ECAT Physics Comprehensive Practice Test

Complete 50-Question Solved Guide with Detailed Concept Explanations

Target Exam: Engineering College Admission Test (ECAT) • Subject: Physics Full Syllabus

Q1. A body moves from rest with a uniform acceleration of 2 m/s^2 for 10 seconds. The distance covered by the body in the last second is:

- ✔ **19 m**
- 20 m
- 100 m
- 9 m

Detailed Rationale:

Using the formula for distance covered in the n-th second: $S_n = v_i + \frac{a}{2}(2n - 1)$. Since the body starts from rest, $v_i = 0$, $a = 2\text{ m/s}^2$, and $n = 10$. Substituting these values gives: $S_{10} = 0 + \frac{2}{2}(2(10) - 1) = 20 - 1 = 19\text{ m}$.

Q2. The horizontal range of a projectile is maximum when the angle of projection with the horizontal is:

- 30°
- ✔ **45°**
- 60°
- 90°

Detailed Rationale:

The horizontal range formula is $R = \frac{v_i^2 \sin(2\theta)}{g}$. The range is maximum when $\sin(2\theta)$ reaches its maximum value of 1. This occurs when $2\theta = 90^\circ$, which implies $\theta = 45^\circ$.

Q3. If the momentum of a body is increased by 50%, its kinetic energy will increase by:

- 50%
- 100%
- ✔ **125%**
- 225%

Detailed Rationale:

Kinetic energy relates to momentum via $K.E. = \frac{P^2}{2m}$. If momentum increases by 50%, the new momentum is $1.5P$. The new kinetic energy becomes $K.E.' = \frac{(1.5P)^2}{2m} = 2.25 \left(\frac{P^2}{2m} \right) = 2.25 K.E.$ This represents an increase of $2.25 - 1 = 1.25$ or 125%.

Q4. A rocket works on the principle of conservation of:

- Mass
- Energy
- ✔ **Linear momentum**
- Angular momentum

Detailed Rationale:

A rocket expels high-velocity exhaust gases backward. To conserve linear momentum, the rocket gains an equal and opposite forward momentum. This is a direct application of the law of conservation of linear momentum.

Q5. The escape velocity from the Earth's surface depends upon:

- The mass of the body
- The direction of projection
- ✔ **The mass and radius of the planet**
- The height from which it is projected only

Detailed Rationale:

The escape velocity formula is derived by equating gravitational potential energy to kinetic energy: $v_{esc} = \sqrt{\frac{2GM}{R}}$, where M is the mass of the planet and R is its radius. It is completely independent of the mass of the escaping object.

Q6. When a fluid passes through a pipe of changing cross-section, the product of cross-sectional area and fluid speed remains constant. This is called:

- Bernoulli's principle
- ✔ **Equation of continuity**
- Torricelli's theorem
- Stokes' law

Detailed Rationale:

The Equation of Continuity states that for an incompressible fluid flowing through a tube, the mass flow rate remains constant: $A_1 v_1 = A_2 v_2 = \text{constant}$. This represents the conservation of mass in fluid dynamics.

Q7. The time period of a simple pendulum depends upon:

- The mass of the bob
- The amplitude of oscillation
- ✔ **The length of the pendulum**
- The material of the bob

Detailed Rationale:

The time period of a simple pendulum under a small-angle approximation is given by $T = 2\pi\sqrt{\frac{L}{g}}$. This demonstrates that the period depends only on the length L of the pendulum and gravitational acceleration g.

Q8. When two identical waves traveling in opposite directions along the same line superimpose, they form:

- Beats
- ✔ **Stationary waves**
- Shock waves
- Progressive waves

Detailed Rationale:

Stationary (standing) waves are formed when two identical waves with the same frequency and amplitude travel through a medium in opposite directions and interfere. They form fixed points called nodes (zero amplitude) and antinodes (maximum amplitude).

