JEE Main Physics
Sample Paper – 20

Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** contains **20 Multiple Choice Questions (MCQ)**. Each correct answer carries **+4 marks**; each wrong answer carries -1 **mark**. Unattempted questions carry **0 marks**.
- **Section B** contains **10 Numerical Value Questions (NVQ)**. Attempt **any 5**. Each correct answer carries **+4 marks**. There is **no negative marking** in Section B.
- The syllabus is based on **NCERT Physics (Class XI & XII)**.
- **No personal calculators** are allowed. An on-screen virtual calculator is provided.

SECTION A – Multiple Choice Questions (Q1–Q20)

Q1. A body is dropped from rest and falls freely under gravity. Taking $g = 10\,\text{m/s}^2$, how long does it take to fall a distance of $h = 80\,\text{m}$?

(A) $4\,\text{s}$

(B) $6\,\text{s}$

(C) $8\,\text{s}$

(D) $16\,\text{s}$

Q2. A rocket ejects gases at a speed v_{rel} relative to the rocket at a mass flow rate $|dm/dt|$. The thrust force on the rocket is:

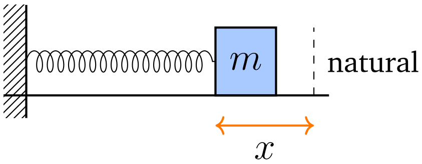
(A) $F_{thrust} = \frac{1}{2} v_{rel} \cdot |dm/dt|$

(B) $F_{thrust} = v_{rel}^2 \cdot |dm/dt|$

(C) $F_{thrust} = v_{rel} \cdot |dm/dt|$

(D) $F_{thrust} = \frac{v_{rel}}{|dm/dt|}$

Q3. A spring of spring constant k is compressed by a distance x from its natural length and then released. The work done by the spring on the block when it returns to the natural length position is:



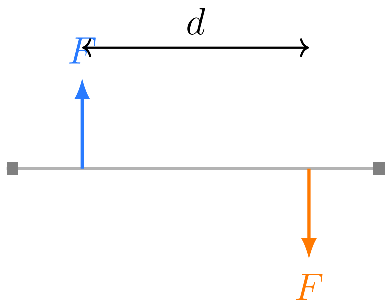
(A) $W = -\frac{1}{2}kx^2$

(B) $W = \frac{1}{2}kx^2$

(C) $W = kx^2$

(D) $W = 2kx^2$

Q4. A couple is formed by two equal and opposite parallel forces F acting on a rigid bar separated by a perpendicular distance d. The moment of the couple (torque) about any point is:



(A) $\tau = F/d$

(B) $\tau = F + d$

(C) $\tau = F^2 d$

(D) $\tau = Fd$

Q5. How does the acceleration due to gravity g vary with depth d below the Earth's surface, assuming Earth has uniform density and radius R?

(A) $g_d = g\left(1 - \frac{d}{R}\right)$

(B) $g_d = g\left(1 + \frac{d}{R}\right)$

(C) $g_d = g\left(1 - \frac{d^2}{R^2}\right)$

(D) $g_d = \frac{g\,R^2}{(R-d)^2}$

Q6. A liquid of surface tension T, density ρ, and contact angle θ rises in a capillary tube of radius r. The height of the capillary rise is:

(A) $h = \dfrac{T\cos\theta}{\rho g r}$

(B) $h = \dfrac{T\cos\theta}{2\rho g r}$

(C) $h = \dfrac{2T\cos\theta}{\rho g r}$

(D) $h = \dfrac{4T\cos\theta}{\rho g r}$

Q7. The molar specific heat at constant volume (C_V) for a diatomic ideal gas with 5 degrees of freedom is:

(A) $C_V = \frac{3}{2}R$

(B) $C_V = \frac{5}{2}R$

(C) $C_V = \frac{7}{2}R$

(D) $C_V = 3R$

Q8. From kinetic theory, the pressure exerted by an ideal gas in terms of gas density ρ and mean square speed $\overline{v^2}$ is:

(A) $P = \frac{1}{2}\rho\,\overline{v^2}$

(B) $P = \rho\,\overline{v^2}$

(C) $P = \frac{2}{3}\rho\,\overline{v^2}$

(D) $P = \frac{1}{3}\rho\,\overline{v^2}$

Q9. A particle executes SHM described by $x = A\cos(\omega t)$. Its acceleration a as a function of displacement x is:

(A) $a = -\omega^2 x$

(B) $a = +\omega^2 x$

(C) $a = -\omega\, x$

(D) $a = -\omega^2 x^2$

Q10. For a stretched string of length L, tension T, and linear mass density μ, the fundamental frequency of vibration is:

(A) $f = \frac{1}{L}\sqrt{\frac{T}{\mu}}$

(B) $f = \frac{1}{4L}\sqrt{\frac{T}{\mu}}$

(C) $f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

(D) $f = 2L\sqrt{\frac{T}{\mu}}$

Q11. Regarding the Van de Graaff generator, which of the following statements is correct?

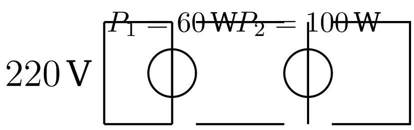
(A) Charge accumulates on the inner surface of the spherical shell; the potential is limited by breakdown of the material.

(B) Charge resides on the outer surface of the spherical shell and can be accumulated to very high potentials because charge continuously moves to the outer surface.

(C) The generator works on Faraday's law of electromagnetic induction.

(D) The maximum potential achievable is limited by the charge capacity of the belt.

Q12. Two bulbs of power $P_1 = 60\,\text{W}$ and $P_2 = 100\,\text{W}$, both rated at $220\,\text{V}$, are connected in series across a $220\,\text{V}$ supply. Which bulb glows brighter?



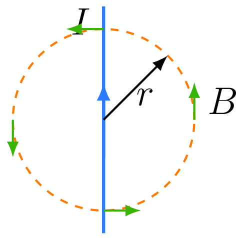
(A) Both glow equally bright.

(B) The 100 W bulb glows brighter.

(C) Neither bulb glows because the total wattage exceeds 220 V rating.

(D) The 60 W bulb glows brighter.

Q13. Using Ampère's circuital law, the magnetic field at a perpendicular distance r from a long straight wire carrying current I is:



(A) $B = \dfrac{\mu_0 I}{2\pi r}$

(B) $B = \dfrac{\mu_0 I}{4\pi r}$

(C) $B = \dfrac{\mu_0 I}{4\pi r^2}$

(D) $B = \dfrac{\mu_0 I}{2\pi r^2}$

Q14. In a step-up transformer with number of turns $N_s > N_p$ in the secondary and primary coils respectively, which statement is correct (assuming 100% efficiency)?

(A) Output voltage is lower and output current is higher.

(B) Output voltage and current are both higher than input.

(C) Output voltage is higher and output current is lower.

(D) Output voltage and current are both lower than input.

Q15. Which of the following is **NOT** a source of electromagnetic waves?

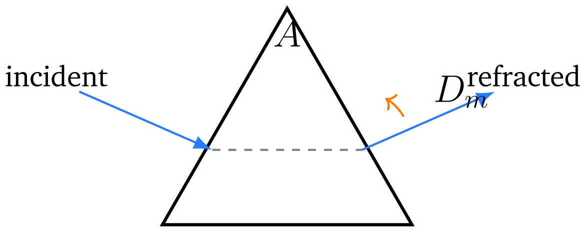
(A) An electron oscillating in an LC circuit.

(B) A stationary electric charge.

(C) An electron undergoing centripetal acceleration.

(D) An oscillating electric dipole.

