JEE Main Physics
Sample Paper – 15

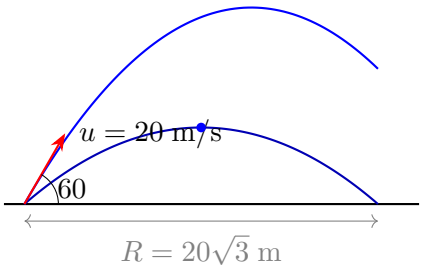
Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** contains **20 Multiple Choice Questions (MCQ)**. Each question has four options with only one correct answer. Correct answer: **+4 marks**; Wrong answer: -1 **mark**; Unattempted: **0 marks**.
- **Section B** contains **10 Numerical Value Questions (NVQ)**. Attempt any **5** questions. Correct answer: **+4 marks**; Wrong/Unattempted: **0 marks**.
- The syllabus is based on **NCERT Physics** (Class XI & XII).
- Personal calculators are **not** permitted. An on-screen virtual calculator will be provided.

SECTION A — Multiple Choice Questions (Q1–Q20)

Q1. A ball is projected from the ground with speed $u = 20$ m/s at an angle of 60 above the horizontal ($g = 10$ m/s^2). The horizontal range of the projectile is:



(A) $10\sqrt{3}$ m

(B) 20 m

(C) $20\sqrt{3}$ m

(D) 40 m

Q2. A 5 kg block is released from rest on a rough inclined plane (angle $\theta = 37$, $\sin 37 = 0.6$, $\cos 37 = 0.8$) with kinetic friction coefficient $\mu_k = 0.3$ ($g = 10$ m/s^2). The acceleration of the block down the incline is:

(A) $3.6\ \mathrm{m/s^2}$

(B) $6\ \mathrm{m/s^2}$

(C) $2.4\ \mathrm{m/s^2}$

(D) $4.8\ \mathrm{m/s^2}$

Q3. A ball of mass $0.5\ \mathrm{kg}$ slides from rest down a frictionless ramp of height $h = 5\ \mathrm{m}$ ($g = 10\ \mathrm{m/s^2}$). By conservation of energy, the speed of the ball at the bottom of the ramp is:

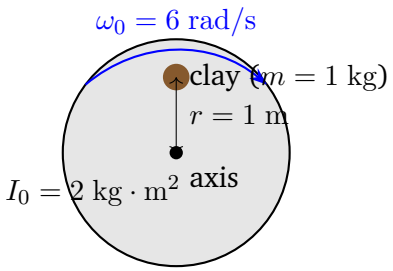
(A) $5\ \mathrm{m/s}$

(B) $7.5\ \mathrm{m/s}$

(C) $8.5\ \mathrm{m/s}$

(D) $10\ \mathrm{m/s}$

Q4. A horizontal turntable (disc) of moment of inertia $I_0 = 2\ \mathrm{kg \cdot m^2}$ spins freely at $\omega_0 = 6\ \mathrm{rad/s}$. A lump of clay of mass $m = 1\ \mathrm{kg}$ is dropped onto the disc at a radius $r = 1\ \mathrm{m}$ from the axis. By conservation of angular momentum, the new angular velocity ω of the disc-clay system is:



(A) $6\ \mathrm{rad/s}$

(B) $4\ \mathrm{rad/s}$

(C) $3\ \mathrm{rad/s}$

(D) $12\ \mathrm{rad/s}$

Q5. A planet's mean distance from the Sun is doubled (new distance $r' = 2r$). By Kepler's Third Law ($T^2 \propto r^3$), the new orbital period T' in terms of the original period T is:

(A) $2T$

(B) $4T$

(C) $2\sqrt{2}\,T$

(D) $8T$

Q6. A spring-mass system has mass $m = 2\ \text{kg}$, spring constant $k = 50\ \text{N/m}$, and amplitude of oscillation $A = 0.2\ \text{m}$. The speed of the mass at the mean position (where all energy is kinetic) is:

(A) $0.5\ \text{m/s}$

(B) $2\ \text{m/s}$

(C) $0.2\ \text{m/s}$

(D) $1\ \text{m/s}$

Q7. A steel rod of length $L_0 = 2\ \text{m}$ at 20C is heated to 120C. The coefficient of linear thermal expansion of steel is $\alpha = 12 \times 10^{-6}\ \text{C}^{-1}$. The increase in length ΔL is:

