ECAT PHYSICS COMPREHENSIVE QUESTION BANK

50 Solved Multiple Choice Questions • Clean Typography Edition

Advanced Engineering Test Level • Ticked & Highlighted Keys with Explanations

Q1. The dimensional formula for torque is identical to the dimensional formula of:

Power	Force
✓ **Work**	Linear momentum

Solution & Explanation:
Torque is defined as the cross product of position vector and force (Torque = r x F). Its unit is N-m, which has dimensions $[M\ L^2\ T^{-2}]$. Since work is force multiplied by displacement ($W = F \cdot d$), it shares the exact same unit (Joule) and dimensions $[M\ L^2\ T^{-2}]$.

Q2. A ball is thrown vertically upward with a speed of 19.6 m/s. The maximum height attained by the ball is (Take g = 9.8 m/s²):

9.8 m	✓ **19.6 m**
39.2 m	4.9 m

Solution & Explanation:
Using the third equation of motion under constant gravity: $v_f^2 = v_i^2 - 2gh$. At peak height, $v_f = 0$. Hence, $0 = (19.6)^2 - 2(9.8)h$ which simplifies to $19.6h = 384.16$, leading to $h = 19.6$ meters.

Q3. An object moves along a circular path of radius r with a constant speed v. The acceleration of the object is:

Zero	v/r directed along the tangent
✓ **v^2/r directed toward the center**	v^2/r directed away from the center

Solution & Explanation:
Even with uniform speed, a particle traveling along a circular trajectory constantly changes direction. This generates a centripetal acceleration defined by $a_c = v^2/r$, which is always directed radially inward toward the center of curvature.

Q4. The area under a force-time (F-t) graph yields which of the following mechanical quantities?

Work done	Power expended
✓ **Change in momentum (Impulse)**	Kinetic energy

Solution & Explanation:
By definition, the mathematical area under a force over time curve is Impulse (J = Average Force x time). According to Newton's Second Law, impulse is identically equal to the absolute change in linear momentum (Δp).

Q5. If a feather and a hammer are dropped simultaneously from the same height in a complete vacuum:

The hammer hits the ground first because it is heavier	The feather hits the ground first due to less cross-sectional area
✓ **Both hit the ground at the exact same instant**	They will float and never hit the ground

Solution & Explanation:
In a vacuum, air resistance is completely absent. The gravitational acceleration ($g = GM/R^2$) acts uniformly on all objects regardless of their mass. Because their downward acceleration is identical, they fall and land together.

Q6. A solid sphere and a hollow cylinder of equal mass and radius roll down an inclined plane without slipping from rest. Which one reaches the bottom first?

The hollow cylinder	✓ **The solid sphere**
Both reach at the same time	It depends on the angle of inclination

Solution & Explanation:
The solid sphere has a smaller moment of inertia ($I = 2/5\ mr^2 = 0.4mr^2$) compared to the hollow cylinder ($I = mr^2$). Objects with less rotational inertia distribute less potential energy into rotational kinetic energy, leaving more energy available for linear acceleration down the incline.

Q7. The working mechanism of a hydraulic lift is directly founded upon:

Archimedes' principle	✓ **Pascal's principle**
Bernoulli's equation	Torricelli's law

Solution & Explanation:
Pascal's principle states that any pressure change applied to an enclosed, incompressible fluid is transmitted undiminished throughout the fluid to all walls of the container. This allows a small input force over a small area to generate a massive lifting force over a larger output area.

Q8. When water droplets combine into a larger single drop, the total surface energy of the system:

Increases	✓ **Decreases**
Remains unchanged	Becomes zero

Solution & Explanation:
Combining small droplets reduces the total surface area for a given volume. Because surface energy is proportional to surface area (E = Surface Tension x Area), a decrease in total surface area automatically results in a lower surface energy configuration.

Q9. A block attached to an ideal spring oscillates with simple harmonic motion. At the equilibrium position:

Kinetic energy is zero and potential energy is maximum	✓ **Kinetic energy is maximum and potential energy is zero**
Both energies are equal and maximum	Both energies are zero

Solution & Explanation:
At the equilibrium line ($x = 0$), the spring is completely unstretched, making elastic potential energy ($U = 0.5\ kx^2 = 0$). Because total mechanical energy is conserved, all energy exists as kinetic energy, matching maximum velocity ($v = \omega A$).

