JEE Main Physics
Sample Paper – 10

Duration: 60 Minutes | Maximum Marks: 100

Instructions

- **Section A** contains 20 Multiple Choice Questions (Q1–Q20). 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 (Q21–Q30). Attempt **any 5** questions. Correct answer: **+4** marks; Wrong or unattempted: **0** marks (no negative marking).
- The syllabus is based on Class 11 & 12 NCERT Physics as per the JEE Main official syllabus.
- Use of personal calculators, log tables, and electronic devices is strictly prohibited.
- A simple on-screen virtual calculator is provided in the CBT interface.
- Rough work may be done in the space provided within the question paper. Do not write anything on the Answer Sheet that is not required.

SECTION A (Single Correct MCQ) Q1 – Q20 [+4 / −1]

Q1. Train A travels due east at $40\ \mathrm{m/s}$ and Train B travels due west (i.e., toward Train A) at $20\ \mathrm{m/s}$ on a parallel track. The magnitude of the velocity of Train B as observed by a passenger sitting in Train A is:

(A) $60\ \mathrm{m/s}$

(B) $40\ \mathrm{m/s}$

(C) $20\ \mathrm{m/s}$

(D) $80\ \mathrm{m/s}$

Q2. A block of mass $m = 10\ \mathrm{kg}$ rests on a rough horizontal surface. The coefficient of static friction between the block and the surface is $\mu_s = 0.5$

($g = 10\ \text{m/s}^2$). The minimum horizontal force required to just start the block sliding is:

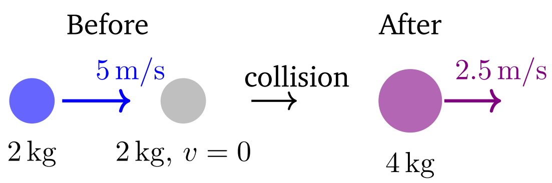
(A) 20 N

(B) 100 N

(C) 25 N

(D) 50 N

Q3. A ball of mass $2\ \text{kg}$ moving at $5\ \text{m/s}$ collides head-on with a stationary ball of mass $2\ \text{kg}$. The two balls stick together after the collision (perfectly inelastic). The kinetic energy lost in the collision is:



(A) 25 J

(B) 12.5 J

(C) 6.25 J

(D) 0 J

Q4. A disk has moment of inertia $I = 2\ \text{kg} \cdot \text{m}^2$ about its central axis. A net torque of $\tau = 6\ \text{N} \cdot \text{m}$ is applied to it. The resulting angular acceleration of the disk is:

(A) $12\ \text{rad/s}^2$

(B) $2\ \text{rad/s}^2$

(C) $3\ \text{rad/s}^2$

(D) $6\ \text{rad/s}^2$

Q5. The escape velocity from the surface of the Earth is the minimum speed an object must have to escape the Earth's gravitational pull. If g is the acceleration due to gravity at the Earth's surface and R is the Earth's radius, which of the following correctly expresses the escape velocity v_e?

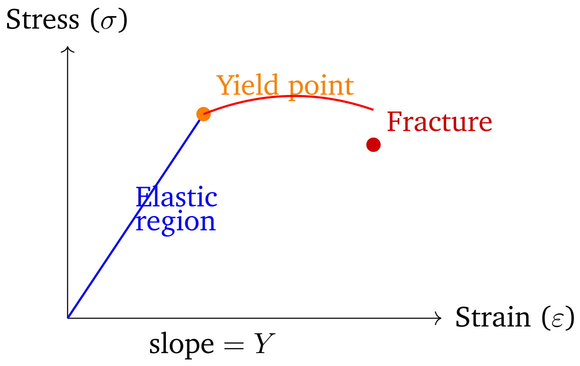
(A) $v_e = \sqrt{2gR}$

(B) $v_e = \sqrt{gR}$

(C) $v_e = 2\sqrt{gR}$

(D) $v_e = \sqrt{\dfrac{g}{R}}$

Q6. A metallic wire has Young's modulus $Y = 2 \times 10^{11}$ Pa, length $L = 2$ m and cross-sectional area $A = 1\ \text{mm}^2 = 10^{-6}\ \text{m}^2$. When a load stretches it by $\Delta L = 1$ mm, the stress developed in the wire is:



(A) 2×10^8 Pa

(B) 1×10^8 Pa

(C) 4×10^8 Pa

(D) 1×10^{11} Pa

Q7. One mole of a monatomic ideal gas undergoes an isobaric (constant pressure) process in which its temperature rises by $\Delta T = 40$ K. The molar heat capacity at constant pressure for a monatomic ideal gas is $C_p = \dfrac{5R}{2}$. The heat supplied to the gas is:

(A) $60R$

(B) $100R$

(C) $80R$

(D) $200R$

Q8. According to the kinetic theory of gases, the average translational kinetic energy of a single molecule of an ideal gas at absolute temperature T is (where k_B is the Boltzmann constant):

(A) k_BT

(B) $\frac{1}{2}k_BT$

(C) $\frac{3}{2}k_BT$

(D) $3k_BT$

Q9. A simple pendulum of length $L = 1$ m is set into oscillation at a location where $g = 10\ \text{m/s}^2$. Its time period (in seconds) is closest to:

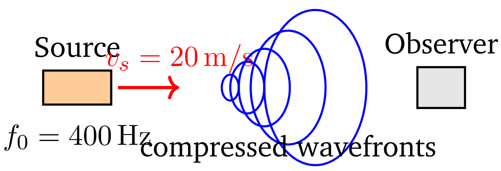
(A) $\frac{2\pi}{\sqrt{10}}\ \text{s}\ (\approx 1.99\ \text{s})$

(B) π s

(C) $2\ \pi$ s

(D) $\frac{\pi}{2}$ s

Q10. A source emitting sound at frequency $f_0 = 400$ Hz moves toward a stationary observer at speed $v_s = 20$ m/s. The speed of sound in air is $v = 340$ m/s. The frequency heard by the observer is:



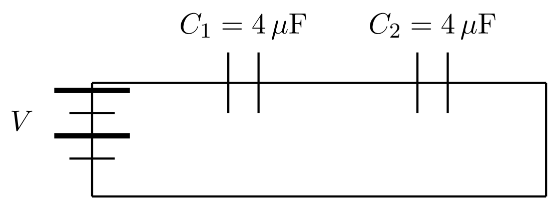
(A) 400 Hz

(B) 380 Hz

(C) 450 Hz

(D) 425 Hz

Q11. Two capacitors $C_1 = 4\ \mu$F and $C_2 = 4\ \mu$F are connected in series across a battery. The equivalent capacitance of the combination is:



(A) 8 μF

(B) 2 μF

(C) 4 μF

(D) 1 μF

Q12. In a Wheatstone bridge, the resistances in the four arms are $P = 2\ \Omega$, $Q = 4\ \Omega$, $R = 3\ \Omega$, and S is the unknown resistance. If the bridge is in the balanced condition (galvanometer reads zero), the value of S is:

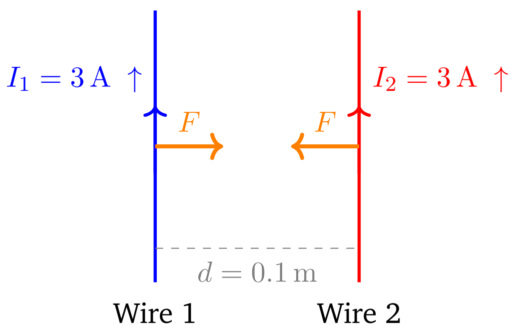
(A) 1.5 Ω

(B) 4 Ω

(C) 6 Ω

(D) 12 Ω

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



(A) $18\ \mu\text{N/m}$

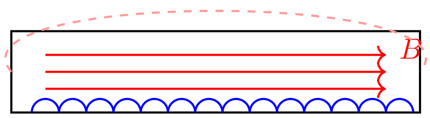
(B) $9\ \mu\text{N/m}$

(C) $36\ \mu\text{N/m}$

(D) $6\ \mu\text{N/m}$

Q14. A solenoid has $N = 1000$ turns, cross-sectional area $A = 4 \times 10^{-4}\ \text{m}^2$, and length $l = 0.2\ \text{m}$. Its self-inductance L (in mH) is ($\mu_0 = 4\pi \times 10^{-7}\ \text{H/m}$):

weak field outside



$N = 1000$ turns, $l = 0.2\ \text{m}$, $A = 4 \times 10^{-4}\ \text{m}^2$

(A) $0.4\pi\ \text{mH}$

(B) $4\pi\ \text{H}$

(C) $40\pi\ \text{mH}$

(D) $0.8\pi\ \text{mH}$

Q15. A series LCR circuit has inductance $L = 0.1\ \text{H}$ and capacitance $C = 0.1\ \text{F}$. The angular frequency at resonance ω_0 (in rad/s) is:

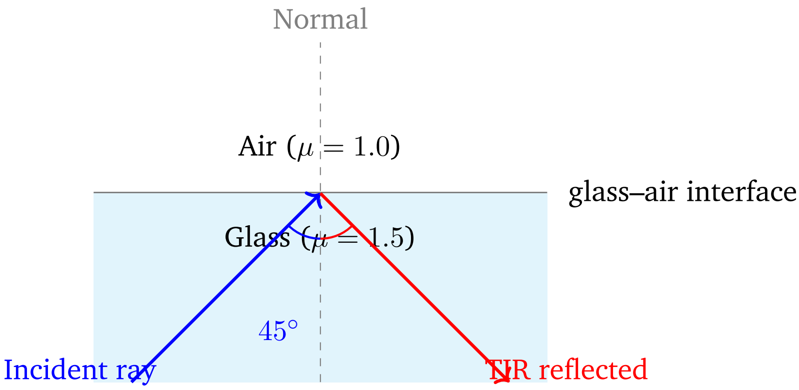
(A) $100\ \text{rad/s}$

(B) $10\ \text{rad/s}$

(C) $1\ \text{rad/s}$

(D) $\sqrt{10}\ \text{rad/s}$

Q16. A ray of light travels inside a glass medium of refractive index $\mu = 1.5$ and strikes the glass-air interface. The critical angle θ_c for this interface satisfies $\sin\theta_c = 1/\mu = 2/3$ ($\theta_c \approx 41.8°$). If the angle of incidence at the interface is $45°$, which statement is correct?



(A) The ray refracts into air with a small refraction angle.

(B) The ray passes through the interface without bending.

(C) Total internal reflection occurs; no light enters the air.

(D) The ray is partially refracted and partially reflected.

Q17. In a single-slit diffraction experiment, light of wavelength $\lambda = 500$ nm passes through a slit of width $a = 0.25$ mm. The screen is placed at $D = 1$ m from the slit. The total width of the central diffraction maximum on the screen is:

(A) 4 mm

(B) 2 mm

(C) 8 mm

(D) 1 mm

Q18. In a photoelectric experiment, the stopping potential V_s for incident light of frequency ν is related to the work function ϕ of the metal by (h = Planck's constant, e = electron charge). When the frequency is increased from ν_1 to ν_2, the stopping potential changes from V_1 to V_2. Which of the following correctly relates $V_2 - V_1$ to $\nu_2 - \nu_1$?

(A) $V_2 - V_1 = \frac{e}{h}(\nu_2 - \nu_1)$

(B) $V_2 - V_1 = \frac{\phi}{e}(\nu_2 - \nu_1)$

(C) $V_2 - V_1 = h(\nu_2 - \nu_1)$

(D) $V_2 - V_1 = \frac{h}{e}(\nu_2 - \nu_1)$

Q19. The binding energy per nucleon varies with mass number A. Among the following nuclei, which one has the **highest** binding energy per nucleon?

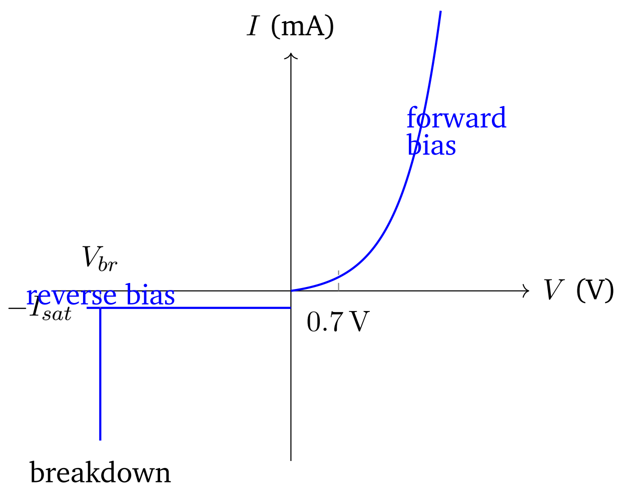
(A) ${}^{1}_{1}\mathrm{H}$ (Hydrogen)

(B) ${}^{56}_{26}\mathrm{Fe}$ (Iron)

(C) ${}^{4}_{2}\mathrm{He}$ (Helium)

(D) ${}^{235}_{92}\mathrm{U}$ (Uranium)

Q20. The current-voltage (I-V) characteristic of a p-n junction silicon diode is shown below. Which statement about the I-V characteristic is correct?