(A) $2.4\ \text{mm}$

(B) $0.24\ \text{mm}$

(C) $24\ \text{mm}$

(D) $0.024\ \text{mm}$

Q8. For an isochoric (constant-volume) process on an ideal gas, the work done **by** the gas is:

(A) $nC_p\Delta T$

(B) Zero

(C) $P\Delta V$

(D) $nC_v\Delta T$

Q9. The average translational kinetic energy of a single ideal gas molecule at temperature $T = 300\ \text{K}$ is $\frac{3}{2}k_BT$ (where $k_B = 1.38 \times 10^{-23}\ \text{J/K}$). The value in joules is approximately:

(A) $4.14 \times 10^{-21}\ \text{J}$

(B) 2.07×10^{-21} J

(C) 6.21×10^{-21} J

(D) 8.28×10^{-21} J

Q10. A pipe of length $L = 1$ m is closed at one end. The speed of sound in air is $v = 340$ m/s. The fundamental resonant frequency of the pipe is $f_1 = v/(4L) = 85$ Hz. The next resonant frequency (first overtone) for a pipe closed at one end is:

(A) 170 Hz

(B) 340 Hz

(C) 425 Hz

(D) 255 Hz

Q11. A parallel-plate capacitor of capacitance C_0 is fully charged to a voltage V by a battery (which remains connected). A dielectric slab of dielectric constant $\kappa = 4$ is then inserted between the plates. The charge stored on the capacitor:

(A) quadruples (becomes $4Q_0$)

(B) doubles

(C) halves

(D) remains unchanged

Q12. A battery has EMF $\mathcal{E} = 12$ V and internal resistance $r = 2\ \Omega$. It drives current through an external resistance $R = 4\ \Omega$. The terminal voltage (voltage across the external resistance) is:

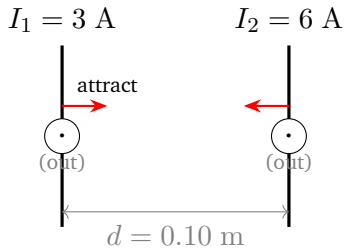
(A) 12 V

(B) 8 V

(C) 6 V

(D) 10 V

Q13. Two long parallel wires separated by $d = 0.10$ m carry currents $I_1 = 3$ A and $I_2 = 6$ A in the same direction ($\mu_0 = 4\pi \times 10^{-7}$ T $\cdot$ m/A). The force per unit length between the wires is:



(A) 1.8×10^{-5} N/m

(B) 7.2×10^{-5} N/m

(C) 3.6×10^{-5} N/m

(D) 9×10^{-5} N/m

Q14. An inductor of self-inductance $L = 0.5$ H carries a steady current $I = 4$ A. The energy stored in the magnetic field of the inductor is:

(A) 1 J

(B) 2 J

(C) 8 J

(D) 4 J

Q15. In a series LCR circuit, $R = 6\ \Omega$, $X_L = 14\ \Omega$, $X_C = 6\ \Omega$. The power factor $\cos\phi$ of the circuit is:

(A) 0.6

(B) 0.8

(C) 1.0

(D) 0.5

Q16. The refractive index of glass is $n = 1.5$. The critical angle θ_c for total internal reflection at the glass-air interface is:

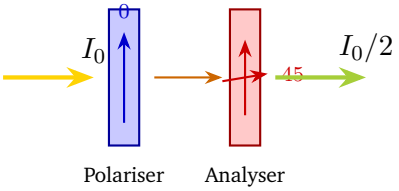
(A) 30

(B) 42

(C) 60

(D) 45

Q17. Plane-polarised light of intensity I_0 is incident on a Polaroid whose transmission axis makes an angle of 45 with the direction of polarisation. By Malus's Law, the transmitted intensity is:



(A) I_0

(B) $I_0/4$

(C) $I_0/2$

(D) $I_0/\sqrt{2}$

Q18. An X-ray tube operates at an accelerating voltage of $V = 20\ \text{kV}$. The minimum wavelength (cut-off wavelength) of the X-rays produced is ($h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s}$, $c = 3 \times 10^8\ \text{m/s}$, $e = 1.6 \times 10^{-19}\ \text{C}$):

(A) 0.62 nm

(B) 0.62 Å

(C) 0.12 nm

(D) 0.062 nm

Q19. The nucleus $^{238}_{92}\text{U}$ undergoes alpha decay. The daughter nucleus produced is:

(A) $^{234}_{90}\text{Th}$

(B) $^{234}_{91}\text{Pa}$

(C) $^{238}_{90}\text{Th}$

(D) $^{236}_{90}\text{Th}$

Q20. Arsenic (As, Group V element) is used to dope a silicon crystal. In the resulting n-type semiconductor, which statement is correct?