Q9. The velocity of sound in a gas is directly proportional to:

- The absolute temperature
- ✔ **The square root of absolute temperature**
- The pressure of the gas
- The square of absolute temperature

Detailed Rationale:

According to the Laplace correction, the speed of sound in an ideal gas is given by $v = \sqrt{\frac{\gamma RT}{M}}$. This proves that the velocity v is directly proportional to the square root of the absolute temperature $\sqrt{T}$.

Q10. In a Young's Double Slit Experiment, if the distance between the slits is halved and the distance to the screen is doubled, the fringe width becomes:

- Unchanged
- Doubled
- ✔ **Four times**
- Halved

Detailed Rationale:

Fringe width is given by the formula $Y = \frac{\lambda D}{d}$. If the screen distance D becomes $2D$ and the slit separation d becomes $d/2$, the new fringe width is $Y' = \frac{\lambda (2D)}{d/2} = 4 \left(\frac{\lambda D}{d}\right) = 4Y$.

Q11. Light waves are confirmed to be transverse waves because they exhibit:

- Interference
- Diffraction
- ✔ **Polarization**
- Refraction

Detailed Rationale:

Polarization is the property where wave vibrations are restricted to a single plane. Only transverse waves can be polarized because their oscillations are perpendicular to the direction of propagation. Longitudinal waves (like sound) cannot be polarized.

Q12. A magnifying glass of focal length 5 cm is used by a person with normal vision (near point = 25 cm). Its maximum magnifying power is:

- 5
- ✔ **6**
- 4
- 7.5

Detailed Rationale:

The maximum magnifying power of a simple microscope/magnifying glass occurs when the image is formed at the near point (least distance of distinct vision, $D = 25\text{ cm}$). The formula is $M = 1 + \frac{D}{f}$. Substituting the values: $M = 1 + \frac{25}{5} = 1 + 5 = 6$.

Q13. An ideal gas undergoing an isothermal expansion does work against its surroundings. The heat energy added to the gas is:

- Zero
- ✔ **Equal to the work done**
- Less than the work done
- Used to increase internal energy

Detailed Rationale:

In an isothermal process, the temperature remains constant ($\Delta T = 0$), which implies the change in internal energy is zero ($\Delta U = 0$). According to the First Law of Thermodynamics, $Q = \Delta U + W$. Since $\Delta U = 0$, the heat added Q is exactly equal to the work done W.

Q14. The efficiency of a Carnot engine operating between temperatures T1 (source) and T2 (sink) is given by:

- ✔ **(T1 - T2) / T1**
- (T1 - T2) / T2
- T2 / T1
- T1 / T2

Detailed Rationale:

The efficiency η of a Carnot engine depends only on the absolute temperatures of the reservoirs: $\eta = 1 - \frac{T_2}{T_1}$. Finding a common denominator gives $\eta = \frac{T_1 - T_2}{T_1}$.

Q15. Electric field intensity due to an infinite sheet of charge with uniform surface charge density σ is:

- σ / ε_0
- ✔ **$\sigma / 2\varepsilon_0$**
- $2\sigma / \varepsilon_0$
- $\sigma^2 / 2\varepsilon_0$

> **Detailed Rationale:**
>
> Using Gauss's Law with a cylindrical surface cutting through an infinite sheet of charge, the flux passes through both circular end caps. This gives $2EA = \frac{q_{enclosed}}{\varepsilon_0} = \frac{\sigma A}{\varepsilon_0}$. Solving for E yields $E = \frac{\sigma}{2\varepsilon_0}$.

Q16. The equivalent capacitance of three capacitors, each of capacitance C, connected in series is:

- 3C
- ✔ **C / 3**
- 3 / C
- C

> **Detailed Rationale:**
>
> For capacitors connected in series, the reciprocals of individual capacitances add up to give the reciprocal of equivalent capacitance: $\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C}$. Taking the reciprocal gives $C_{eq} = \frac{C}{3}$.

Q17. A wire of resistance R is stretched uniformly to double its original length. Its new resistance will be:

- 2R
- ✔ **4R**
- R / 2
- 16R

Detailed Rationale:

When a wire is stretched, its volume remains constant ($V = A \cdot L$). Doubling the length ($L' = 2L$) forces the cross-sectional area to be halved ($A' = A/2$). Using the resistance formula $R = \frac{\rho L}{A}$, the new resistance is $R' = \frac{\rho (2L)}{A/2} = 4 \left(\frac{\rho L}{A}\right) = 4R$.