(A) In forward bias, current decreases as voltage increases.

(B) In reverse bias, large current flows immediately.

(C) In forward bias, significant current flows only after the knee voltage (≈ 0.7 V for Si).

(D) The diode obeys Ohm's law in both bias directions.

SECTION B (Numerical Value Questions)
Q21 – Q30 Attempt ANY 5 [+4 / 0]

Q21. A ball is thrown vertically upward with an initial speed $u = 30$ m/s ($g = 10$ m/s^2). Find the time (in seconds) taken by the ball to reach the maximum height.

(Enter the exact numerical value as your answer.)

Q22. A solid disk of mass $M = 2$ kg and radius $R = 0.5$ m rotates about its central axis (perpendicular to its plane). Find its moment of inertia (in $\text{kg} \cdot \text{m}^2$).

(Enter the exact numerical value as your answer.)

Q23. A block of mass 5 kg is pushed along a horizontal floor through a displacement of 4 m. The coefficient of kinetic friction between the block and floor is $\mu_k = 0.3$ ($g = 10$ m/s^2). Find the magnitude of the work done by friction on the block (in joules).

(Enter the exact numerical value as your answer.)

Q24. A satellite orbits the Earth at a height $h = R$ above the Earth's surface, where R is the Earth's radius. If $v_0 = \sqrt{GM/R}$ is the orbital speed at the surface (just above it), find the ratio v/v_0 of the orbital speed v at height $h = R$ to v_0. (Give the answer to 2 decimal places.)

(Enter the exact numerical value as your answer.)

Q25. A fixed volume of gas has pressure $P_1 = 2 \times 10^5$ Pa at temperature $T_1 = 300$ K. If the temperature is raised to $T_2 = 600$ K at the same volume (using Gay-Lussac's law), find the new pressure P_2 (in units of 10^5 Pa).

(Enter the exact numerical value as your answer.)

Q26. Two identical point charges $q = 2$ nC each are placed $d = 0.20$ m apart. Find the electric potential at the midpoint between them (in volts). (Use $k = 9 \times 10^9 \ \text{N} \cdot \text{m}^2/\text{C}^2$.)

(Enter the exact numerical value as your answer.)

Q27. A $100\ \mathrm{W}$ electric bulb is connected to a $200\ \mathrm{V}$ supply. Find the current (in amperes) through the bulb.

(Enter the exact numerical value as your answer.)

Q28. A proton (mass $m = 1.67 \times 10^{-27}\ \mathrm{kg}$, charge $q = 1.6 \times 10^{-19}\ \mathrm{C}$) moves in a uniform magnetic field $B = 0.1\ \mathrm{T}$. The cyclotron frequency $f = qB/(2\pi m)$ of the proton is approximately (in MHz). (Use $\pi \approx 3.14$.)

(Enter the answer to 2 decimal places.)

Q29. An object is placed $15\ \mathrm{cm}$ in front of a concave (converging) lens of focal length $-10\ \mathrm{cm}$ (diverging lens, so $f = -10\ \mathrm{cm}$). Using the thin lens formula $1/v - 1/u = 1/f$, find the magnitude of the image distance $|v|$ (in cm). (Take $u = -15\ \mathrm{cm}$.)

(Enter the exact numerical value as your answer.)

Q30. The mass defect of the helium nucleus ${}_{2}^{4}\mathrm{He}$ is $\Delta m = 0.0304\ \mathrm{u}$. Find the binding energy of the nucleus in MeV. (Use $1\ \mathrm{u} = 931.5\ \mathrm{MeV/c^2}$.)

(Enter the answer to 1 decimal place.)

DETAILED SOLUTIONS

Sol. Q1.

Solution

Topic: Kinematics — Relative Motion (Two Trains Approaching)

When two objects move toward each other, their relative velocity is the sum of their individual speeds (since they move in opposite directions).

Train A moves east at 40 m/s; Train B moves west at 20 m/s. Taking east as positive:

$$v_A = +40 \text{ m/s}, \qquad v_B = -20 \text{ m/s}$$

Velocity of Train B as seen by a passenger in Train A:

$$v_{B \,\text{rel}\, A} = v_B - v_A = -20 - 40 = -60 \text{ m/s}$$

The magnitude is **60** m/s (directed westward as seen from Train A).

