
- **Option C:** Formula for an astronomical telescope in near-point adjustment ($M = -\frac{f_o}{f_e}[1 + \frac{f_e}{D}]$).
- **Option D:** Incorrect combinations of focal lengths and tube length.

Final Answer: $\boxed{M = -\frac{L}{f_o}\left(1 + \frac{D}{f_e}\right)}$ (Option B)

Answer: (B) Go Back to Question 15

Q16.

Solution

Concept: In a BJT, emitter current is the sum of base and collector currents ($I_E = I_B + I_C$). In Common-Emitter (CE) configuration, input control current is I_B and output amplified current is I_C.

Step 1 — The DC current gain (β_{dc}) of a transistor in Common-Emitter configuration is defined as the ratio of output collector current (I_C) to input base current (I_B):

$$\beta = \frac{I_C}{I_B}$$

Since base current I_B is very small ($\sim$ 1 to 5% of I_E), β is typically large (20 to 200).

Why other options are wrong:

- **Option B:** I_C/I_E defines the common-base (CB) current gain ($\alpha < 1$).
- **Option C:** I_B/I_E is the defect recombination loss fraction in the base ($1 - \alpha$).
- **Option D:** I_E/I_C is the reciprocal of common-base gain ($1/\alpha$).

Final Answer: $\boxed{\beta = \frac{I_C}{I_B}}$ (Option A)

Answer: (A) Go Back to Question 16

Q17.

Solution

Concept: Commercial electricity consumption is billed in kilowatt-hours; conservative fields exhibit path-independent zero loop work.

Step 1 — One Kilowatt-hour (1 kWh = 1000 W × 3600 s = 3.6×10^6 J) is the commercial Board of Trade (BOT) unit of electrical energy, commonly termed one **Kilowatt-hour** (or Unit).

Step 2 — A force field where work done around any closed loop is strictly zero ($\oint \vec{F} \cdot d\vec{r} = 0$), conserving total mechanical energy without heat dissipation, is called a **Conservative Force** field.

Final Answer: 1. Kilowatt-hour 2. Conservative Force

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

Q18.

Solution

Concept: Telescope magnifying power scales as f_o/f_e; large objective aperture gathers faint light and resolves tight angular separation.

Step 1 — In normal adjustment (infinity focus), angular magnifying power is the ratio of objective focal length to eyepiece focal length: $M = -\frac{f_o}{f_e}$.

Step 2 — Why Large Aperture D: (1) **Light Gathering Power:** Light collected scales with aperture area ($\propto D^2$), making extremely faint distant stars and nebulae brightly visible. (2) **High Resolving Power:** By Airy's limit (R.P. = $\frac{D}{1.22\lambda}$), larger diameter D minimizes diffraction blurring, allowing the telescope to clearly resolve closely spaced binary stars.

Final Answer: 1. M = -f$_o$ $\frac{}{f_e}$ 2. Large D increases light gathering ($\propto D^2$) & resolving power ($D/1.22\lambda$)

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

Q19.

Solution

Concept: Wheatstone bridge null balance equates ratio of resistances in adjacent arms, eliminating meter impedance errors.

Step 1 — When galvanometer current $I_g = 0$, bridge node potentials are equal ($V_B = V_D$), giving balance condition:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Step 2 — Why High Accuracy: A Wheatstone bridge is a **null-deflection (zero-current) measurement method**. When balanced, no current flows through the galvanometer or measurement branch. Thus, the accuracy is completely unaffected by internal resistances of the power supply, galvanometer, or connecting leads, unlike voltmeter-ammeter deflections.

Final Answer: 1. $R_1 \overline{R_2 = \frac{R_3}{R_4}}$ 2. Null method ($I_g = 0$): unaffected by meter/battery internal resistance

Answer: (See above) Go Back to Question 19

Q20.

Solution

Concept: Sustaining nuclear fission chain reactions requires balancing neutron production against leakage and absorption.

Step 1 — Critical Mass: The minimum physical mass of fissile material (^{235}U or ^{239}Pu) required to maintain a steady, self-sustaining fission chain reaction (where neutron multiplication factor $k = 1$) without fizzling out due to surface neutron leakage is called Critical Mass.

Step 2 — Reactor Components: (a) **Moderator:** Light atomic nuclei (heavy water D_2O, graphite) that slow down fast prompt fission neutrons (~ 2 MeV) via elastic collisions to slow thermal speeds (~ 0.04 eV), enabling efficient capture by ^{235}U. (b) **Control Rods:** Strong neutron-absorbing materials (cadmium, boron) inserted into the core to absorb excess neutrons, regulating multiplication factor k and controlling reactor power output.

Final Answer:
1. Min mass for self-sustaining chain ($k = 1$)
2. Moderator slows neutrons; Control rods absorb neutrons

Answer: (See above) Go Back to Question 20

Q21.