(A) Holes are the majority charge carriers.

(B) Electrons are the majority charge carriers.

(C) The Fermi level shifts below the centre of the bandgap.

(D) The conductivity of silicon decreases after doping.

SECTION B — Numerical Value Questions (Q21–Q30) Attempt any 5

Q21. An object of mass $m = 2\ \text{kg}$ is raised from height $h_1 = 5\ \text{m}$ to $h_2 = 10\ \text{m}$ above the ground ($g = 10\ \text{m/s}^2$). The work done against gravity (in joules) is _____.

Q22. In SHM, a system has spring constant $k = 25\ \text{N/m}$ and mass $m = 1\ \text{kg}$. The ratio of maximum acceleration to maximum velocity, equal to angular frequency $\omega = a_{\max}/v_{\max}$ (in rad/s), is _____.

Q23. In an ideal step-down transformer, the primary coil has $N_1 = 500$ turns with $V_1 = 220\ \text{V}$ and $I_1 = 2\ \text{A}$; the secondary coil has $N_2 = 50$ turns. The secondary current I_2 (in amperes) is _____.

Q24. In Young's double-slit experiment, with only one slit open, the intensity at the centre of the screen is I_0. When both slits are open (coherent equal sources), the intensity at the centre (constructive interference) is $4I_0$. The ratio of intensity with both slits open to that with only one slit open is _____.

Q25. The speed of longitudinal (compressional) waves in steel is $v = \sqrt{Y/\rho}$, where Young's modulus $Y = 2 \times 10^{11}\ \text{Pa}$ and density $\rho = 8000\ \text{kg/m}^3$. The wave speed (in m/s) is _____.

Q26. The gravitational force between Earth ($M_E = 6 \times 10^{24}\ \text{kg}$) and Moon

($M_M = 7.4 \times 10^{22}$ kg) with $r = 3.8 \times 10^8$ m and $G = 6.67 \times 10^{-11}$ N $\cdot$ m^2/kg^2. Find the force in units of 10^{20} N (round to nearest integer): _____.

Q27. In a series RLC circuit with $R = 60\ \Omega$, $X_L = 100\ \Omega$, $X_C = 20\ \Omega$, the impedance Z (in Ω) is _____.

Q28. A capacitor $C = 4\ \mu$F is charged to a voltage $V = 500$ V. The energy stored (in joules) is _____.

Q29. A body moving at $v_0 = 30$ m/s decelerates uniformly at $a = 5$ m/s^2. The distance (in metres) covered before the body comes to rest is _____.

Q30. In the Bohr model, the radius of the 3rd orbit of hydrogen is $r_n = n^2 a_0$ where $a_0 = 0.529$. The value of r_3 in angstroms is _____.

Detailed Solutions

Q1.

Solution

Topic: Kinematics — Projectile Range

The horizontal range of a projectile is given by:

$$R = \frac{u^2 \sin 2\theta}{g}$$

Here $u = 20$ m/s, $\theta = 60$, $g = 10$ m/s^2.

$$\sin 2\theta = \sin 120 = \frac{\sqrt{3}}{2}$$

$$R = \frac{(20)^2 \times \frac{\sqrt{3}}{2}}{10} = \frac{400 \times \frac{\sqrt{3}}{2}}{10} = \frac{200\sqrt{3}}{10} = 20\sqrt{3} \text{ m}$$

Answer: (C)

Q2.

Solution

Topic: Laws of Motion — Rough Inclined Plane

The net acceleration of a block sliding down a rough incline is:

$$a = g(\sin\theta - \mu_k \cos\theta)$$

$$a = 10(0.6 - 0.3 \times 0.8) = 10(0.6 - 0.24) = 10 \times 0.36 = 3.6 \text{ m/s}^2$$

Answer: (A)

Q3.