Answer: (A)

Sol. Q2.

Solution

Topic: Laws of Motion — Minimum Force to Overcome Static Friction

The normal force on the block on a horizontal surface equals its weight:

$$N = mg = 10 \times 10 = 100 \text{ N}$$

The maximum static friction force (which must be overcome to start sliding) is:

$$F_{\text{min}} = \mu_s N = 0.5 \times 100 = \mathbf{50} \text{ N}$$

Answer: (D)

Sol. Q3.

Solution

Topic: Work-Energy Theorem — Perfectly Inelastic Collision

Before collision: Ball 1 has $KE_i = \frac{1}{2}(2)(5)^2 = 25$ J. Ball 2 is at rest.

After collision (they stick together, mass $= 4$ kg): By conservation of momentum:

$$(2)(5) + (2)(0) = (2+2)\,v_f \implies v_f = \frac{10}{4} = 2.5 \text{ m/s}$$

$$KE_f = \frac{1}{2}(4)(2.5)^2 = \frac{1}{2}(4)(6.25) = 12.5 \text{ J}$$

Kinetic energy lost:

$$\Delta KE = KE_i - KE_f = 25 - 12.5 = \mathbf{12.5} \text{ J}$$

Answer: (B)

Sol. Q4.

Solution

Topic: Rotational Motion — Newton's Second Law for Rotation

The rotational analog of Newton's second law is $\tau = I\alpha$. Solving for angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{6 \text{ N}\cdot\text{m}}{2 \text{ kg}\cdot\text{m}^2} = \mathbf{3} \text{ rad/s}^2$$

Answer: (C)

Sol. Q5.

Solution

Topic: Gravitation — Escape Velocity from Earth's Surface

Escape velocity is derived by setting the total mechanical energy equal to zero (object just barely escapes to infinity):

$$\frac{1}{2}mv_e^2 - \frac{GMm}{R} = 0 \implies v_e = \sqrt{\frac{2GM}{R}}$$

Since $g = GM/R^2$, we have $GM = gR^2$, so:

$$v_e = \sqrt{\frac{2gR^2}{R}} = \sqrt{\mathbf{2gR}}$$

Numerically, $v_e = \sqrt{2 \times 10 \times 6.4 \times 10^6} \approx 11.3 \text{ km/s}$.

Answer: (A)

Sol. Q6.

Solution

Topic: Properties of Solids — Stress in a Stretched Wire

Stress is defined as force per unit area. Using Young's modulus Y = Stress/Strain:

$$\text{Strain} = \frac{\Delta L}{L} = \frac{1 \times 10^{-3}}{2} = 5 \times 10^{-4}$$

$$\text{Stress} = Y \times \text{Strain} = 2 \times 10^{11} \times 5 \times 10^{-4} = \mathbf{1 \times 10^8}\ \text{Pa}$$

The stress-strain graph (shown in the question) is linear in the elastic region; the slope of that linear portion equals Y.

Answer: (D)

Sol. Q7.

Solution

Topic: Thermodynamics — Isobaric Heat Addition (Monatomic Gas)

For an isobaric process, the heat added to n moles of gas is $Q = nC_p\Delta T$.

For a monatomic ideal gas, $C_p = \frac{5R}{2}$.

With $n = 1$ mol and $\Delta T = 40$ K:

$$Q = 1 \times \frac{5R}{2} \times 40 = \frac{5R \times 40}{2} = \mathbf{100R}$$

Answer: (B)

Sol. Q8.

Solution

Topic: Kinetic Theory — Average Translational Kinetic Energy per Molecule

The kinetic theory of gases gives the average translational kinetic energy of a single gas molecule at temperature T as:

$$\langle KE_{\text{trans}} \rangle = \frac{3}{2} k_B T$$

This arises from the equipartition theorem: each translational degree of freedom (there are 3) contributes $\frac{1}{2} k_B T$.

At $T = 300$ K: $\langle KE \rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \times 300 \approx 6.21 \times 10^{-21}$ J.

Answer: (C)

Sol. Q9.

Solution

Topic: Oscillations — Time Period of a Simple Pendulum

The time period of a simple pendulum of length L in a gravitational field g is:

$$T = 2\pi \sqrt{\frac{L}{g}}$$

With $L = 1$ m and $g = 10$ m/s^2:

$$T = 2\pi \sqrt{\frac{1}{10}} = \frac{2\pi}{\sqrt{10}} \approx \frac{6.283}{3.162} \approx \mathbf{1.99} \text{ s} \approx \mathbf{2} \text{ s}$$

Option (A) expresses the exact answer $\dfrac{2\pi}{\sqrt{10}}$ s.