Q18. The color code of a carbon resistor has stripes: Yellow, Violet, Orange, Gold. Its resistance value is:

- ✔ **47 kΩ ± 5%**
- 57 kΩ ± 10%
- 4.7 kΩ ± 5%
- 470 kΩ ± 2%

Detailed Rationale:

According to the standard resistor color code scheme: Yellow = 4, Violet = 7, Orange = 3 (representing a multiplier of 10^3), and Gold = $\pm 5\%$ tolerance. Combining these gives $47 \times 10^3\ \Omega = 47\text{ k}\Omega$ with a tolerance of $\pm 5\%$.

Q19. Kirchhoff's First Law (Current Law) for an electrical node is a statement of the conservation of:

- Energy
- ✔ **Charge**
- Mass
- Momentum

Detailed Rationale:

Kirchhoff's Current Law (Junction Rule) states that the sum of currents entering any node equals the sum of currents leaving that node. Because electric current is the flow of electric charge, this rule is a direct consequence of the law of conservation of charge.

Q20. A charged particle moves through a uniform magnetic field in a circular path. The work done by the magnetic force on the charge is:

- Maximum
- ✔ **Zero**
- Dependent on the velocity of the particle
- Dependent on the magnetic field strength

Detailed Rationale:

The magnetic force acting on a moving charge is always perpendicular to its velocity vector ($\vec{F} = q \vec{v} \times \vec{B}$). Since the force is perpendicular to the direction of motion at every instant, the dot product for mechanical work $W = \vec{F} \cdot \vec{d} = Fd\cos(90^\circ) = 0$.

Q21. Two parallel wires carrying currents in opposite directions will:

- Attract each other
- ✔ **Repel each other**
- Have no force between them
- Rotate around each other

Detailed Rationale:

Using Ampere's right-hand rule to determine magnetic fields and the magnetic force rule ($\vec{F} = I \vec{L} \times \vec{B}$), wires with currents flowing in opposite directions generate forces that push them apart. Parallel currents attract, while anti-parallel currents repel.

Q22. A galvanometer can be converted into an ammeter by connecting a:

- High resistance in series
- ✔ **Low resistance in parallel**
- High resistance in parallel
- Low resistance in series

Detailed Rationale:

To convert a sensitive galvanometer into an ammeter capable of measuring large currents, a low resistance (called a shunt resistor, R_s) is connected in parallel with the galvanometer meter coil. This diverts the majority of the current safely around the coil.

Q23. The self-inductance of a solenoid is directly proportional to:

- The number of turns
- ✔ **The square of the number of turns**
- The inverse of its cross-sectional area
- The length of the solenoid

Detailed Rationale:

The formula for the self-inductance of an ideal solenoid is $L = \frac{\mu_0 N^2 A}{l}$, where N is the total number of turns, A is the cross-sectional area, and l is the length. This expression shows that inductance scales with the square of the number of turns (N^2).

Q24. In an ideal transformer, if the step-up voltage ratio is 1:10, the current ratio from primary to secondary will be:

- 1:10
- ✔ **10:1**
- 1:100
- 1:1

Detailed Rationale:

An ideal transformer preserves electrical power without losses ($P_{primary} = P_{secondary}$), which means $V_p I_p = V_s I_s$. If the voltage steps up by a factor of 10 ($\frac{V_s}{V_p} = 10$), the current must step down by that same factor of 10, meaning $\frac{I_p}{I_s} = 10$, giving a current ratio of 10:1.

Q25. The peak value of an alternating current is 10 A. Its root-mean-square (rms) value is:

- 5 A
- ✔ **7.07 A**
- 14.14 A
- 6.37 A

Detailed Rationale:

For a sinusoidal alternating current, the root-mean-square current I_{rms} relates to the peak current I_0 by the equation $I_{rms} = \frac{I_0}{\sqrt{2}} \approx 0.707 \times I_0$. For $I_0 = 10\text{ A}$, $I_{rms} = 0.707 \times 10 = 7.07\text{ A}$.