Solution

Concept: Matching mechanical laws with their fluid equations and elastic deformation rules.

Step 1 — Hooke's Law affirms that within the elastic limit, stress is directly proportional to strain, so (a) matches (iii).

Step 2 — Stokes' Law formulates viscous drag force $F = 6\pi\eta r v$ on a falling sphere, so (b) matches (i).

Step 3 — Bernoulli's Equation expresses conservation of total fluid energy along a streamline, so (c) matches (iv).

Step 4 — Torricelli's Theorem gives speed of efflux $v = \sqrt{2gh}$ from an orifice at depth h, so (d) matches (ii).

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

Answer: (See above) **Go Back to Question 21**

Q22.

Solution

Concept: Matching logic gates with their Boolean algebraic formulas and functional descriptions.

Step 1 — OR Gate performs logical addition ($Y = A + B$), producing HIGH if any input is HIGH, so (a) matches (iii).

Step 2 — AND Gate performs logical multiplication ($Y = A \cdot B$), producing HIGH only if all inputs are HIGH, so (b) matches (iv).

Step 3 — NOT Gate is an inverter ($Y = \overline{A}$), complementing input state, so (c) matches (i).

Step 4 — NOR Gate ($Y = \overline{A + B}$) is a universal gate formed by inverting OR output, 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: Damped oscillations lose energy over time; resonance occurs when driving frequency matches natural frequency, producing maximum amplitude.

Step 1 — Statement 1 is **TRUE (T)**. In damped SHM, resistive friction/drag continuously removes mechanical energy, causing vibration amplitude to decay exponentially ($A(t) = A_0 e^{-bt/2m}$).

Step 2 — Statement 2 is **FALSE (F)**. At Resonance (when driving frequency ω equals system natural frequency ω_0), energy transfer is maximum, causing forced vibration amplitude to reach an absolute **maximum**, not minimum.

Final Answer: 1. T 2. F

Answer: (See above) Go Back to Question 23

Q24.

Solution

Concept: Ideal transformers step voltage according to turns ratio N_s/N_p; electromagnetic induction requires continuously changing magnetic flux ($d\Phi_B/dt \neq 0$).

Step 1 — To operate as a Step-Up transformer ($V_s > V_p$), the secondary coil must contain more turns than the primary coil, requiring a turns ratio strictly greater than unity:

$$\frac{N_s}{N_p} > 1 \implies N_s > N_p$$

Step 2 — A steady Direct Current (DC) voltage produces a constant, unvarying magnetic flux ($\Phi_B = \text{const}$). According to Faraday's law ($E = -N\frac{d\Phi_B}{dt}$), since $\frac{d\Phi_B}{dt} = 0$, **zero induced EMF** is generated across the secondary coil. Thus, transformers cannot step up or step down DC voltages.

Final Answer: 1. $\frac{N_s}{N_p>1\ (N_s>N_p) \quad \text{2. Steady DC produces zero flux change } (d\Phi/dt = 0)\text{, so zero secondary EMF}}$

Answer: (See above) Go Back to Question 24

Q25.

Solution

Concept: Optical fibers trap light inside a high-index central core using total internal reflection from lower-index cladding.

Step 1 — In an optical fiber, the central light-guiding glass cylinder of high refractive index (μ_1) is called the **Core**, which is surrounded by a coaxial outer protecting layer of lower refractive index ($\mu_2 < \mu_1$) called the cladding.

Step 2 — The operational physical principle that traps laser pulses inside the core without optical energy leakage across curved paths is **Total Internal Reflection**.

Final Answer: 1. Core 2. Total Internal Reflection

Answer: (See above) Go Back to Question 25

Q26.

Solution

Concept: Matching nuclear decay radiations with their atomic composition and charge identities.

Step 1 — Alpha (α) particle is a doubly ionized helium nucleus ($^4_2He^{2+}$) containing 2 protons and 2 neutrons, so (a) matches (iv).

Step 2 — Beta (β^-) particle is a high-speed electron ($^{0}_{-1}e$) emitted when a neutron decays into a proton inside the nucleus, so (b) matches (i).

Step 3 — Gamma (γ) photon is a high-energy neutral electromagnetic photon emitted during nuclear de-excitation, so (c) matches (ii).

Step 4 — Positron (β^+) is the positively charged antiparticle of the electron ($^{0}_{+1}e$), so (d) matches (iii).

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

Answer: (See above) Go Back to Question 26

Q27.

Solution

Concept: Bohr postulated non-radiating stationary orbits; bound atomic electrons possess negative total energy.

Step 1 — Statement 1 is **FALSE (F)**. Bohr's first postulate explicitly affirms that an electron revolving in a quantized stationary circular orbit is non-radiating ($\frac{dE}{dt} = 0$), preventing spiraling energy loss.