Answer: (A)

Sol. Q10.

Solution

Topic: Waves — Doppler Effect (Moving Source, Stationary Observer)

When a source moves **toward** a stationary observer, the observed frequency is higher than the source frequency. The Doppler formula is:

$$f' = f_0 \times \frac{v}{v - v_s}$$

where $v = 340\ \mathrm{m/s}$ (speed of sound) and $v_s = 20\ \mathrm{m/s}$ (speed of source):

$$f' = 400 \times \frac{340}{340 - 20} = 400 \times \frac{340}{320} = 400 \times \frac{17}{16} = \mathbf{425}\ \mathrm{Hz}$$

Answer: (D)

Sol. Q11.

Solution

Topic: Electrostatics — Capacitors in Series

For two capacitors in series, the equivalent capacitance C_{eq} is given by:

$$\frac{1}{C_{\mathrm{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = \frac{1}{2}$$

$$C_{\mathrm{eq}} = \mathbf{2}\ \mu\mathrm{F}$$

Note: For n equal capacitors of capacitance C in series, $C_{\mathrm{eq}} = C/n$; here $4/2 = 2\ \mu\mathrm{F}$.

Answer: (B)

Sol. Q12.

Solution

Topic: Current Electricity — Wheatstone Bridge Condition

The Wheatstone bridge is balanced when:

$$\frac{P}{Q} = \frac{R}{S} \implies S = \frac{Q \cdot R}{P}$$

Substituting $P = 2\ \Omega$, $Q = 4\ \Omega$, $R = 3\ \Omega$:

$$S = \frac{4 \times 3}{2} = \frac{12}{2} = \mathbf{6\ \Omega}$$

$\boxed{\textbf{Answer: (C)}}$

Sol. Q13.

Solution

Topic: Magnetic Effects of Current — Force between Parallel Wires

Two parallel wires carrying currents in the same direction attract each other. The magnitude of the force per unit length is:

$$\frac{F}{l} = \frac{\mu_0 I_1 I_2}{2\pi d} = \frac{4\pi \times 10^{-7} \times 3 \times 3}{2\pi \times 0.10}$$

$$= \frac{4\pi \times 9 \times 10^{-7}}{2\pi \times 0.10} = \frac{4 \times 9 \times 10^{-7}}{2 \times 0.10} = \frac{36 \times 10^{-7}}{0.20} = 18 \times 10^{-6}\ \mathrm{N/m} = \mathbf{18}\ \mu\mathrm{N/m}$$

The force is attractive (same-direction currents attract).

$\boxed{\textbf{Answer: (A)}}$

Sol. Q14.

Solution

Topic: Electromagnetic Induction — Self-Inductance of a Solenoid

The self-inductance of a solenoid is:

$$L = \frac{\mu_0 N^2 A}{l}$$

Substituting $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H/m}$, $N = 1000$, $A = 4 \times 10^{-4}\ \mathrm{m}^2$, $l = 0.2\ \mathrm{m}$:

$$L = \frac{4\pi \times 10^{-7} \times (1000)^2 \times 4 \times 10^{-4}}{0.2} = \frac{4\pi \times 10^{-7} \times 10^6 \times 4 \times 10^{-4}}{0.2}$$

$$= \frac{4\pi \times 4 \times 10^{-5}}{0.2} = \frac{16\pi \times 10^{-5}}{0.2} = 80\pi \times 10^{-5}\ \mathrm{H} = 8\pi \times 10^{-4}\ \mathrm{H} = \mathbf{0.8}\pi\ \mathrm{mH}$$

$\boxed{\textbf{Answer: (D)}}$

Sol. Q15.

Solution

Topic: AC Circuits — LCR Series Resonance Angular Frequency

At resonance, inductive reactance equals capacitive reactance: $\omega_0 L = 1/(\omega_0 C)$, giving:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.1 \times 0.1}} = \frac{1}{\sqrt{0.01}} = \frac{1}{0.1} = \mathbf{10}\ \mathrm{rad/s}$$

Answer: (B)

Sol. Q16.