Q16. A prism of apex angle A and refractive index n produces minimum deviation D_m. The relation between n, A, and D_m is:



(A) $n = \dfrac{\sin\frac{A}{2}}{\sin\frac{A+D_m}{2}}$

(B) $n = \dfrac{\cos\frac{A+D_m}{2}}{\cos\frac{A}{2}}$

(C) $n = \dfrac{\sin A}{\sin D_m}$

(D) $n = \dfrac{\sin\frac{A+D_m}{2}}{\sin\frac{A}{2}}$

Q17. In Young's Double Slit Experiment (YDSE), one of the slits is covered by a glass slab of thickness t and refractive index n. Which statement correctly describes the shift of the central bright fringe?

(A) The central bright fringe shifts toward the slit covered by the slab because the optical path through that slit increases.

(B) The central bright fringe shifts away from the slit covered by the slab.

(C) The fringe pattern disappears entirely.

(D) The central fringe remains at the centre but the fringe width changes.

Q18. In Compton scattering, X-rays scatter off a stationary electron. How does the wavelength of the scattered X-ray compare to the incident wavelength?

(A) It decreases.

(B) It remains unchanged.

(C) It increases.

(D) It may increase or decrease depending on the scattering angle.

Q19. When a parent nucleus ${}^{A}_{Z}X$ undergoes alpha decay and emits an alpha particle ${}^{4}_{2}\mathrm{He}$, the resulting daughter nucleus is:

(A) ${}^{A-2}_{Z-4}Y$

(B) ${}^{A-4}_{Z-2}Y$

(C) ${}^{A+4}_{Z+2}Y$

(D) ${}^{A-4}_{Z+2}Y$

Q20. In a common-emitter transistor amplifier configuration, the phase difference between the input signal voltage and the output voltage is:

(A) 0 (no phase difference)

(B) 90

(C) 270

(D) 180 (phase reversal)

SECTION B – Numerical Value Questions (Q21–Q30)

Attempt any 5

Q21. A bullet of mass $10\,\text{g}$ is fired horizontally at $200\,\text{m/s}$ into a wooden block of mass $990\,\text{g}$ initially at rest on a frictionless surface. The bullet embeds itself in the block. Find the common velocity (in m/s) of the bullet-block system after impact.

Q22. A block of mass $m = 4\,\text{kg}$ is moving on a horizontal floor. The coefficient of kinetic friction between the block and the floor is $\mu = 0.5$. Take $g = 10\,\text{m/s}^2$. What constant horizontal force (in N) is required to keep the block moving at constant velocity?

Q23. An object of height $5\,\text{cm}$ is placed $20\,\text{cm}$ in front of a converging lens of focal length $10\,\text{cm}$. Find the magnitude of the height of the image (in cm).

Q24. In a YDSE, the path difference at a particular point on the screen is 2.5λ. The point corresponds to which dark fringe? Enter the order (number) of the dark fringe.

Q25. Calculate the energy (in eV) required to remove the electron from the $n = 2$ level of a hydrogen atom. The ground state energy of hydrogen is -13.6 eV.

Q26. A current of 2 A flows through a conductor for 5 minutes. Calculate the total charge (in coulombs) that passes through any cross-section of the conductor.

Q27. An LC circuit consists of an inductor $L = 0.5$ H and a capacitor $C = 2\,\mu$F. Find the resonant frequency of oscillation (in Hz). Take $\pi \approx 3.14$.

Q28. Calculate the rms speed (in m/s) of nitrogen molecules ($M = 28 \times 10^{-3}$ kg/mol) at temperature $T = 300$ K. Use $R = 8.314$ J mol^{-1}K^{-1}.

Q29. Find the number of neutrons in the nucleus $^{238}_{92}$U.

Q30. In a photoelectric effect experiment, the work function of the metal is $\phi = 2.5$ eV. Light of frequency $\nu = 1.5 \times 10^{15}$ Hz is incident on the surface. Find the maximum kinetic energy (in eV) of the emitted photoelectrons. Use $h = 4.14 \times 10^{-15}$ eV $\cdot$ s.

SOLUTIONS

Sol. 1.