Q26. At resonance frequency, the impedance of a series RLC circuit is:

- Maximum and purely reactive
- ✔ **Minimum and purely resistive**
- Zero
- Infinite

Detailed Rationale:

In a series RLC circuit, total impedance is $Z = \sqrt{R^2 + (X_L - X_C)^2}$. At resonance, the inductive reactance equals the capacitive reactance ($X_L = X_C$), making the reactive term zero. Thus, impedance reduces to its minimum possible value, $Z = R$, which is purely resistive.

Q27. The property of a material by which it regains its original shape and size after the removal of a deforming force is known as:

- Plasticity
- ✔ **Elasticity**
- Ductility
- Brittleness

Detailed Rationale:

Elasticity is the physical property of a material that enables it to return to its original shape and structural dimensions after external deforming forces or stresses are removed.

Q28. Which of the following materials is an example of a crystalline solid?

- Glass
- ✔ **Copper**
- Rubber
- Plastic

Detailed Rationale:

Copper is a metal characterized by a highly ordered, repeating 3D crystalline lattice structure throughout its solid state. Materials like glass, rubber, and plastic are classified as amorphous or non-crystalline solids.

Q29. A semiconductor material in its extremely pure form without any added impurities is called:

- Extrinsic semiconductor
- ✔ **Intrinsic semiconductor**
- n-type semiconductor
- p-type semiconductor

Detailed Rationale:

An intrinsic semiconductor is a completely pure semiconductor crystal without any dopant impurities added. Its electrical conductivity is determined solely by internal thermal energy creating electron-hole pairs.

Q30. The depletion region of a p-n junction diode contains:

- Free electrons only
- Holes only
- ✔ **Immobile ions**
- Both free electrons and holes

Detailed Rationale:

When a p-n junction is formed, mobile electrons and holes near the boundary diffuse across and recombine with each other. This leaves behind fixed, uncompensated donor and acceptor ions bound within the crystal lattice, creating a region depleted of mobile charge carriers.

Q31. In a transistor, the base region is always:

- Thick and highly doped
- ✔ **Thin and lightly doped**
- Thick and lightly doped
- Thin and highly doped

> **Detailed Rationale:**
> The base layer of a bipolar junction transistor is deliberately engineered to be extremely thin and lightly doped. This structural layout minimizes the recombination of charge carriers passing through it, allowing almost all carriers injected from the emitter to successfully reach the collector.

Q32. According to Einstein's Special Theory of Relativity, the speed of light in a vacuum:

- Depends on the velocity of the observer
- ✔ **Is independent of the motion of the source or observer**
- Increases when moving toward the light source
- Decreases as the universe expands

> **Detailed Rationale:**
> The second postulate of Einstein's Special Theory of Relativity states that the speed of light in a vacuum is an absolute universal constant ($c = 3 \times 10^8\text{ m/s}$), which remains completely independent of the relative motion of either the light source or the observer.

Q33. The rest mass of a photon is:

- ✔ **Zero**
- 9.11×10^{-31} kg
- 1.67×10^{-27} kg
- Infinite

Detailed Rationale:

Photons are localized packets of electromagnetic energy. Because they constantly move at the speed of light, they have relativistic momentum and energy, but their invariant rest mass (m_0) is identically zero.

Q34. The photoelectric effect demonstrates the:

- Wave nature of light
- ✔ **Particle nature of light**
- Transverse nature of light waves
- Magnetic properties of light

Detailed Rationale:

The photoelectric effect could not be explained by classical wave theory. It was successfully explained by Einstein by modeling light as a stream of discrete energy particles called photons, proving the particle-like behavior of electromagnetic radiation.

Q35. In the Compton scattering experiment, the change in wavelength (Compton shift) is maximum when the scattering angle of the photon is:

- 0°
- 90°
- ✔ **180°**
- 45°

Detailed Rationale:

The formula for the Compton shift is $\Delta \lambda = \frac{h}{m_e c}(1 - \cos\theta)$. The shift is maximized when the term $(1 - \cos\theta)$ is at its maximum value. This occurs at $\theta = 180^\circ$ (backscattering), where $\cos(180^\circ) = -1$, yielding a maximum shift of $\Delta \lambda_{max} = \frac{2h}{m_e c}$.