Q10. The speed of an electromagnetic wave in a vacuum is given by which relationship of permittivity (ε_0) and permeability (μ_0)?

Square root of ($\varepsilon_0 \times \mu_0$)	$1 / (\varepsilon_0 \times \mu_0)$
✓ **1 / Square root of ($\varepsilon_0 \times \mu_0$)**	ε_0 / μ_0

Solution & Explanation:
Derived from Maxwell's equations, the speed of light and all other electromagnetic radiation in a vacuum is defined by $c = 1 / \sqrt{(\varepsilon_0 \mu_0)}$. Substituting the constant values gives exactly 3×10^8 m/s.

Q11. When a light wave travels from air into a dense glass block, which of its properties remains completely unaltered?

Velocity	Wavelength
✓ **Frequency**	Amplitude

Solution & Explanation:
Frequency is an intrinsic property determined solely by the source emitting the wave. When crossing an optical medium interface, the wave velocity decreases and its wavelength shortens proportionally ($v = f\lambda$), leaving frequency constant.

Q12. Two sound waves of slightly different frequencies f1 = 256 Hz and f2 = 260 Hz are sounded together. The number of beats heard per second is:

2 beats/s	✓ **4 beats/s**
258 beats/s	8 beats/s

Solution & Explanation:
The beat frequency (f_{beat}) produced by the interference of two wave trains is equal to the absolute difference between their individual frequencies: $f_{beat} = |f1 - f2| = |256 - 260| = 4$ Hz.

Q13. To eliminate spherical aberration in optical mirror systems, the ideal configuration is to use a:

Concave spherical mirror	✓ **Parabolic mirror**
Plane mirror	Convex spherical mirror

Solution & Explanation:
Spherical mirrors fail to focus parallel rays grazing outer edges to the exact same focus as central rays. Parabolic mirrors reflect all parallel incoming rays directly through a single focal point, completely eliminating spherical aberration.

Q14. According to the First Law of Thermodynamics, a system undergoing a completely adiabatic process satisfies which condition?

$\Delta U = 0$	$W = 0$
✓ **$Q = 0$**	P = constant

Solution & Explanation:
An adiabatic process is one that occurs without any heat exchange between the system and its surroundings. Setting $Q = 0$ in the first law expression ($\Delta U = Q - W$) simplifies to $\Delta U = -W$.

Q15. The absolute temperature of an ideal gas is a direct macroscopic measure of its molecules':

Average potential energy	✓ **Average translational kinetic energy**
Total linear momentum	Average vibrational amplitude

Solution & Explanation:
Kinetic theory proves that the average translational kinetic energy of gas molecules is directly proportional to the absolute temperature: $KE = 1.5\ kT$, where k is Boltzmann's constant.

Q16. The work done in moving a test charge along an equipotential surface of any geometry is:

Always positive	Always negative
✓ **Zero**	Dependent on the path taken

Solution & Explanation:
The work done moving a charge q between two points is given by $W = q\ \Delta V$. By definition, every point on an equipotential surface has the exact same electrical potential, so $\Delta V = 0$, meaning $W = 0$.

Q17. Two point charges +q and -q are separated by a small distance d. The electric potential at any point on the perpendicular bisector of this dipole is:

Maximum	✓ **Zero**
Dependent on charge magnitude only	Infinite

Solution & Explanation:
Any point along the perpendicular bisector line is at an equal distance r from both charges. The total scalar electric potential is V = (k·q/r) + (k·(-q)/r) = 0.

Q18. Ohm's Law is valid for conductor devices under the strict condition that their:

Voltage remains constant	Resistance increases linearly
✓ **Temperature remains constant**	Current is alternating

Solution & Explanation:
The resistance of metallic conductors changes with temperature due to increased lattice vibrations. Ohm's Law (V = IR) assumes a constant resistance, which holds true only if temperature and other physical states remain uniform.

Q19. A potentiometer is considered superior to a standard voltmeter for measuring electromotive force (emf) because:

It has a very low internal resistance	✓ **It draws zero current from the source at balance condition**
It is smaller and highly portable	It works on alternating current networks

Solution & Explanation:
A standard voltmeter draws a small current, which drops a fraction of the voltage across the source's internal resistance (V = E - Ir). A potentiometer measures potential difference using a null-deflection method, drawing zero current and revealing the true emf.