Solution

Concept: Free fall from rest — using kinematic equation $h = \frac{1}{2}gt^2$.

Step-by-step:

$$h = \frac{1}{2}gt^2$$
$$80 = \frac{1}{2} \times 10 \times t^2$$
$$t^2 = \frac{80 \times 2}{10} = 16$$
$$t = 4\,\text{s}$$

Why other options are wrong:

- (B) $t = 6\,\text{s}$: would give $h = \frac{1}{2}(10)(36) = 180\,\text{m} \neq 80\,\text{m}$.
- (C) $t = 8\,\text{s}$: would give $h = 320\,\text{m}$.
- (D) $t = 16\,\text{s}$: would give $h = 1280\,\text{m}$.

Answer: (A)

Sol. 2.

Solution

Concept: Rocket propulsion — Newton's 3rd law applied to variable-mass systems.

By the rocket equation, the rate of change of momentum of the exhaust gases equals the thrust on the rocket:

$$F_{thrust} = v_{rel} \cdot \left|\frac{dm}{dt}\right|$$

where v_{rel} is the speed of ejected gases relative to the rocket.

Why other options are wrong:

- (A) Factor of $\frac{1}{2}$ has no physical basis here.
- (B) v_{rel}^2 has dimensions of $\text{m}^2/\text{s}^2 \cdot \text{kg/s}$, not force.
- (D) Division instead of multiplication — dimensionally incorrect for force.

Answer: (C)

Sol. 3.

Solution

Concept: Work-energy theorem / elastic potential energy of a spring.

When a spring compressed by x is released, the elastic potential energy stored is $U = \frac{1}{2}kx^2$. This is converted entirely to kinetic energy of the block. The work done *by the spring on the block* is:

$$W_{spring \to block} = \frac{1}{2}kx^2$$

(positive, since the spring pushes the block in the direction of displacement).

Why other options are wrong:

- (A) $-\frac{1}{2}kx^2$ is the work done *on* the spring when compressing it.
- (C) kx^2 is double the correct value.
- (D) $2kx^2$ is four times too large.

Answer: (B)

Sol. 4.

Solution

Concept: A couple consists of two equal, opposite, parallel forces; its torque (moment) about any point equals $\tau = F \times d$.

For two forces $+F$ and $-F$ separated by perpendicular distance d, choose any moment point O:

$$\tau = F \cdot r_1 + F \cdot r_2 = F(r_1 + r_2) = F \cdot d$$

This result is **independent of the chosen point** O — a defining property of a couple.

Why other options are wrong:

- (A) F/d has dimensions of force per length, not torque.
- (B) $F + d$ is dimensionally inconsistent.
- (C) F^2d has dimensions of $\text{N}^2 \cdot \text{m}$, not torque.

Answer: (D)

Solution

Concept: Variation of g with depth inside Earth (uniform density model).

At depth d, only the inner sphere of radius $(R - d)$ contributes gravitational pull:

$$g_d = g \cdot \frac{R-d}{R} = g\left(1 - \frac{d}{R}\right)$$

g decreases linearly with depth and becomes zero at the centre ($d = R$).

Why other options are wrong:

Sol. 5.

- (B) g cannot increase with depth under uniform density.
- (C) Quadratic form applies to variation with altitude, not depth.
- (D) This form is for altitude above surface, not depth.

Answer: (A)

Solution

Concept: Capillary rise — equilibrium between surface tension force and weight of liquid column.

Upward force = $2\pi r T \cos\theta$. Weight of liquid column = $\pi r^2 h\rho g$.

Setting equal:

$$2\pi r T\cos\theta = \pi r^2 h\rho g \implies h = \frac{2T\cos\theta}{\rho g r}$$

Why other options are wrong:

Sol. 6.

- (A) Missing the factor of 2 in the numerator.
- (B) Has the factor of 2 in the denominator — incorrect derivation.
- (D) Factor of 4 is wrong; arises only in specific non-standard geometries.