Step 2 — Statement 2 is **TRUE (T)**. The total mechanical energy ($E_n = -13.6/n^2$ eV) is strictly negative because electrostatic attractive potential energy is twice as large as kinetic energy ($U_n = -2K_n$), confirming the electron is bound to the nucleus.

Final Answer: 1. F 2. T

Answer: (See above) Go Back to Question 27

Q28.

Solution

Concept: Ground waves suffer rapid ground tilt attenuation at VHF/UHF; optical fibers use laser light for ultra-high bandwidth communication.

Step 1 — Statement 1 is **FALSE (F)**. Ground wave propagation is severely attenuated by earth absorption and tilt at frequencies above 2 MHz. VHF/UHF television and radar signals (> 100 MHz) strictly require line-of-sight Space Wave propagation.

Step 2 — Statement 2 is **TRUE (T)**. Optical fiber communication utilizes infrared and visible laser carrier frequencies ($\sim 10^{14}$ Hz), providing immense data bandwidth (> 100 Gbps) and complete immunity to electromagnetic interference.

Final Answer: 1. F 2. T

Answer: (See above) Go Back to Question 28

Q29.

Solution

Concept: Center of mass represents the unique point where total body mass behaves as if concentrated; static friction self-adjusts up to $\mu_s N$ to prevent impending slipping.

Step 1 — Alternative (i) - Center of Mass: The point in or near a discrete system of particles where the entire mass of the system can be imagined to be concentrated for describing translational motion is called Center of Mass. For n discrete particles:

$$\vec{R}_{\text{cm}} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots + m_n\vec{r}_n}{m_1 + m_2 + \ldots + m_n} = \frac{\sum_{i=1}^{n} m_i\vec{r}_i}{\sum_{i=1}^{n} m_i}$$

Step 2 — Alternative (ii) - Static vs Kinetic Friction:

Static Friction (f_s)	Kinetic Friction (f_k)
1. Operates between surfaces at rest relative to each other when external force is applied.	1. Operates between surfaces in actual relative sliding motion across each other.
2. Self-adjusting force in magnitude and direction ($0 \le f_s \le \mu_s N$).	2. Constant magnitude force ($f_k = \mu_k N$), strictly smaller than limiting friction ($\mu_k < \mu_s$).

Static friction is self-adjusting because as external pulling force F increases from zero, f_s automatically increases identically ($f_s = F$) to maintain equilibrium until reaching limiting threshold $f_{s,\text{max}} = \mu_s N$.

Final Answer: $\vec{R}_{\text{cm}} = \frac{\sum m_i\vec{r}_i}{\sum m_i}$; or Static friction adjusts to match external pull up to $\mu_s N$

Answer: (See above) Go Back to Question 29

Q30.

Solution

Concept: Mayer's relation equates specific heat difference to gas constant ($C_p - C_v = R$). Heating at constant pressure requires extra energy to perform expansion work against atmosphere.

Step 1 — Mayer's Relation: For one mole of an ideal gas, the difference between molar specific heat capacity at constant pressure (C_p) and at constant volume (C_v) is exactly equal to universal gas constant R:

$$C_p - C_v = R$$

Step 2 — Physical Reason why $C_p > C_v$: When heat is supplied to a gas at constant volume (V = const), no external work is done ($W = P\Delta V = 0$). All supplied heat goes exclusively into increasing the internal kinetic energy (temperature) of gas molecules ($\Delta Q_v = \Delta U$).

Step 3 — When the same gas is heated at constant pressure (P = const), the gas expands ($\Delta V > 0$) and performs mechanical work against external atmosphere ($W = P\Delta V$). Therefore, to achieve the exact same temperature rise (ΔT), additional heat must be supplied to provide this expansion work ($\Delta Q_p = \Delta U + P\Delta V$). Hence, $\Delta Q_p > \Delta Q_v \implies C_p > C_v$.

Final Answer: $C_p - C_v = R$; $C_p > C_v$ because constant pressure heating requires extra energy for expansion work $P\Delta V$

Answer: (See above) Go Back to Question 30

Q31.

Solution

Concept: Magnetic flux counts field lines traversing an area ($\Phi_B = \vec{B} \cdot \vec{A}$); electric dipole moment quantifies charge separation strength ($\vec{p} = q \cdot 2\vec{a}$).

Step 1 — Alternative (i) - Magnetic Flux: The total number of magnetic field lines passing perpendicularly through a surface area is called Magnetic Flux (Φ_B). For uniform field $\vec{B}$ and area normal vector $\vec{A}$:

$$\Phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$$

SI unit of magnetic flux is **Weber** (Wb or T m^2).