Solution

Topic: Work-Energy — Conservation of Mechanical Energy

On a frictionless ramp, potential energy converts entirely to kinetic energy:

$$mgh = \frac{1}{2}mv^2 \implies v = \sqrt{2gh}$$

$$v = \sqrt{2 \times 10 \times 5} = \sqrt{100} = 10 \text{ m/s}$$

Answer: (D)

Q4.

Solution

Topic: Rotational Motion — Conservation of Angular Momentum

When the clay drops onto the disc (no external torque), angular momentum is conserved:

$$I_0\,\omega_0 = I_{\text{new}}\,\omega$$

The new moment of inertia: $I_{\text{new}} = I_0 + mr^2 = 2 + 1 \times (1)^2 = 3\ \text{kg}\cdot\text{m}^2$

$$\omega = \frac{I_0\,\omega_0}{I_{\text{new}}} = \frac{2 \times 6}{3} = \frac{12}{3} = 4\ \text{rad/s}$$

Answer: (B)

Q5.

Solution

Topic: Gravitation — Kepler's Third Law

Kepler's Third Law: $T^2 \propto r^3$, so $T \propto r^{3/2}$.

$$\frac{T'}{T} = \left(\frac{r'}{r}\right)^{3/2} = (2)^{3/2} = 2\sqrt{2}$$

$$T' = 2\sqrt{2}\,T$$

Answer: (C)

Q6.

Solution

Topic: SHM — Maximum Speed at Mean Position

The angular frequency: $\omega = \sqrt{k/m} = \sqrt{50/2} = \sqrt{25} = 5\ \text{rad/s}$

Maximum speed (at mean position):

$$v_{\max} = \omega A = 5 \times 0.2 = 1\ \text{m/s}$$

Answer: (D)

Q7.

Solution

Topic: Properties of Matter — Linear Thermal Expansion

$$\Delta L = L_0\,\alpha\,\Delta T = 2 \times 12 \times 10^{-6} \times (120 - 20)$$

$$\Delta L = 2 \times 12 \times 10^{-6} \times 100 = 2400 \times 10^{-6}\ \text{m} = 2.4 \times 10^{-3}\ \text{m} = 2.4\ \text{mm}$$

Answer: (A)

Q8.

Solution

Topic: Thermodynamics — Isochoric (Constant-Volume) Process

Work done by a gas is $W = \int P\,dV$. In an isochoric process, volume is constant, so $dV = 0$.

$$W = P \times \Delta V = P \times 0 = 0$$

No work is done by (or on) the gas.

Answer: (B)

Q9.

Solution

Topic: Kinetic Theory — Average Translational Kinetic Energy

$$\langle KE \rangle = \frac{3}{2}k_B T = \frac{3}{2} \times 1.38 \times 10^{-23} \times 300$$

$$= \frac{3}{2} \times 4.14 \times 10^{-21} = 3 \times 2.07 \times 10^{-21} = 6.21 \times 10^{-21}\ \text{J}$$

Answer: (C)

Q10.

Solution

Topic: Waves — Harmonics of a Closed Pipe

A pipe closed at one end supports only **odd harmonics**:

$$f_n = \frac{(2n-1)v}{4L}, \quad n = 1, 2, 3, \ldots$$

Fundamental ($n = 1$): $f_1 = \dfrac{340}{4 \times 1} = 85$ Hz

First overtone ($n = 2$, i.e. 3rd harmonic):

$$f_3 = 3f_1 = 3 \times 85 = 255 \text{ Hz}$$

(Note: 170 Hz and 340 Hz are harmonics of an *open* pipe.)

Answer: (D)

Q11.

Solution

Topic: Electrostatics — Dielectric with Battery Connected

When the battery remains connected, the terminal voltage V across the capacitor is **fixed**.

$$C' = \kappa C_0 = 4C_0$$

$$Q' = C'V = 4C_0V = 4Q_0$$

The charge **quadruples**.

Answer: (A)

Q12.

Solution

Topic: Current Electricity — Terminal Voltage of a Battery

Current in the circuit:

$$I = \frac{\mathcal{E}}{R + r} = \frac{12}{4 + 2} = \frac{12}{6} = 2 \text{ A}$$

Terminal voltage (voltage across external resistance):

$$V_t = IR = 2 \times 4 = 8 \text{ V}$$

Alternatively: $V_t = \mathcal{E} - Ir = 12 - 2 \times 2 = 8$ V.

Answer: (B)

Q13.