Answer: (C)

Solution

Concept: Equipartition of energy — each degree of freedom contributes $\frac{1}{2}RT$ to molar internal energy.

For a diatomic gas ($f = 5$ degrees of freedom):

$$U = \frac{f}{2}RT = \frac{5}{2}RT \quad \Rightarrow \quad C_V = \frac{dU}{dT} = \frac{5}{2}R$$

Why other options are wrong:

Sol. 7.

- (A) $\frac{3}{2}R$ applies to monatomic gases ($f = 3$).
- (C) $\frac{7}{2}R$ applies at very high temperatures when vibrational modes are acti-

vated ($f = 7$).

- (D) $3R$ is the Dulong-Petit value for solids.

Answer: (B)

Sol. 8.

Solution

Concept: Kinetic theory derivation of pressure.

From the kinetic theory of gases, the pressure exerted by N molecules of mass m in volume V is:

$$P = \frac{1}{3}\frac{Nm}{V}\overline{v^2} = \frac{1}{3}\rho\,\overline{v^2}$$

where $\rho = Nm/V$ is the gas density and $\overline{v^2}$ is the mean square speed.

Why other options are wrong:

- (A) Factor $\frac{1}{2}$ gives $P = \frac{1}{2}\rho\overline{v^2}$ — that is the kinetic energy density, not pressure.
- (B) No fraction: $P = \rho\overline{v^2}$ overcounts by factor 3.
- (C) $\frac{2}{3}$ arises in the derivation of mean kinetic energy, not pressure directly.

Answer: (D)

Sol. 9.

Solution

Concept: Simple Harmonic Motion — relationship between acceleration and displacement.

Given $x = A\cos(\omega t)$:

$$v = \frac{dx}{dt} = -A\omega\sin(\omega t)$$
$$a = \frac{dv}{dt} = -A\omega^2\cos(\omega t) = -\omega^2 x$$

This defines SHM: acceleration is proportional to displacement and directed toward equilibrium.

Why other options are wrong:

- (B) Positive sign would imply the particle accelerates away from equilibrium — unstable, not oscillatory.
- (C) $a = -\omega x$ is dimensionally inconsistent (a has units m/s^2, ωx has units m/s).
- (D) $-\omega^2 x^2$ is not linear in x and not SHM.

Sol. 10.

Answer: (A)

Solution

Concept: Stationary waves on a stretched string — law of vibration.

For a string fixed at both ends, nodes form at both ends. In the fundamental mode, $L = \lambda/2$, so $\lambda = 2L$. The wave speed $v = \sqrt{T/\mu}$, so:

$$f = \frac{v}{\lambda} = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

Why other options are wrong:

- (A) $\frac{1}{L}\sqrt{T/\mu}$ corresponds to the second harmonic (first overtone).
- (B) $\frac{1}{4L}\sqrt{T/\mu}$ is for pipes closed at one end (quarter-wave resonator).
- (D) $2L\sqrt{T/\mu}$ is dimensionally wrong (units: m · m/s = m^2/s, not Hz).

Sol. 11.

Answer: (C)

Solution

Concept: Van de Graaff generator — electrostatic machine for generating high voltages.

The key principle is that charge deposited on the inner surface of a conductor immediately migrates to the outer surface (by Gauss's law, there is no electric field inside a conductor). The belt continuously transfers charge to the inner surface, which then moves to the outside of the large spherical shell, allowing accumulation of very large charge and high potential.

Why other options are wrong:

- (A) Charge goes to the *outer*, not inner, surface.
- (C) It operates on electrostatic induction and charge transfer, not Faraday's law of EMI.
- (D) The limiting factor is dielectric breakdown of the surrounding air (or gas), not the belt's charge capacity.

Answer: (B)

Solution

Concept: Bulbs in series — power dissipation depends on resistance.

The resistance of each bulb at rated conditions: $R = V^2/P$.

$$R_1 = \frac{(220)^2}{60} \approx 806.7\,\Omega \qquad R_2 = \frac{(220)^2}{100} = 484\,\Omega$$

In series, the same current I flows. Power dissipated: $P = I^2 R$.