Q36. According to the de Broglie hypothesis, the wavelength associated with a moving electron is inversely proportional to its:

- Mass only
- Velocity only
- ✔ **Momentum**
- Kinetic energy

Detailed Rationale:

The de Broglie relation states that any moving particle has an associated wave character with a wavelength given by $\lambda = \frac{h}{p}$, where h is Planck's constant and p is the linear momentum ($p = mv$). Therefore, wavelength is inversely proportional to momentum.

Q37. Heisenberg's Uncertainty Principle states that it is impossible to simultaneously measure both the precise position and precise:

- Mass of a subatomic particle
- ✔ **Linear momentum of a particle**
- Charge of a particle
- Spin state of a particle

Detailed Rationale:

Heisenberg's Uncertainty Principle states that position and momentum are complementary conjugate variables. Mathematically, $\Delta x \cdot \Delta p_x \ge \frac{\hbar}{2}$. A more precise measurement of a particle's position inherently introduces greater uncertainty into its linear momentum measurement.

Q38. The radius of the first Bohr orbit of a hydrogen atom is 0.53 Å. The radius of its third Bohr orbit will be:

- 1.59 Å
- ✔ **4.77 Å**
- 2.12 Å
- 0.17 Å

Detailed Rationale:

According to Bohr's atomic model, the radius of the n-th electron orbit scales with the square of the principal quantum number: $r_n = n^2 \cdot r_1$. For the third orbit ($n=3$), $r_3 = 3^2 \times 0.53\text{ Å} = 9 \times 0.53 = 4.77\text{ Å}$.

Q39. When an electron transitions from a higher outer orbit to the second orbit (n=2) in a hydrogen atom, the spectral lines emitted form the:

- Lyman series
- ✔ **Balmer series**
- Paschen series
- Brackett series

Detailed Rationale:

The Balmer series corresponds to electron transitions from higher energy shells ($n = 3, 4, 5, \dots$) down to the second orbit ($n=2$). The photons emitted during these specific transitions fall within the visible spectrum of light.

Q40. X-rays are electromagnetic radiations characterized by having:

- Long wavelengths and low frequencies
- ✔ **High frequencies and short wavelengths**
- Velocities less than visible light
- Positive electric charge characteristics

Detailed Rationale:

X-rays are highly energetic electromagnetic waves located beyond ultraviolet radiation. They possess very high frequencies and extremely short wavelengths (typically between $0.01\text{ to }10\text{ nm}$), and travel at the speed of light without carrying any net electrical charge.

Q41. The operation of a LASER relies fundamentally on the process of:

- Spontaneous emission
- ✔ **Stimulated emission**
- Photoelectric absorption
- Thermal ionization

Detailed Rationale:

LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. It relies on an incident photon interacting with an excited atom, stimulating it to drop energy levels and emit an identical twin photon with matching phase, frequency, polarization, and direction.

Q42. The mass defect of a stable nucleus is always:

- Zero
- ✔ **Positive (mass of nucleus < mass of individual nucleons)**
- Negative (mass of nucleus > mass of individual nucleons)
- Variable depending on temperature

Detailed Rationale:

The mass defect (Δm) is always a positive value, meaning the measured mass of a stable nucleus is always less than the combined sum of the masses of its constituent protons and neutrons. This missing mass is converted into the nuclear binding energy keeping the core stable.

Q43. One atomic mass unit (1 amu or u) is equivalent to an energy of approximately:

- ✔ **931.5 MeV**
- 1.6 x 10^-19 J
- 0.511 MeV
- 1836 MeV

> **Detailed Rationale:**
> By applying Einstein's mass-energy equation $E = mc^2$ to a mass of $1\text{ amu} \approx 1.66 \times 10^{-27}\text{ kg}$ and converting the resulting Joule value into Mega-electron-volts ($1\text{ MeV} = 1.6 \times 10^{-13}\text{ J}$), the equivalent energy value is approximately 931.5 MeV.