Q20. The magnetic field inside a long, tightly wound current-carrying solenoid is:

Zero	Highly non-uniform
✓ **Uniform and parallel to the axis**	Circular around the outer shell

Solution & Explanation:
Applying Ampere's Law inside an ideal long solenoid shows that the field lines run closely parallel and tightly packed along the central axis, producing a strong, uniform magnetic field defined by $B = \mu_0 n I$.

Q21. The SI unit of magnetic flux density is the Tesla. One Tesla is dimensionally equivalent to:

1 N·A/m	✓ **1 N/(A·m)**
1 J/(A·m²)	1 N·m/A

Solution & Explanation:
From the magnetic force equation on a current-carrying wire ($F = I L B$), solving for B yields $B = F / (I L)$. Thus, the unit Tesla (T) equals Newtons per Ampere-meter [N / (A·m)].

Q22. Lenz's Law of electromagnetic induction is a direct consequence of the law of conservation of:

Charge	Mass
✓ **Energy**	Momentum

Solution & Explanation:
Lenz's Law states that an induced current always flows in a direction that opposes the change that created it. This opposition requires mechanical work to be done, which transforms into electrical energy, satisfying the conservation of energy.

Q23. An alternating current circuit contains only a pure capacitor. The phase relationship shows that:

✓ **Current leads voltage by 90°**	Voltage leads current by 90°
Current and voltage are in phase	Current lags voltage by 45°

Solution & Explanation:
In a purely capacitive AC circuit, the alternating voltage must build charge across the plates over time. Consequently, the alternating current wave reaches its peak exactly a quarter-cycle ahead of the voltage wave, leading by 90 degrees.

Q24. The quality factor (Q-factor) of a resonant series RLC circuit is inversely proportional to:

The inductance L	The capacitance C
✓ **The resistance R**	The resonant frequency

Solution & Explanation:
The formula for the quality factor of a series RLC circuit is Q = (1/R) x √(L/C). This mathematical definition proves that Q is inversely proportional to the circuit's series resistance R.

Q25. The stress required to double the length of a wire of Young's Modulus Y is:

✓ **Y**	2Y
Y/2	4Y

Solution & Explanation:
Doubling a wire's length means its final length is $2L_0$, yielding an elongation of $\Delta L = L_0$. The strain is Strain = $\Delta L / L_0 = L_0 / L_0 = 1$. Since Young's Modulus is defined as Stress / Strain, Stress = Y x 1 = Y.

Q26. Which magnetic material category exhibits a strong spontaneous magnetization that remains even after the external field is removed?

Diamagnetic materials	Paramagnetic materials
✓ **Ferromagnetic materials**	Electrodynamic materials

Solution & Explanation:
Ferromagnetic materials (like iron and nickel) contain microscopic structures called magnetic domains. When aligned by an external field, they stay locked in position, retaining strong permanent magnetization.

Q27. An ideal operational amplifier (op-amp) has which of the following input and output impedance characteristics?

- Zero input impedance and infinite output impedance
- ✓ **Infinite input impedance and zero output impedance**
- Infinite input impedance and infinite output impedance
- Zero input impedance and zero output impedance

Solution & Explanation:
An ideal op-amp features infinite input impedance so it draws zero signal current from the input source, and zero output impedance so it can deliver maximum power to any output load without internal voltage losses.

Q28. The ripple frequency of a full-wave rectifier working on a 50 Hz main AC line input is:

- 25 Hz
- 50 Hz
- ✓ **100 Hz**
- 200 Hz

Solution & Explanation:
A full-wave rectifier converts both positive and negative half-cycles of the input AC wave into positive output pulses. This process doubles the pulse rate, making the ripple frequency exactly 2 x 50 Hz = 100 Hz.

Q29. The logic gate that outputs a LOW (0) signal only when all of its inputs are HIGH (1) is a:

- NOR gate
- AND gate
- ✓ **NAND gate**
- XOR gate

Solution & Explanation:
A NAND gate performs an inverted AND operation. It produces a continuous HIGH output for all input combinations except when both inputs are 1, which switches the output to 0.

Q30. According to length contraction in Special Relativity, if an observer watches a spacecraft fly past at near-light speed, its length along the direction of motion appears:

Stretched	✓ **Shortened**
Exactly the same	Alternating in size

Solution & Explanation:
The Lorentz length contraction formula is $L = L_0 \times \sqrt{(1 - v^2/c^2)}$. For relativistic velocities approaching light speed, the radical term scales below 1, meaning the observed length L shrinks relative to its rest length L_0.