Step 2 — (a) **Maximum Flux:** Occurs when surface is held perpendicular to field lines, meaning normal vector $\vec{A}$ is parallel to $\vec{B}$ ($\theta = 0^\circ \implies \cos 0^\circ = 1 \implies \Phi_{\text{max}} = BA$). (b) **Zero Flux:** Occurs when surface is held parallel to field lines, meaning normal vector $\vec{A}$ is perpendicular to $\vec{B}$ ($\theta = 90^\circ \implies \cos 90^\circ = 0 \implies \Phi = 0$).

Step 3 — Alternative (ii) - Electric Dipole Moment: An electric dipole consists of two equal and opposite point charges $+q$ and $-q$ separated by a small vector distance $2\vec{a}$. Dipole moment is defined as:

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

Direction: strictly along dipole axis from negative charge ($-q$) to positive charge ($+q$). SI unit: **Coulomb-meter** (C m).

Final Answer: $\Phi_B = BA\cos\theta$ (in Wb), max at 0°, zero at 90°; or $\vec{p} = q(2\vec{a})$ (in C m) from $-q$ to $+q$

Answer: (See above) Go Back to Question 31

Q32.

Solution

Concept: Doppler effect in light causes apparent frequency shifts when relative motion occurs between a light source and an observer; redshift indicates receding astronomical motion.

Step 1 — Doppler Effect in Light: The apparent change in the frequency (or wavelength) of electromagnetic light waves perceived by an observer due to relative motion between the luminous source and observer is called Doppler Effect in Light.

Step 2 — Redshift and Blueshift: (a) **Redshift:** When a light source (like a galaxy) moves away from Earth, perceived frequency decreases and observed wavelength shifts toward the longer wavelength red end of the spectrum ($\Delta\lambda > 0$). (b) **Blueshift:** When a light source moves toward Earth, perceived frequency increases and wavelength shifts toward the shorter wavelength blue end ($\Delta\lambda < 0$).

Step 3 — Measuring Recession Velocity: For radial recession velocity $v \ll c$, fractional wavelength shift is directly proportional to recession speed:

$$\frac{\Delta\lambda}{\lambda} = \frac{\lambda_{\text{observed}} - \lambda_{\text{emitted}}}{\lambda_{\text{emitted}}} = \frac{v}{c} \implies v = c\left(\frac{\Delta\lambda}{\lambda}\right)$$

By measuring the redshift ($\Delta\lambda$) of characteristic spectral lines (like Hydrogen alpha) in galactic spectra, astronomers precisely compute recession velocity v and prove the expansion of the universe (Hubble's law).

Final Answer: Redshift: wavelength stretches as galaxy recedes ($\Delta\lambda > 0$); recession speed $v = c(\Delta\lambda/\lambda)$

Answer: (See above)

Go Back to Question 32

Q33.

Solution

Concept: Electrical resonance occurs in series LCR circuits when inductive and reactive reactances cancel out ($X_L = X_C$), producing purely resistive minimum impedance.

Step 1 — Electrical Resonance: In a series LCR AC circuit, resonance is the phenomenon where the circuit impedance becomes absolute minimum ($Z = R$) and the alternating current reaches maximum peak amplitude for a given applied voltage.

Step 2 — Condition for Resonance: Occurs when inductive reactance equals capacitive reactance:

$$X_L = X_C \implies \omega_0 L = \frac{1}{\omega_0 C} \implies \omega_0^2 = \frac{1}{LC} \implies \omega_0 = \frac{1}{\sqrt{LC}}$$

where $\omega_0 = 2\pi f_0$ is the resonant angular frequency.

Step 3 — Impedance and Power Factor at Resonance:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0} = R \text{ (Minimum Impedance)}$$

Since net reactance is zero, voltage and current are perfectly in phase ($\phi = 0°$). Power factor is:

$$\cos\phi = \frac{R}{Z} = \frac{R}{R} = 1.0 \text{ (Maximum Unity Power Factor)}$$

Final Answer: Resonance condition: $X_L = X_C \implies \omega_0 = 1/\sqrt{LC}$; at resonance, $Z = R$ and power factor $\cos\phi = 1$

Answer: (See above) Go Back to Question 33

Q34.

Solution

Concept: Radioactive decay law states $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$, where $n = \frac{t}{T_{1/2}}$ is the number of half-lives. Decay constant is $\lambda = \frac{0.693}{T_{1/2}}$.

**Step 1 — ** Given remaining activity ratio $\frac{A}{A_0} = \frac{N}{N_0} = \frac{1}{8}$ after elapsed time $t = 15$ hours.