Q44. During a radioactive beta-minus (β-) decay process, a nucleus emits an electron and a(n):

- Alpha particle
- ✔ **Antineutrino**
- Neutrino
- Proton

> **Detailed Rationale:**
> In beta-minus (β^-) decay, a neutron inside the nucleus converts into a proton, an electron, and an electron antineutrino ($\bar{\nu}_e$). The antineutrino is an uncharged lepton required to conserve lepton number, angular momentum, and mass-energy.

Q45. The half-life of a radioactive isotope is 4 days. After 12 days, the fraction of the original radioactive material remaining undecayed will be:

1/3

1/4

✔ **1/8**

1/16

Detailed Rationale:

The number of elapsed half-lives is $n = \frac{\text{Total Time}}{\text{Half-life}} = \frac{12\text{ days}}{4\text{ days}} = 3$. The fraction of remaining undecayed radioactive material is calculated using the exponential relationship $(\frac{1}{2})^n = (\frac{1}{2})^3 = \frac{1}{8}$.

Q46. Which of the following nuclear radiations possesses the highest ionizing power?

✔ **Alpha particles**

Beta particles

Gamma rays

Neutrons

Detailed Rationale:

Alpha particles possess the highest ionizing power because they are relatively heavy helium nuclei with a large $+2e$ charge. This large charge and slow velocity increase their probability of interacting strongly with atomic electron shells and stripping electrons away.

Q47. According to the Standard Model of particle physics, protons and neutrons are composed of elementary particles called quarks. A proton consists of:

- Three down quarks
- ✔ **Two up quarks and one down quark**
- One up quark and two down quarks
- Two down quarks and one strange quark

Detailed Rationale:

Quarks carry fractional electric charges: an up quark (u) has a charge of $+\frac{2}{3}e$, and a down quark (d) has a charge of $-\frac{1}{3}e$. A proton's valence structure is uud, meaning its net charge is $+\frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +1e$.

Q48. The dimensional formula for the universal gravitational constant G is:

- ✔ **[M^-1L^3T^-2]**
- [ML^2T^-2]
- [M^1L^3T^-1]
- [M^-2L^2T^-2]

Detailed Rationale:

From Newton's gravitational law, $F = G\frac{m_1m_2}{r^2} \Rightarrow G = \frac{Fr^2}{m_1m_2}$. Substituting the fundamental dimensional blocks for force ($[MLT^{-2}]$), radius ($[L^2]$), and mass ($[M^2]$) yields: $G = \frac{[MLT^{-2}][L^2]}{[M^2]} = [M^{-1}L^3T^{-2}]$.

Q49. Two vectors A and B are perpendicular to each other if their:

- ✔ **Dot product is zero**
- Cross product is zero
- Dot product is equal to unity
- Magnitudes are equal

Detailed Rationale:

The scalar (dot) product of two vectors is given by $\vec{A} \cdot \vec{B} = AB \cos\theta$. If two non-zero vectors are perpendicular to each other, the angle $\theta = 90^\circ$, and since $\cos(90^\circ) = 0$, their dot product evaluates to exactly zero.

Q50. A uniform beam of weight 100 N is pivoted at its center. If a weight of 50 N is hung at a distance of 2 m to the left of the pivot, where must a 25 N weight be hung to keep the beam horizontally balanced?

- ✔ **4 m to the right of the pivot**
- 2 m to the right of the pivot
- 1 m to the left of the pivot
- 8 m to the right of the pivot

Detailed Rationale:

For the beam to remain in rotational equilibrium, the total counterclockwise torque must balance the clockwise torque around the central pivot point: $\tau_{ccw} = \tau_{cw} \Rightarrow F_1 \cdot d_1 = F_2 \cdot d_2$. Substituting the values: $50\text{ N} \times 2\text{ m} = 25\text{ N} \times d_2 \Rightarrow 100 = 25 \cdot d_2 \Rightarrow d_2 = 4\text{ m}$ to the right.