Solution

Topic: Ray Optics — Total Internal Reflection

For glass ($\mu = 1.5$) to air interface, the critical angle θ_c satisfies:

$$\sin\theta_c = \frac{1}{\mu} = \frac{1}{1.5} = \frac{2}{3} \implies \theta_c \approx 41.8^\circ$$

The angle of incidence is 45°. Since $45^\circ > \theta_c \approx 41.8^\circ$, the condition for total internal reflection is met. The ray does **not** enter the air; it is completely reflected back into the glass.

Answer: (C)

Sol. Q17.

Solution

Topic: Wave Optics — Width of Central Maximum in Single-Slit Diffraction

The first diffraction minima occur at angles satisfying $a\sin\theta = \pm\lambda$. For small angles, the distance from the centre to the first minimum on the screen is:

$$y_1 = D \cdot \frac{\lambda}{a} = 1\ \mathrm{m} \times \frac{500 \times 10^{-9}\ \mathrm{m}}{0.25 \times 10^{-3}\ \mathrm{m}} = \frac{500 \times 10^{-9}}{2.5 \times 10^{-4}} = 2 \times 10^{-3}\ \mathrm{m} = 2\ \mathrm{mm}$$

The total width of the central maximum (between the two first minima on either side):

$$W = 2y_1 = 2 \times 2\ \mathrm{mm} = \mathbf{4}\ \mathrm{mm}$$

Answer: (A)

Sol. Q18.

Solution

Topic: Dual Nature of Radiation — Photoelectric Effect (Stopping Potential)

Einstein's photoelectric equation: $eV_s = h\nu - \phi$.

At frequency ν_1: $eV_1 = h\nu_1 - \phi$

At frequency ν_2: $eV_2 = h\nu_2 - \phi$

Subtracting the first from the second:

$$e(V_2 - V_1) = h(\nu_2 - \nu_1) \implies V_2 - V_1 = \frac{h}{e}(\nu_2 - \nu_1)$$

This shows the stopping potential increases linearly with frequency; the slope of the V_s vs ν graph is h/e.

Answer: (D)

Sol. Q19.

Solution

Topic: Nuclei — Binding Energy per Nucleon

The binding energy per nucleon (BE/A) peaks near $A \approx 56$ at approximately $8.8\ \mathrm{MeV/nucleon}$ for iron ($^{56}\mathrm{Fe}$). This peak represents the most stable configuration of nucleons.

For comparison:

- $^1_1\mathrm{H}$: $\approx 0\ \mathrm{MeV/nucleon}$ (no binding; single proton)
- $^4_2\mathrm{He}$: $\approx 7.1\ \mathrm{MeV/nucleon}$
- $^{56}_{26}\mathrm{Fe}$: $\approx 8.8\ \mathrm{MeV/nucleon}$ (maximum)
- $^{235}_{92}\mathrm{U}$: $\approx 7.6\ \mathrm{MeV/nucleon}$

Answer: (B)

Sol. Q20.

Solution

Topic: Electronic Devices — p-n Junction Diode I-V Characteristic

The p-n junction diode has an exponential I-V characteristic $I = I_0(e^{eV/k_BT} - 1)$.

In **forward bias**, negligible current flows until the forward voltage exceeds the knee voltage (≈ 0.7 V for silicon), after which current rises steeply.

In **reverse bias**, only a very small reverse saturation current (I_0, typically μA or nA) flows until breakdown voltage is reached.

Statement (C) correctly describes that in forward bias, significant current flows only after the knee voltage ≈ 0.7 V.

Answer: (C)

Sol. Q21.

Solution

Topic: Kinematics — Time to Reach Maximum Height

At maximum height, the vertical velocity becomes zero. Using $v = u - gt$ with $v = 0$:

$$t = \frac{u}{g} = \frac{30}{10} = \mathbf{3}\ \text{s}$$

Answer: (3)

Sol. Q22.

Solution

Topic: Rotational Motion — Moment of Inertia of a Solid Disk

The moment of inertia of a uniform solid disk about its central axis (perpendicular to its plane) is:

$$I = \frac{1}{2}MR^2 = \frac{1}{2} \times 2 \times (0.5)^2 = \frac{1}{2} \times 2 \times 0.25 = \mathbf{0.25}\ \text{kg} \cdot \text{m}^2$$

Answer: (0.25)

Sol. Q23.

Solution

Topic: Work-Energy Theorem — Work Done by Kinetic Friction

The kinetic friction force is $f_k = \mu_k mg = 0.3 \times 5 \times 10 = 15$ N.