**Step 2 — ** Express remaining fraction as a power of $\frac{1}{2}$:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \implies \frac{1}{8} = \left(\frac{1}{2}\right)^3 \implies n = 3 \text{ half-lives}$$

**Step 3 — ** Calculate Half-Life Period ($T_{1/2}$):

$$n = \frac{t}{T_{1/2}} \implies 3 = \frac{15 \text{ hours}}{T_{1/2}} \implies T_{1/2} = \frac{15 \text{ hours}}{3} = 5.0 \text{ hours}$$

**Step 4 — ** Calculate Decay Constant (λ):

$$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{0.693}{5.0 \text{ hours}} = 0.1386 \text{ hour}^{-1} \approx 3.85 \times 10^{-5} \text{ s}^{-1}$$

Final Answer: $\boxed{T_{1/2} = 5.0 \text{ hours}, \quad \lambda \approx 0.1386 \text{ h}^{-1} \ (3.85 \times 10^{-5} \text{ s}^{-1})}$

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

Q35.

Solution

Concept: Sustained interference requires interfering light waves to maintain time-independent phase differences and equal wavelengths.

Step 1 — Condition 1 - Coherent Sources: The two interfering light sources must be strictly **Coherent Sources**, meaning they must continuously emit light waves having exactly the same wavelength (and frequency) with a constant (time-independent) phase difference ($\Delta\phi$ = const).

Step 2 — Condition 2 - Monochromatic Light: The sources must emit strictly **Monochromatic Light** (single well-defined wavelength λ). If white light is used, overlapping multi-colored fringe patterns blur together into uniform illumination.

Step 3 — Additional Practical Conditions: For maximum contrast (perfectly dark minima), the two interfering waves should have **equal amplitudes** ($a_1 = a_2 \implies I_{\text{min}} = 0$), and the two slits should be extremely narrow and positioned close together ($d \ll D$).

Final Answer: 1. Sources must be coherent ($\Delta\phi$ = const) 2. Light must be strictly monochromatic (single λ)

Answer: (See above) Go Back to Question 35

Q36.

Solution

Concept: Atomic mass unit (1 u) is $1/12^{th}$ the mass of a carbon-12 atom; nuclear binding energy is $E = \Delta m \times 931.5$ MeV.

Step 1 — Alternative (i) - Atomic Mass Unit & Energy: One Atomic Mass Unit (1 u = 1.6605×10^{-27} kg) is defined as exactly one-twelfth ($\frac{1}{12}$) of the rest mass of an unbound neutral Carbon-12 ($^{12}_{6}$C) atom in its ground state.

Step 2 — Calculate energy equivalent of mass defect $\Delta m = 0.030$ u:

$$E = \Delta m \times 931.5 \text{ MeV/u} = 0.030 \text{ u} \times 931.5 \text{ MeV/u} = 27.945 \text{ MeV} \approx 27.95 \text{ MeV}$$

Step 3 — Alternative (ii) - Natural vs Artificial Radioactivity:

Natural Radioactivity	Artificial (Induced) Radioactivity
1. Spontaneous decay of unstable heavy nuclei found in nature ($Z > 83$).	1. Man-made transformation of stable nuclei into radioactive isotopes by particle bombardment.
2. Occurs spontaneously without external excitation or bombardment.	2. Initiated artificially by bombarding target nuclei with neutrons, alpha particles, or protons.
Example: $^{226}_{8}8\text{Ra} \rightarrow^{222}_{8} 6\text{Rn} +^{4}_{2} \text{He}$	Example: $^{27}_{1}3\text{Al} +^{4}_{2} \text{He} \rightarrow^{30}_{1} 5\text{P}^{*} +^{1}_{0} \text{n}$

Final Answer: $E \approx 27.95$ MeV; or Natural vs Artificial Radioactivity table

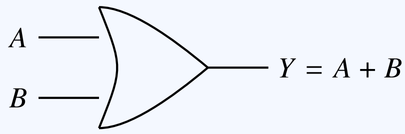
Answer: (See above) Go Back to Question 36

Q37.

Solution

Concept: OR gate performs logical addition; demodulation removes high-frequency RF carrier wave to retrieve low-frequency audio modulating signal.

Step 1 — Alternative (i) - OR Gate: Symbol has curved shield input face and pointed arrow tip. Boolean expression: $Y = A + B$.



Truth Table: $(A = 0, B = 0 \implies Y = 0)$; $(0, 1 \implies 1)$; $(1, 0 \implies 1)$; $(1, 1 \implies 1)$. Output is HIGH if any input is HIGH.

Step 2 — Alternative (ii) - Demodulation (Detection): The electronic process of separating and recovering the low-frequency audio modulating information signal from a high-frequency modulated radio carrier wave at the receiver is called **Demodulation** or **Detection**.

Step 3 — Why Diode Detector is Used: An AM carrier wave has symmetric positive and negative half-cycles whose average over time is zero. A semiconductor diode conducts strictly in one direction (during positive half-cycles only), rectifying the RF wave into pulsating positive half-cycles. A parallel filter capacitor C then charges to peak envelope voltage, filtering out high-frequency RF pulsations and delivering the clean, smooth low-frequency audio envelope voltage to the speaker.