Since $R_1 > R_2$, the 60 W bulb dissipates more power and glows brighter.

Why other options are wrong:

Sol. 12.

- (A) They cannot glow equally — different resistances.
- (B) The 100 W bulb has lower resistance and hence less power in series.
- (C) Both bulbs will glow; the total voltage is still 220 V, well within limits.

Answer: (D)

Solution

Concept: Ampère's Circuital Law applied to a long straight current-carrying wire.

Choose a circular Amperian loop of radius r coaxial with the wire. By symmetry, B is constant and tangential:

$$\oint \vec{B} \cdot d\vec{l} = B(2\pi r) = \mu_0 I_{enc} = \mu_0 I$$

$$\boxed{B = \frac{\mu_0 I}{2\pi r}}$$

Why other options are wrong:

Sol. 13.

- (B) $\mu_0 I/(4\pi r)$ would apply if the loop subtended half the full angle.
- (C) $1/r^2$ dependence applies to a magnetic dipole, not an infinite wire.
- (D) $1/r^2$ in the denominator is dimensionally and physically incorrect for this geometry.

Answer: (A)

Solution

Concept: Transformer — voltage and current transformation with energy conservation.

For an ideal transformer:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} > 1 \quad \Rightarrow \quad V_s > V_p$$

By energy conservation ($V_p I_p = V_s I_s$):

$$I_s = I_p \cdot \frac{V_p}{V_s} < I_p$$

So the step-up transformer increases voltage and decreases current.

Why other options are wrong:

Sol. 14.

- (A) Describes a step-down transformer.
- (B) Both cannot increase simultaneously — violates conservation of energy.
- (D) Both decreasing describes a step-down transformer.

Answer: (C)

Solution

Concept: Sources of electromagnetic waves — only *accelerating* charges radiate EM waves.

Sol. 15.

- A stationary charge creates a static electric field only — no time-varying $\vec{E}$ or $\vec{B}$, hence no radiation.
- An oscillating charge (LC circuit), a charge in circular motion, and an oscillating dipole all undergo acceleration and therefore radiate EM waves.

Why other options are wrong:

- (A) An electron oscillating in an LC circuit is accelerating — it does radiate (this is the basis of radio antennas).
- (C) Centripetal acceleration means the charge is accelerating — it radiates (synchrotron radiation).
- (D) An oscillating electric dipole has accelerating charges — it is the classical model of an antenna.

Answer: (B)

Solution

Concept: Prism formula at minimum deviation.

At minimum deviation, the ray inside the prism is parallel to the base. By geometry:

$$r = \frac{A}{2} \qquad i = \frac{A + D_m}{2}$$

Applying Snell's law at the first surface:

$$n = \frac{\sin i}{\sin r} = \frac{\sin\dfrac{A+D_m}{2}}{\sin\dfrac{A}{2}}$$

Why other options are wrong:

Sol. 16.

- (A) Inverts the ratio — gives $1/n$, the refractive index of air with respect to glass.
- (B) Uses cosine instead of sine — mathematically incorrect.
- (C) $\sin A/\sin D_m$ has no geometric basis in prism optics.

Answer: (D)

Solution

Concept: YDSE with a glass slab — optical path change.

The glass slab of thickness t and refractive index n increases the optical path through that slit by $(n-1)t$. For the central bright fringe (zero path difference), the geometric path through the *other* slit must compensate. The fringe pattern shifts toward the slit with the slab.

Why other options are wrong:

Sol. 17.

- (B) Shift is toward, not away from, the covered slit.
- (C) The fringe pattern is preserved (same coherent source), only shifted.
- (D) Fringe width $\beta = \lambda D/d$ does not depend on n of the slab; only position shifts.

Answer: (A)

Solution

Concept: Compton Effect — scattering of X-rays by free electrons.