Solution

Topic: Magnetism — Force Between Parallel Current-Carrying Wires

Force per unit length between two parallel wires:

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

$$= \frac{4\pi \times 10^{-7} \times 3 \times 6}{2\pi \times 0.10} = \frac{4\pi \times 10^{-7} \times 18}{2\pi \times 0.10} = \frac{4 \times 18 \times 10^{-7}}{2 \times 0.10} = \frac{72 \times 10^{-7}}{0.20} = 3.6 \times 10^{-5}\ \text{N/m}$$

Currents in the same direction $\Rightarrow$ force is **attractive**.

Answer: (C)

Q14.

Solution

Topic: Electromagnetic Induction — Energy Stored in an Inductor

$$U = \frac{1}{2}LI^2 = \frac{1}{2} \times 0.5 \times (4)^2 = \frac{1}{2} \times 0.5 \times 16 = 4\ \text{J}$$

Answer: (D)

Q15.

Solution

Topic: AC Circuits — Power Factor of LCR Circuit

Net reactance: $X = X_L - X_C = 14 - 6 = 8\ \Omega$

Impedance:

$$Z = \sqrt{R^2 + X^2} = \sqrt{6^2 + 8^2} = \sqrt{36 + 64} = \sqrt{100} = 10\ \Omega$$

Power factor:

$$\cos\phi = \frac{R}{Z} = \frac{6}{10} = 0.6$$

Answer: (A)

Q16.

Solution

Topic: Ray Optics — Critical Angle for Total Internal Reflection

At the critical angle, light refracts at 90 into the less dense medium (air):

$$\sin\theta_c = \frac{1}{n} = \frac{1}{1.5} = \frac{2}{3} \approx 0.6667$$

$$\theta_c = \arcsin\left(\tfrac{2}{3}\right) \approx 41.8 \approx 42$$

Answer: (B)

Q17.

Solution

Topic: Wave Optics — Malus's Law

Malus's Law: when plane-polarised light of intensity I_0 passes through a Polaroid with its transmission axis at angle θ to the polarisation direction,

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

Here $\theta = 45$:

$$I = I_0\cos^2 45 = I_0 \times \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_0}{2}$$

Answer: (C)

Q18.

Solution

Topic: Dual Nature of Radiation — Cut-off Wavelength of X-rays

The minimum (cut-off) wavelength corresponds to an electron giving *all* its kinetic energy to a single photon:

$$eV = \frac{hc}{\lambda_{\min}} \implies \lambda_{\min} = \frac{hc}{eV}$$

$$\lambda_{\min} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times20\times10^{3}} = \frac{19.89\times10^{-26}}{3.2\times10^{-15}} = 6.22\times10^{-11}\ \text{m} \approx 0.062\ \text{nm}$$

Answer: (D)

Q19.

Solution

Topic: Nuclei — Alpha Decay

In alpha (α) decay, a ${}^{4}_{2}\mathrm{He}$ nucleus is emitted:

$$ {}^{238}_{92}\mathrm{U} \longrightarrow {}^{A-4}_{Z-2}X + {}^{4}_{2}\mathrm{He} $$

$$ A' = 238 - 4 = 234, \quad Z' = 92 - 2 = 90 \implies \text{Thorium (Th)} $$

Daughter nucleus: ${}^{234}_{90}\mathrm{Th}$

Answer: (A)

Q20.

Solution

Topic: Semiconductors — n-Type Doping

Arsenic (As) belongs to Group V and has 5 valence electrons. When it replaces a silicon atom (4 valence electrons) in the crystal lattice, it contributes one **extra electron** as a free carrier (donor impurity). This makes **electrons the majority charge carriers** and the semiconductor is called **n-type**. The Fermi level shifts *toward* the conduction band (above the mid-gap), and conductivity *increases*.

Answer: (B)

Section B — Numerical Value Solutions

Q21.

Solution

Topic: Work-Energy — Work Done Against Gravity

Work done against gravity when raising a mass between two heights:

$$ W = mg(h_2 - h_1) = 2 \times 10 \times (10 - 5) = 2 \times 10 \times 5 = 100 \text{ J} $$

Answer: (100)

Q22.