Final Answer: OR symbol & truth table; or Demodulation recovers audio from RF carrier via diode rectification & capacitor envelope filtering

Answer: (See above) Go Back to Question 37

Q38.

Solution

Concept: Center of mass velocity is weighted momentum average $\vec{v}_{\text{cm}} = \frac{\sum m_i \vec{v}_i}{\sum m_i}$; physical pendulum oscillates under gravity torque $\tau = -mgl\sin\theta$.

Step 1 — Alternative (i) - CM Velocity & Momentum Conservation: Let two particles of masses m_1 and m_2 have velocities $\vec{v}_1$ and $\vec{v}_2$. Differentiating CM position vector $\vec{R}_{\text{cm}} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1+m_2}$ with respect to time t:

$$\vec{v}_{\text{cm}} = \frac{d\vec{R}_{\text{cm}}}{dt} = \frac{m_1\frac{d\vec{r}_1}{dt} + m_2\frac{d\vec{r}_2}{dt}}{m_1+m_2} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{M} = \frac{\vec{p}_{\text{total}}}{M}$$

where $M = m_1 + m_2$ is total mass and $\vec{p}_{\text{total}} = m_1\vec{v}_1 + m_2\vec{v}_2$ is total system momentum.

Step 2 — Differentiating CM velocity gives CM acceleration: $\vec{a}_{\text{cm}} = \frac{d\vec{v}_{\text{cm}}}{dt} = \frac{1}{M}\frac{d\vec{p}_{\text{total}}}{dt}$. By Newton's second law for systems of particles, internal forces cancel in equal opposite pairs, leaving $\vec{F}_{\text{ext}} = M\vec{a}_{\text{cm}} = \frac{d\vec{p}_{\text{total}}}{dt}$.

Step 3 — If net external force is zero ($\vec{F}_{\text{ext}} = 0$):

$$\frac{d\vec{p}_{\text{total}}}{dt} = 0 \implies \vec{p}_{\text{total}} = m_1\vec{v}_1 + m_2\vec{v}_2 = \text{constant vector}$$

proving total linear momentum is conserved.

Step 4 — Alternative (ii) - Compound Pendulum: Let a rigid body of mass m and moment of inertia I about pivot S be displaced by small angle θ. Restoring torque of gravity acting at center of mass C located at distance l from pivot is $\tau = -mgl\sin\theta \approx -mgl\theta$.

Step 5 — Since $\tau = I\alpha$, angular acceleration is $\alpha = -\left(\frac{mgl}{I}\right)\theta$. Comparing with SHM equation $\alpha = -\omega^2\theta$:

$$\omega = \sqrt{\frac{mgl}{I}} \implies T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{mgl}}$$

Final Answer: $\boxed{\vec{v}_{\text{cm}} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1+m_2},\ \frac{dp}{dt} = F_{\text{ext}} = 0 \implies p = \text{const};\ \text{or } T = 2\pi\sqrt{\frac{I}{mgl}}}$

Answer: (See above)

Go Back to Question 38

Q39.

Solution

Concept: Kepler's empirical planetary laws enabled Newton to equate circular centripetal force $F = m\omega^2 r = m(4\pi^2 r/T^2)$ to $T^2 \propto r^3$, revealing $F \propto 1/r^2$.

Step 1 — Kepler's Three Laws: (a) **Law of Orbits:** Every planet revolves around the Sun in an elliptical orbit with the Sun situated at one of its foci. (b) **Law of Areas:** The radius vector drawn from the Sun to a planet sweeps out equal areas in equal intervals of time (dA/dt = const, conserving angular momentum). (c) **Law of Periods:** The square of the orbital time period (T) of a planet is directly proportional to the cube of the semi-major axis (r) of its elliptical orbit:

$$T^2 \propto r^3 \implies T^2 = Kr^3$$

Step 2 — Newton's Deduction of Inverse-Square Law: Assume a planet of mass m moves in a circular orbit of radius r around the Sun with speed $v = \frac{2\pi r}{T}$. The required centripetal force holding the planet in orbit is:

$$F = \frac{mv^2}{r} = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 mr}{T^2}$$

Step 3 — Substitute Kepler's third law ($T^2 = Kr^3$) into the centripetal force denominator:

$$F = \frac{4\pi^2 mr}{Kr^3} = \left(\frac{4\pi^2 m}{K}\right)\frac{1}{r^2} \implies F \propto \frac{1}{r^2}$$

Thus, Newton proved that gravitational attraction between the Sun and planets varies inversely as the square of their orbital separation ($F \propto 1/r^2$).