The Compton shift formula:

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1-\cos\phi)$$

Since $\frac{h}{m_e c} > 0$ and $(1-\cos\phi) \geq 0$ for all scattering angles ϕ, we always have $\Delta\lambda \geq 0$, i.e., the scattered wavelength is **greater than or equal to** the incident wavelength.

Why other options are wrong:

Sol. 18.

- (A) Decrease would violate conservation of energy (photon cannot gain energy from a stationary electron).
- (B) Wavelength is unchanged only at $\phi = 0$ (forward scattering) — not the general case.
- (D) The shift is always non-negative; it cannot decrease.

Answer: (C)

Solution

Concept: Alpha decay — conservation of mass number and atomic number.

An alpha particle is ${}_2^4\text{He}$ (mass number 4, atomic number 2).

Conservation laws:

$$A_{daughter} = A - 4 \qquad Z_{daughter} = Z - 2$$

$${}_Z^A X \longrightarrow {}_{Z-2}^{A-4}Y + {}_2^4\text{He}$$

Why other options are wrong:

Sol. 19.

- (A) ${}_{Z-4}^{A-2}Y$: mass and charge numbers are swapped.
- (C) ${}_{Z+2}^{A+4}Y$: mass and charge increase — impossible in alpha decay.
- (D) ${}_{Z+2}^{A-4}Y$: atomic number increases — would be alpha emission in reverse sense.

Answer: (B)

Solution

Concept: Common-Emitter (CE) transistor amplifier — phase relationship.

In a CE configuration, when the base voltage increases, the collector current increases, causing a larger voltage drop across the collector resistance R_C. This *decreases* the output voltage V_{CE}. Hence, the output is inverted with respect to the input — a phase difference of 180.

Why other options are wrong:

Sol. 20.

- (A) 0: no phase difference occurs in common-base configuration, not CE.
- (B) 90: phase shift of 90° occurs in reactive networks, not in a resistive CE amplifier.
- (C) 270: equivalent to -90, not physically realised in this basic configura-

tion.

Answer: (D)

SECTION B SOLUTIONS – Numerical Value Questions

Sol. 21.

Solution

Concept: Conservation of linear momentum in a perfectly inelastic collision.

Given: $m_1 = 10\,\text{g} = 0.01\,\text{kg}$, $u_1 = 200\,\text{m/s}$; $m_2 = 990\,\text{g} = 0.99\,\text{kg}$, $u_2 = 0$.

Conservation of momentum:

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$0.01 \times 200 + 0 = (0.01 + 0.99)\,v$$

$$2 = 1.0 \times v \implies v = \mathbf{2}\,\text{m/s}$$

Answer: (2)

Sol. 22.

Solution

Concept: Kinetic friction — force required for constant velocity equals the frictional force.

Given: $m = 4\,\text{kg}$, $\mu_k = 0.5$, $g = 10\,\text{m/s}^2$.

For constant velocity, net force $= 0$, so applied force F equals kinetic friction f_k:

$$F = f_k = \mu_k \cdot mg = 0.5 \times 4 \times 10 = \mathbf{20}\,\text{N}$$

Answer: (20)

Sol. 23.

Solution

Concept: Thin lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ and magnification.

Given: $u = -20\,\text{cm}$ (sign convention: object on left), $f = +10\,\text{cm}$, $h_o = 5\,\text{cm}$.

Image position:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} + \frac{1}{-20} = \frac{2-1}{20} = \frac{1}{20} \implies v = +20\,\text{cm}$$

Magnification:

$$m = \frac{v}{u} = \frac{20}{-20} = -1$$

$$h_i = |m| \times h_o = 1 \times 5 = \mathbf{5}\,\text{cm}$$

(Image is real, inverted, same size as object.)

Answer: (5)

Sol. 24.

Solution

Concept: Condition for dark fringes in YDSE — path difference $= (2m-1)\frac{\lambda}{2}$ for mth dark fringe.

Given: Path difference $\Delta = 2.5\lambda$.