Q31. In a photoelectric experiment, increasing the intensity of the incident light beam while keeping its frequency constant will increase the:

Maximum kinetic energy of photoelectrons	Stopping potential
✓ **Photoelectric current**	Threshold frequency

Solution & Explanation:
Light intensity is a measure of photon flux (photons striking per second). Higher intensity means more photons hit the metal emitter, releasing more electrons per second and increasing the measured photoelectric current.

Q32. The maximum kinetic energy of emitted photoelectrons depends directly upon the incident radiation's:

Intensity	✓ **Frequency**
Velocity	Total exposure time

Solution & Explanation:
According to Einstein's equation (KE_max = hf - Work Function), the maximum energy of photoelectrons scales linearly with the frequency (f) of the incoming photons, completely independent of light intensity.

Q33. The production of X-rays via electron deceleration against a heavy metal target is often described as the inverse process of:

The Compton effect	✓ **The Photoelectric effect**
Nuclear fission	Pair production

Solution & Explanation:
The photoelectric effect uses incoming photons to eject bound electrons from a metal surface. X-ray production does the opposite: high-speed kinetic electrons strike a metal target, converting their kinetic energy into outgoing photons.

Q34. An electron, a proton, and an alpha particle all travel with identical velocities. Which particle has the shortest de Broglie wavelength?

The electron	The proton
✓ **The alpha particle**	All share the exact same wavelength

Solution & Explanation:
The de Broglie wavelength relation is $\lambda = h / (m \cdot v)$. For a fixed velocity v, wavelength is inversely proportional to mass. Since the alpha particle is the heaviest of the three, it has the shortest wavelength.

Q35. The total energy of an electron spinning inside the stable hydrogen Bohr orbit is negative. This negative sign signifies that:

The electron has negative mass equivalents	✓ **The electron is bound to the positive nucleus**
The atom is highly unstable	The electron repels the proton core

Solution & Explanation:
A negative total energy value indicates a bound state. It means energy must be added to the system from an external source to free the electron from the attractive electrostatic pull of the positive nucleus.

Q36. Laser light is highly monochromatic. This specific property means that the beam consists of:

Perfectly parallel ray tracks	✓ **A single, sharply defined wavelength**
Waves locked in phase over time	Extreme optical energy density

Solution & Explanation:
The term 'monochromatic' translates directly to 'single color'. In physics, this means the emitted laser light is concentrated within an extremely narrow frequency spectrum, sharing one precise wavelength.

Q37. The binding energy per nucleon curve peaks near which stable isotope, making it one of the most tightly bound cores?

✓ **Iron-56 (Fe-56)**	Uranium-235 (U-235)
Helium-4 (He-4)	Carbon-12 (C-12)

Solution & Explanation:
The binding energy per nucleon curve reaches its maximum value of about 8.8 MeV per nucleon near Iron-56. This high value makes iron exceptionally stable, marking the structural boundary between nuclear fusion and fission processes.

Q38. During alpha decay, the parent nucleus drops its atomic number (Z) and mass number (A) by which values?

Z decreases by 1, A decreases by 4	✓ **Z decreases by 2, A decreases by 4**
Z decreases by 4, A decreases by 2	Z increases by 2, A decreases by 2

Solution & Explanation:
An alpha particle is a helium nucleus containing 2 protons and 2 neutrons. Ejecting this particle reduces the parent nucleus's mass number A by 4 and its atomic number Z by 2.

Q39. The fundamental force responsible for radioactive beta decay processes in unstable nuclei is the:

Strong nuclear force	Electromagnetic force
✓ **Weak nuclear force**	Gravitational force

Solution & Explanation:
Beta decay involves a subatomic quark flavor change inside a nucleon (e.g., a down quark turning into an up quark to convert a neutron into a proton). Flavor transformations are governed exclusively by the weak nuclear force.

Q40. Nuclear reactors use a material called a moderator to absorb kinetic energy and slow down fast neutrons. A common moderator is:

Liquid sodium metal	✓ **Heavy water (D_2O)**
Cadmium control rods	Solid lead sheets

Solution & Explanation:
Effective moderators contain light nuclei (like deuterium in heavy water or carbon in graphite) that can absorb energy from fast neutrons via elastic collisions without absorbing the neutrons themselves, slowing them down into thermal speeds.