Final Answer: Kepler laws stated; Newton substituted $T^2 \propto r^3$ into centripetal $F = 4\pi^2 mr/T^2$, proving $F \propto 1/r^2$

Answer: (See above) Go Back to Question 39

Q40.

Solution

Concept: Electrostatic potential at distance r is work done per unit charge against Coulomb repulsion from infinity to r: $V = \int_{\infty}^{r} -E\,dx$.

Step 1 — Consider an isolated positive point charge $+q$ fixed at origin O in vacuum. The electric field intensity at an intermediate distance x along a radial line is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$ directed radially outward.

Step 2 — Let a unit positive test charge (+1 C) be moved from infinity toward $+q$. The infinitesimal work dW done by an external agent against Coulomb repulsive force in moving the test charge through a small radial displacement $-dx$ toward origin is:

$$dW = -F\,dx = -E\,dx = -\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}dx$$

Step 3 — Total electrostatic potential V at distance r is obtained by integrating dW from $x = \infty$ to $x = r$:

$$V = \int_{\infty}^{r} -\frac{q}{4\pi\varepsilon_0 x^2}dx = -\frac{q}{4\pi\varepsilon_0}\int_{\infty}^{r} x^{-2}dx = -\frac{q}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_{\infty}^{r}$$

Step 4 — Evaluating limits:

$$V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r} - \frac{1}{\infty}\right) = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

Since $q > 0$, potential V is positive, confirming external work must be done against repulsion to bring a positive test charge from infinity.

Final Answer: $\boxed{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}}$

Answer: (See above) Go Back to Question 40

Q41.

Solution

Concept: In Young's Double Slit Experiment, geometric path difference between coherent rays arriving at point P is $\Delta x \approx \frac{yd}{D}$. Constructive interference requires $\Delta x = n\lambda$.

Step 1 — In the YDSE geometry shown in the diagram, two coherent slits S_1 and S_2 separated by distance d illuminate a screen at distance D. Consider point P at vertical height y_n from central maximum O.

Step 2 — Drop perpendicular S_1M onto ray S_2P. For $D \gg d$, rays S_1P and S_2P are nearly parallel, making angle $\angle S_2S_1M = \theta \approx \angle POC$. In right triangle $\triangle S_1S_2M$, optical path difference is:

$$\Delta x = S_2P - S_1P = S_2M = d\sin\theta$$

Step 3 — For small angles ($\theta \ll 1$ rad), $\sin\theta \approx \tan\theta = \frac{y_n}{D}$. Substituting into path difference:

$$\Delta x = d\left(\frac{y_n}{D}\right) = \frac{y_n d}{D}$$

Step 4 — Bright Fringes (Constructive Interference): Path difference must be integral multiples of wavelength ($\Delta x = n\lambda$):

$$\frac{y_n d}{D} = n\lambda \implies y_n = \frac{n\lambda D}{d} \quad \text{where } n = 0, 1, 2, \ldots$$

Step 5 — Fringe Width (β): Fringe width is the distance between any two consecutive bright fringes ($y_{n+1} - y_n$):

$$\beta = y_{n+1} - y_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d} = \frac{\lambda D}{d}$$

(Identical fringe width $\beta = \lambda D/d$ is obtained for consecutive dark minima $\Delta x = (2n-1)\lambda/2$).

Final Answer: $\boxed{\beta = \frac{\lambda D}{d}}$

Answer: (See above) Go Back to Question 41

Q42.

Solution

Concept: Biot-Savart law integrates differential current loop contributions $dB = \frac{\mu_0 I dl}{4\pi r^2}$; symmetry cancels vertical field components while axial components add up ($dB_x = dB\sin\phi = dB\frac{R}{r}$).

Step 1 — Part (i) - Coil Axial Magnetic Field: Consider a circular wire loop of radius R centered at origin lying in yz-plane carrying current I. To find field at point P on axial x-axis at distance x, consider current element dl at top point A. Distance of P from dl is $r = \sqrt{R^2 + x^2}$.

Step 2 — Since current element dl is perpendicular to position vector $\vec{r}$ ($\theta = 90°$), Biot-Savart law gives field magnitude at P:

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin 90°}{r^2} = \frac{\mu_0}{4\pi}\frac{Idl}{R^2 + x^2}$$

Step 3 — Field vector $d\vec{B}$ is perpendicular to $\vec{r}$ making angle ϕ with vertical. Resolving into components: vertical component $dB_y = dB\cos\phi$ is cancelled by an identical opposite element at the bottom of the loop. Axial component $dB_x = dB\sin\phi$ points along positive x-axis. From right triangle $\triangle OAP$, $\sin\phi = \frac{R}{r} = \frac{R}{\sqrt{R^2+x^2}}$.