Solution

Topic: SHM — Ratio of Maximum Acceleration to Maximum Velocity

Angular frequency: $\omega = \sqrt{k/m} = \sqrt{25/1} = 5$ rad/s

Maximum acceleration: $a_{\max} = \omega^2 A$

Maximum velocity: $v_{\max} = \omega A$

$$\frac{a_{\max}}{v_{\max}} = \frac{\omega^2 A}{\omega A} = \omega = 5 \text{ rad/s}$$

Answer: (5)

Q23.

Solution

Topic: AC Circuits — Ideal Transformer

For an ideal transformer, power is conserved: $V_1 I_1 = V_2 I_2$, and $\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2}$.

$$I_2 = I_1 \times \frac{N_1}{N_2} = 2 \times \frac{500}{50} = 2 \times 10 = 20 \text{ A}$$

(Alternatively: $V_2 = V_1 \times N_2/N_1 = 220 \times 50/500 = 22$ V; then $I_2 = V_1 I_1/V_2 = 440/22 = 20$ A.)

Answer: (20)

Q24.

Solution

Topic: Wave Optics — YDSE Intensity Ratio

With one slit open, intensity at centre $= I_0$.

With both slits open (coherent equal-amplitude sources), constructive interference at centre:

$$I_{\text{both}} = (A_1 + A_2)^2 = (\sqrt{I_0} + \sqrt{I_0})^2 = (2\sqrt{I_0})^2 = 4I_0$$

$$\text{Ratio} = \frac{I_{\text{both}}}{I_{\text{one}}} = \frac{4I_0}{I_0} = 4$$

Answer: (4)

Q25.

Solution

Topic: Waves — Speed of Longitudinal Waves in a Solid

$$v = \sqrt{\frac{Y}{\rho}} = \sqrt{\frac{2 \times 10^{11}}{8 \times 10^3}} = \sqrt{\frac{2 \times 10^{11}}{8 \times 10^3}} = \sqrt{2.5 \times 10^7}$$

$$= \sqrt{25 \times 10^6} = 5 \times 10^3 = 5000 \text{ m/s}$$

Answer: (5000)

Q26.

Solution

Topic: Gravitation — Gravitational Force Between Earth and Moon

$$F = \frac{GM_E M_M}{r^2} = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 7.4 \times 10^{22}}{(3.8 \times 10^8)^2}$$

Numerator: $6.67 \times 6 \times 7.4 \times 10^{-11+24+22} = 6.67 \times 6 \times 7.4 \times 10^{35}$
$= 6.67 \times 44.4 \times 10^{35} = 296.1 \times 10^{35} = 2.961 \times 10^{37}$

Denominator: $(3.8)^2 \times 10^{16} = 14.44 \times 10^{16} = 1.444 \times 10^{17}$

$$F = \frac{2.961 \times 10^{37}}{1.444 \times 10^{17}} \approx 2.05 \times 10^{20} \text{ N} \approx 2 \times 10^{20} \text{ N}$$

Answer: (2)

Q27.

Solution

Topic: AC Circuits — Impedance of Series RLC Circuit

Net reactance: $X = X_L - X_C = 100 - 20 = 80\ \Omega$

$$Z = \sqrt{R^2 + X^2} = \sqrt{(60)^2 + (80)^2} = \sqrt{3600 + 6400} = \sqrt{10000} = 100\ \Omega$$

Answer: (100)

Q28.

Solution

Topic: Electrostatics — Energy Stored in a Capacitor

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (500)^2 = \frac{1}{2} \times 4 \times 10^{-6} \times 2.5 \times 10^5 = \frac{1}{2} \times 1.0 \text{ J} = 0.5 \text{ J}$$

Answer: (0.5)

Q29.

Solution

Topic: Kinematics — Distance Under Uniform Deceleration

Using $v^2 = v_0^2 - 2as$ and $v = 0$ (body comes to rest):

$$0 = (30)^2 - 2 \times 5 \times s \implies s = \frac{900}{10} = 90 \text{ m}$$

Answer: (90)

Q30.

Solution

Topic: Atoms — Bohr Model Orbital Radius

In the Bohr model, the radius of the n-th orbit is:

$$r_n = n^2 a_0, \quad a_0 = 0.529$$

For the 3rd orbit ($n = 3$):

$$r_3 = 3^2 \times 0.529 = 9 \times 0.529 = 4.761 \approx 4.76$$

Answer: (4.76)

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

21	100	22	5
23	20	24	4
25	5000	26	2
27	100	28	0.5
29	90	30	4.76