Q41. According to the quark structure model, a neutron is composed of which combination of valence quarks?

Two up quarks, one down quark (uud)	Three down quarks (ddd)
✓ **One up quark, two down quarks (udd)**	One up, one down, one strange (uds)

Solution & Explanation:
An up quark carries a charge of +2/3 and a down quark carries -1/3. Combining one up and two down quarks (+2/3 - 1/3 - 1/3 = 0) balances out to the zero net electrical charge of a neutral neutron.

Q42. The cross product of two parallel or anti-parallel vectors always equals:

A unit vector	The product of their absolute magnitudes
✓ **The zero vector**	A vector pointing along the z-axis

Solution & Explanation:
The magnitude of a vector cross product is given by $|A \times B| = AB \sin(\theta)$. For parallel vectors ($\theta = 0°$) or anti-parallel vectors ($\theta = 180°$), $\sin(\theta) = 0$, reducing the cross product entirely to a zero vector.

Q43. A car accelerates uniformly from 10 m/s to 30 m/s over a distance of 100 meters. The acceleration of the car is:

2 m/s²	✓ **4 m/s²**
8 m/s²	1 m/s²

Solution & Explanation:
Using the kinematic equation $v_f^2 = v_i^2 + 2as$, substitute the given values: $(30)^2 = (10)^2 + 2a(100)$ which gives $900 = 100 + 200a$, meaning $800 = 200a$, leading to $a = 4$ m/s².

Q44. The dynamic friction force acting between two sliding solid surfaces is independent of:

The nature of the materials in contact	The normal force pressing them together
✓ **The apparent area of contact**	The roughness profile

Solution & Explanation:
The sliding friction law is Force = μ x Normal Force. While a larger macroscopic area provides more physical contact points, the weight is distributed wider, reducing the localized pressure. These two effects perfectly cancel out.

Q45. When an elevator accelerates straight downward with an acceleration equal to g, the apparent weight of a rider inside is:

Doubled (2mg)	Unchanged (mg)
✓ **Zero (Weightlessness)**	Half its normal weight

Solution & Explanation:
The scale reading inside an elevator equals the normal response force: $N = m(g - a)$. If the elevator enters a free-fall acceleration downward ($a = g$), the equation becomes $N = m(g - g) = 0$, producing absolute apparent weightlessness.

Q46. The geostationary orbit of a communication satellite has an orbital period exactly equal to:

12 hours	✓ **24 hours**
90 minutes	365 days

Solution & Explanation:
A geostationary satellite must stay fixed over one specific geographic spot on Earth. To match the planet's intrinsic rotation, its orbital period must match Earth's rotational period, which is approximately 24 hours.

Q47. Terminal velocity is reached by a falling object when its downward weight is perfectly balanced by the upward:

Buoyant force only	✓ **Viscous drag force**
Centrifugal force	Inertial push

Solution & Explanation:
As an object speeds up during free fall, the air resistance or viscous drag force opposing it grows. When this drag force matches the object's downward weight, the net force becomes zero, and the object stops accelerating, falling at a constant terminal velocity.

Q48. The sound frequency shift heard by an observer due to the relative motion of a source is called the:

Zeeman effect	✓ **Doppler effect**
Raman effect	Tyndall effect

Solution & Explanation:
The Doppler effect is the perceived change in wave frequency resulting from relative motion between the wave source and an observer. Sound waves bunch closer together as the source approaches and stretch farther apart as it moves away.

Q49. Brewster's Law states that a light wave reflecting off a surface is completely polarized when the tangent of the incident angle equals the medium's:

Speed of light	✓ **Refractive index**
Critical angle	Permittivity

Solution & Explanation:
Brewster's Law is written as $n = \tan(\theta)$, where n is the refractive index of the reflecting medium and θ is the specific polarization angle that optimally filters the reflected light waves.

Q50. The total electric flux passing through any closed surface enclosing a net charge Q is given by:

$Q \times \varepsilon_0$	✓ **Q / ε_0**
ε_0 / Q	$4\pi Q$

Solution & Explanation:
Gauss's Law states that the total net electric flux passing through any closed mathematical Gaussian surface is equal to the total net enclosed electric charge (Q) divided by the permittivity of free space (ε_0).