Step 4 — Integrating axial components around circumference $\int dl = 2\pi R$:

$$B = \int dB_x = \int dB\sin\phi = \int\left(\frac{\mu_0 Idl}{4\pi(R^2+x^2)}\right)\left(\frac{R}{\sqrt{R^2+x^2}}\right)$$
$$= \frac{\mu_0 IR}{4\pi(R^2+x^2)^{3/2}}\int_0^{2\pi R} dl = \frac{\mu_0 IR^2}{2(R^2+x^2)^{3/2}}$$

For a coil of N turns: $B = \frac{\mu_0 NIR^2}{2(R^2+x^2)^{3/2}}$.

Step 5 — Part (ii) - Center Field Reduction: At coil center O, axial distance $x = 0$. Substituting $x = 0$:

$$B_{\text{center}} = \frac{\mu_0 IR^2}{2(R^2+0)^{3/2}} = \frac{\mu_0 IR^2}{2R^3} = \frac{\mu_0 I}{2R}$$

Step 6 — Alternative (iii) - Van de Graaff Generator: An electrostatic machine generating potentials > 5 MV for particle acceleration. Working principle: (1) **Corona Discharge:** Sharp metal comb spray points connected to high-voltage DC supply ionize surrounding air, spraying positive charge onto a moving insulating silk/rubber belt. (2) **Hollow Sphere Charge Property:** A collecting comb at top transfers charge from belt to an outer large hollow metal sphere. Since excess charge resides exclusively on the outer surface of a conductor, charge continuously flows outward from belt to sphere regardless of existing sphere potential, building up multi-million volt potentials ($V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$).

Final Answer: $B = \frac{\mu_0 IR^2}{2(R^2+x^2)^{3/2}}$, $B_{\text{center}} = \frac{\mu_0 I}{2R}$; or Van de Graaff Corona & Hollow sphere

Answer: (See above) Go Back to Question 42

Q43.

Solution

Concept: Solid-state energy bands arise from atomic orbital overlap; intrinsic semiconductors gain exponential carrier density when heated ($n_i \propto e^{-E_g/2k_BT}$), whereas metallic lattice scattering increases resistance.

Step 1 — Part (i) - Energy Band Formation & Classification: When atoms are brought close together to form a crystal lattice, overlapping valence electron orbitals split into continuous ranges of energy levels called **Energy Bands**. The highest filled band is the **Valence Band**, separated by a forbidden **Energy Band Gap (E_g)** from the upper unoccupied **Conduction Band**.

Step 2 — Comparison of Solids:

Conductors (Metals)	Semiconductors (Si, Ge)	Electrical Insulators
1. Valence and conduction bands overlap ($E_g \approx 0$).	1. Narrow forbidden band gap ($E_g \sim 0.7$ to 1.1 eV).	1. Very wide forbidden band gap ($E_g > 3$ eV).
2. Abundant free conduction electrons available even at 0 K.	2. Zero conduction electrons at 0 K; thermal excitation generates electron-hole pairs at room temp.	2. Valence electrons tightly bound; no thermal excitation across gap.
3. High electrical conductivity; resistance increases when heated.	3. Moderate conductivity; conductivity increases exponentially when heated.	3. Zero electrical conductivity; behaves as perfect insulator.

Step 3 — Part (ii) - Temperature Dependence of Conductivity: In metals, carrier density (n) is constant; heating increases lattice ion vibration amplitudes, shortening electron relaxation time (τ), which decreases conductivity ($\sigma = ne^2\tau/m$). In intrinsic semiconductors, heating breaks covalent bonds, releasing an **exponential surge of electron-hole pairs** ($n_i \propto T^{3/2}e^{-E_g/2k_BT}$). This massive carrier density increase far outweighs lattice scattering, causing conductivity to rise exponentially.

Step 4 — Alternative (iii) - *n-p-n* BJT CE Amplifier: In Common-Emitter amplifier, weak AC input signal is applied across forward-biased base-emitter junction, and amplified output is taken across load resistor R_C in reverse-biased collector circuit.

Step 5 — Why 180° Phase Reversal: Collector output voltage is governed by Kirchhoff's loop rule: $V_{CE} = V_{CC} - I_C R_C$. During the **positive half-cycle** of input AC signal, forward base bias increases, causing a sharp surge in base current I_B and collector current I_C ($\Delta I_C = \beta \Delta I_B$). Since I_C increases, the voltage drop across load resistor ($I_C R_C$) increases dramatically. Consequently, output collector voltage $V_{CE} = V_{CC} - I_C R_C$ **decreases (becomes negative)**. Thus, a positive input half-cycle produces a negative output half-cycle, demonstrating exact 180° phase reversal.

Final Answer: Band theory table & exponential carrier rise in semiconductors; or BJT CE amplifier $V_{CE} = V_{CC} - I_C R_C$ explains 180° phase reversal

Answer: (See above) Go Back to Question 43

Answer Key

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