Express in the dark-fringe form:

$$2.5\lambda = \frac{5\lambda}{2} = \frac{(2\times 3 - 1)\lambda}{2}$$

This corresponds to the **3rd dark fringe** ($m = 3$).

(Alternatively: bright fringes at $\Delta = 0, \lambda, 2\lambda, 3\lambda, \ldots$; dark fringes at $\Delta = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots$ which are the 1st, 2nd, 3rd dark fringes respectively.)

Answer: (3)

Sol. 25.

Solution

Concept: Bohr model energy levels — $E_n = -13.6/n^2$ eV.

Energy of electron in $n = 2$ level:

$$E_2 = \frac{-13.6}{4} = -3.4\,\text{eV}$$

Energy required to ionise from $n = 2$ (remove electron to $E = 0$):

$$\Delta E = 0 - (-3.4) = \mathbf{3.4}\,\text{eV}$$

Answer: (3.4)

Sol. 26.

Solution

Concept: Charge and current — $Q = I \times t$.

Given: $I = 2\,\text{A}$, $t = 5\,\text{min} = 5 \times 60 = 300\,\text{s}$.

$$Q = I \times t = 2 \times 300 = \mathbf{600}\,\mathrm{C}$$

Answer: (600)

Sol. 27.

Solution

Concept: LC oscillator — resonant frequency $f = \dfrac{1}{2\pi\sqrt{LC}}$.

Given: $L = 0.5\,\mathrm{H}$, $C = 2\,\mu\mathrm{F} = 2 \times 10^{-6}\,\mathrm{F}$.

$$LC = 0.5 \times 2 \times 10^{-6} = 10^{-6}\,\mathrm{H \cdot F}$$

$$\sqrt{LC} = 10^{-3}\,\mathrm{s}$$

$$f = \frac{1}{2\pi \times 10^{-3}} = \frac{1000}{2\pi} = \frac{1000}{6.283} \approx \mathbf{159}\,\mathrm{Hz}$$

Answer: (159)

Sol. 28.

Solution

Concept: RMS speed from kinetic theory — $v_{rms} = \sqrt{3RT/M}$.

Given: $M = 28 \times 10^{-3}\,\mathrm{kg/mol}$, $T = 300\,\mathrm{K}$, $R = 8.314\,\mathrm{J\,mol^{-1}K^{-1}}$.

$$v_{rms} = \sqrt{\frac{3 \times 8.314 \times 300}{28 \times 10^{-3}}} = \sqrt{\frac{7482.6}{0.028}} = \sqrt{267235.7} \approx \mathbf{517}\,\mathrm{m/s}$$

Answer: (517)

Sol. 29.

Solution

Concept: Nuclear composition — number of neutrons $N = A - Z$.

For ${}^{238}_{92}\mathrm{U}$: mass number $A = 238$, atomic number $Z = 92$.

$$N = A - Z = 238 - 92 = \mathbf{146}$$

Answer: (146)

Sol. 30.

Solution

Concept: Photoelectric effect — Einstein's equation $KE_{max} = h\nu - \phi$.

Given: $\phi = 2.5\,$eV, $\nu = 1.5 \times 10^{15}\,$Hz, $h = 4.14 \times 10^{-15}\,$eV · s.

Energy of incident photon:

$$h\nu = 4.14 \times 10^{-15} \times 1.5 \times 10^{15} = 4.14 \times 1.5 = 6.21\,\text{eV}$$

Maximum kinetic energy:

$$KE_{max} = h\nu - \phi = 6.21 - 2.5 = \mathbf{3.71}\,\text{eV}$$

Answer: (3.71)

Answer Key – Section A (MCQs)

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	C	3	B	4	D	5	A
6	C	7	B	8	D	9	A	10	C
11	B	12	D	13	A	14	C	15	B
16	D	17	A	18	C	19	B	20	D

Answer Key – Section B (Numerical)

Q	Ans	Q	Ans
21	2	22	20
23	5	24	3
25	3.4	26	600
27	159	28	517
29	146	30	3.71