Work done by friction (friction opposes motion, so work is negative):

$$W_f = -f_k \cdot d = -15 \times 4 = -60 \text{ J}$$

The magnitude of the work done by friction is **60** J.

Answer: (60)

Sol. Q24.

Solution

Topic: Gravitation — Orbital Speed at Altitude $h = R$

Orbital speed at radius r from Earth's centre: $v = \sqrt{GM/r}$.

At height $h = R$ above the surface, $r = R + h = 2R$:

$$v = \sqrt{\frac{GM}{2R}}$$

Given $v_0 = \sqrt{GM/R}$, the ratio is:

$$\frac{v}{v_0} = \sqrt{\frac{GM/(2R)}{GM/R}} = \sqrt{\frac{1}{2}} = \frac{1}{\sqrt{2}} \approx \mathbf{0.71}$$

Answer: (0.71)

Sol. Q25.

Solution

Topic: Kinetic Theory / Ideal Gas — Gay-Lussac's Law (Constant Volume)

At constant volume, pressure is proportional to absolute temperature (Gay-Lussac's Law):

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \implies P_2 = P_1 \times \frac{T_2}{T_1} = 2 \times 10^5 \times \frac{600}{300} = 2 \times 10^5 \times 2 = 4 \times 10^5 \text{ Pa}$$

In units of 10^5 Pa, the answer is **4**.

Answer: (4)

Sol. Q26.

Solution

Topic: Electrostatics — Electric Potential at Midpoint between Two Charges

Each charge $q = 2\ \mathrm{nC} = 2 \times 10^{-9}\ \mathrm{C}$ is at distance $r = d/2 = 0.10\ \mathrm{m}$ from the midpoint.

Electric potential is a scalar; the total potential at the midpoint is the sum of the potentials due to each charge:

$$V = 2 \times \frac{kq}{r} = 2 \times \frac{9 \times 10^9 \times 2 \times 10^{-9}}{0.10} = 2 \times \frac{18}{0.10} = 2 \times 180 = \mathbf{360}\ \mathrm{V}$$

Answer: (360)

Sol. Q27.

Solution

Topic: Current Electricity — Current through a Bulb (Power and Voltage)

Using the relation $P = VI$:

$$I = \frac{P}{V} = \frac{100\ \mathrm{W}}{200\ \mathrm{V}} = \mathbf{0.5}\ \mathrm{A}$$

Answer: (0.5)

Sol. Q28.

Solution

Topic: Magnetic Effects — Cyclotron Frequency of a Proton

The cyclotron frequency is:

$$f = \frac{qB}{2\pi m} = \frac{1.6 \times 10^{-19} \times 0.1}{2 \times 3.14 \times 1.67 \times 10^{-27}} = \frac{1.6 \times 10^{-20}}{1.04836 \times 10^{-26}}$$

$$= \frac{1.6}{1.04836} \times 10^6\ \mathrm{Hz} \approx 1.526 \times 10^6\ \mathrm{Hz} \approx \mathbf{1.52}\ \mathrm{MHz}$$

Answer: (1.52)

Sol. Q29.

Solution

Topic: Ray Optics — Image Formation by a Diverging Lens

Using the thin lens formula (with sign convention $u = -15$ cm, $f = -10$ cm):

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-10} + \frac{1}{-15} = -\frac{1}{10} - \frac{1}{15} = -\frac{3}{30} - \frac{2}{30} = -\frac{5}{30} = -\frac{1}{6}$$

$$v = -6 \text{ cm}$$

The image is virtual, erect, and on the same side as the object. The magnitude $|v| = \mathbf{6}$ cm.

Answer: (6)

Sol. Q30.

Solution

Topic: Nuclei — Binding Energy from Mass Defect

The binding energy is calculated from the mass defect using Einstein's mass-energy relation:

$$E_b = \Delta m \times 931.5 \text{ MeV/u} = 0.0304 \times 931.5$$

$$= 0.0304 \times 931.5 = 28.3176 \approx \mathbf{28.3} \text{ MeV}$$

This is the total binding energy of ${}^4_2\text{He}$ (helium-4), corresponding to a binding energy per nucleon of $28.3/4 \approx 7.1$ MeV/nucleon.

Answer: (28.3)

ANSWER KEY

Section A — MCQ Answer Key

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

Section B — Numerical Answer Key

Q	Ans	Q	Ans
21	3	22	0.25
23	60	24	0.71
25	4	26	360
27	0.5	28	1.52
29	6	30	28.3