JEE Main Physics Sample Paper – 14

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**; no negative marking.
- The paper is based on the **NCERT Physics syllabus** for JEE Main.
- Personal calculators are **not permitted**. An on-screen virtual calculator is provided.

SECTION A — Multiple Choice Questions (Q1–Q20)

Q1. A body starts from rest and accelerates uniformly at $a = 5\ \text{m/s}^2$. The distance covered in the 4^{th} second of motion is (using $s_n = u + a(2n - 1)/2$):

(A) 17.5 m

(B) 15 m

(C) 20 m

(D) 10 m

Q2. A block of mass $m = 10\ \text{kg}$ rests on a rough horizontal surface with coefficient of static friction $\mu_s = 0.4$ ($g = 10\ \text{m/s}^2$). The minimum horizontal force required to just start moving the block is:

(A) 10 N

(B) 20 N

(C) 40 N

(D) 80 N

Q3. A ball of mass 0.5 kg moving at 4 m/s collides with and sticks to a stationary ball of mass 1.5 kg on a frictionless surface. The kinetic energy of the combined mass after the collision is:

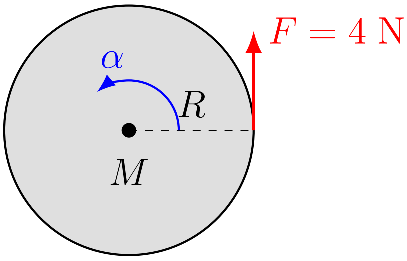
(A) 4 J

(B) 3 J

(C) 2 J

(D) 1 J

Q4. A disc of mass $M = 2$ kg and radius $R = 0.5$ m (moment of inertia $I = MR^2/2$) has a tangential force $F = 4$ N applied at its rim. The angular acceleration of the disc is:



(A) 4 rad/s^2

(B) 8 rad/s^2

(C) 16 rad/s^2

(D) 2 rad/s^2

Q5. A satellite orbits Earth just above its surface (orbital radius $\approx R_E = 6400$ km, $g = 10$ m/s^2). The orbital speed of this satellite is approximately:

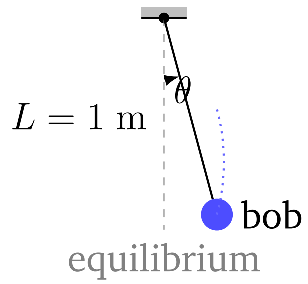
(A) 8 km/s

(B) 4 km/s

(C) 11.2 km/s

(D) 16 km/s

Q6. A simple pendulum of length $L = 1$ m oscillates with small amplitude ($g = 10$ m/s^2, use $\pi^2 \approx 10$). The time period T is:



(A) 1 s

(B) π s

(C) 4 s

(D) 2 s

Q7. Water flows through a horizontal pipe. At a wide section with cross-sectional area $A_1 = 4\ \mathrm{cm}^2$, the speed is $v_1 = 2\ \mathrm{m/s}$. At a narrow section with area $A_2 = 1\ \mathrm{cm}^2$, the speed v_2 (by the equation of continuity) is:

(A) 2 m/s

(B) 4 m/s

(C) 8 m/s

(D) 16 m/s

Q8. A Carnot engine operates between a hot reservoir at $T_H = 800\ \mathrm{K}$ and a cold reservoir at $T_C = 400\ \mathrm{K}$. The efficiency of this ideal engine is:

(A) 25%

(B) 50%

(C) 75%

(D) 40%

Q9. For a diatomic ideal gas (e.g., $\mathrm{N_2}$ or $\mathrm{O_2}$) at room temperature ($f = 5$ degrees of freedom), the ratio of specific heats $\gamma = C_p/C_v$ is:

(A) 1.4

(B) 1.67

(C) 1.0

(D) 2.0

Q10. A source emitting sound at frequency $f_0 = 500$ Hz moves **toward** a stationary observer at speed $v_s = 34$ m/s. Speed of sound $v = 340$ m/s. The frequency heard by the observer is:

(A) 450 Hz

(B) 500 Hz

(C) 556 Hz

(D) 600 Hz

Q11. An electric dipole consists of charges $+q = +2\ \mu\text{C}$ and $-q = -2\ \mu\text{C}$ separated by a distance $d = 4$ cm. The electric dipole moment p is:

(A) $2 \times 10^{-6}\ \text{C} \cdot \text{m}$

(B) $4 \times 10^{-8}\ \text{C} \cdot \text{m}$

(C) $2 \times 10^{-8}\ \text{C} \cdot \text{m}$

(D) $8 \times 10^{-8}\ \text{C} \cdot \text{m}$

Q12. In a balanced Wheatstone bridge, $P = 2\ \Omega$, $Q = 4\ \Omega$, $R = 3\ \Omega$. The unknown resistance S for which the bridge is balanced ($P/Q = R/S$) is:

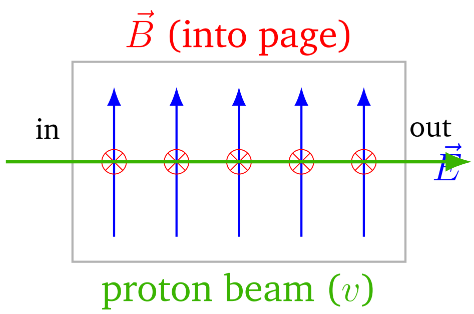
(A) 3 Ω

(B) 6 Ω

(C) 12 Ω

(D) 1.5 Ω

Q13. A proton enters a region with mutually perpendicular electric field $E = 2 \times 10^4$ V/m and magnetic field $B = 0.2$ T (velocity selector). For the proton to pass through undeflected, its velocity must be:



(A) 10^4 m/s

(B) 2×10^5 m/s

(C) 10^5 m/s

(D) 4×10^5 m/s

Q14. A coil of $N = 200$ turns has the magnetic flux through it change from $\Phi_1 = 0.05$ Wb to $\Phi_2 = 0.01$ Wb in $\Delta t = 0.2$ s. The magnitude of the induced EMF is:

(A) 40 V

(B) 20 V

(C) 80 V

(D) 8 V

Q15. In a series LCR circuit with $L = 0.5$ H, $C = 50\ \mu$F $= 50 \times 10^{-6}$ F, the angular frequency at resonance $\omega_0 = 1/\sqrt{LC}$ is:

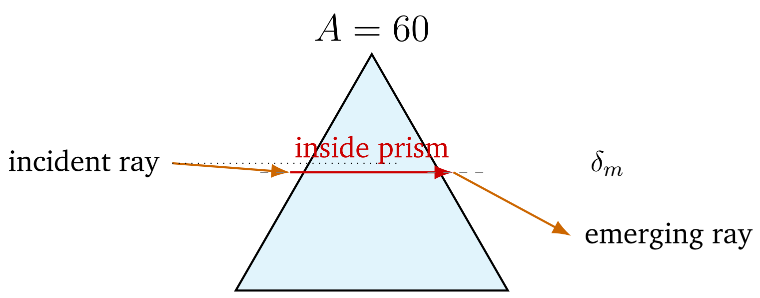
(A) 100 rad/s

(B) 400 rad/s

(C) 50 rad/s

(D) 200 rad/s

Q16. A glass prism of apex angle $A = 60$ and refractive index $n = 1.5$ is used in the position of minimum deviation. At minimum deviation, the refracted ray inside the prism makes equal angles with both faces. The angle of minimum deviation δ_m satisfies $\sin\left(\frac{A + \delta_m}{2}\right) = n \sin\left(\frac{A}{2}\right)$. The value of δ_m is approximately:



(A) 30°

(B) 37°

(C) 45°

(D) 60°

Q17. Unpolarised light of intensity I_0 passes through two ideal Polaroid sheets. The transmission axes of the two Polaroids are at 60 to each other. The intensity of light emerging from the second Polaroid is:

(A) $I_0/2$

(B) $I_0/4$

(C) $I_0/8$

(D) $I_0/16$

Q18. A proton ($m_p = 1.67 \times 10^{-27}$ kg) moves with speed $v = 10^6$ m/s. Its de Broglie wavelength $\lambda = h/(m_p v)$ (use $h = 6.63 \times 10^{-34}$ J $\cdot$ s) is approximately:

(A) 4×10^{-13} m

(B) 4×10^{-7} m

(C) 4×10^{-10} m

(D) 4×10^{-16} m

Q19. The ground-state energy of the hydrogen atom is -13.6 eV. The energy required to excite the electron from the $n = 2$ orbit to the $n = 3$ orbit is:

(A) 3.4 eV

(B) 13.6 eV

(C) 10.2 eV

(D) 1.9 eV

Q20. In a common-emitter transistor amplifier, the current gain $\beta = 100$. If the base current changes by $\Delta I_B = 0.02\ \mathrm{mA}$, the resulting change in the collector current ΔI_C is:

(A) 0.02 mA

(B) 2 mA

(C) 0.2 mA

(D) 20 mA

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

Q21. A block of mass $5\ \mathrm{kg}$ slides from rest down a smooth (frictionless) inclined plane making an angle of 30 with the horizontal ($g = 10\ \mathrm{m/s^2}$). The acceleration of the block (in m/s^2) is:

Q22. A wire of resistance $R = 10\ \Omega$ is uniformly stretched to double its original length (volume remains constant). The new resistance (in Ω) is:

Q23. A capacitor $C = 5\ \mu\mathrm{F}$ is charged and then discharged through a resistor $R = 20\ \Omega$. The time constant $\tau = RC$ in microseconds (μs) is:

Q24. The magnetic flux through a coil of $N = 50$ turns changes from $\Phi_1 = 0.02\ \mathrm{Wb}$ to $\Phi_2 = 0.08\ \mathrm{Wb}$ in $\Delta t = 0.1\ \mathrm{s}$. The induced EMF (in V) is:

Q25. The speed of light is $c = 3 \times 10^8\ \mathrm{m/s}$. The wavelength (in nm) of a photon of frequency $\nu = 6 \times 10^{14}$ Hz is:

Q26. An alpha particle (charge $2e$, where $e = 1.6 \times 10^{-19}$ C) is accelerated through a potential difference of $V = 1000\ \mathrm{V}$. The kinetic energy gained (in keV) is:

Q27. Two coherent sources have intensities in the ratio $I_1 : I_2 = 4 : 1$. The ratio of maximum intensity to minimum intensity in the interference pattern is:

Q28. In the Bohr model of the hydrogen atom, the maximum number of spectral lines that can be emitted when atoms are excited to the $n = 4$ energy level is (considering all possible transitions to lower levels):

Q29. A magnifying glass (convex lens, $f = 25$ cm) is used to view an object placed 15 cm from the lens ($u = -15$ cm). Using the lens formula $1/v - 1/u = 1/f$, the lateral magnification $m = v/u$ (magnitude) is:

Q30. In a Young's double-slit experiment, the slit separation $d = 0.2$ mm, screen distance $D = 1$ m, and wavelength $\lambda = 400$ nm. The fringe width β (in mm) is:

Solutions

SECTION A — Solutions (Q1–Q20)

Solution

Q1. Distance covered in the n^{th} second for uniform acceleration from rest:

$$s_n = u + a\,\frac{2n-1}{2} = 0 + 5 \times \frac{2(4)-1}{2} = 5 \times \frac{7}{2} = 17.5\ \text{m}$$

Answer: (A)

Solution

Q2. The maximum static friction force (which must be overcome to start motion) is:

$$F = \mu_s\, mg = 0.4 \times 10 \times 10 = 40\ \text{N}$$

Answer: (C)

Solution

Q3. By conservation of momentum in a perfectly inelastic collision:

$$v = \frac{m_1 v_1}{m_1 + m_2} = \frac{0.5 \times 4}{0.5 + 1.5} = \frac{2}{2} = 1\ \text{m/s}$$

Kinetic energy of combined mass:

$$KE = \tfrac{1}{2}(m_1 + m_2)v^2 = \tfrac{1}{2} \times 2 \times 1^2 = 1\ \text{J}$$

Answer: (D)

Solution

Q4. Torque produced by the tangential force:

$$\tau = F \times R = 4 \times 0.5 = 2\ \text{N} \cdot \text{m}$$

Moment of inertia of the disc:

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

Angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{2}{0.25} = 8 \text{ rad/s}^2$$

Answer: (B)

Solution

Q5. For a satellite orbiting just above Earth's surface, gravitational force provides centripetal force:

$$v_o = \sqrt{gR_E} = \sqrt{10 \times 6.4 \times 10^6} = \sqrt{6.4 \times 10^7} \approx 8000 \text{ m/s} = 8 \text{ km/s}$$

Answer: (A)

Solution

Q6. Time period of a simple pendulum:

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1}{10}} = \frac{2\pi}{\sqrt{10}}$$

Since $\pi^2 \approx 10$, we have $\sqrt{10} = \pi$, so:

$$T = \frac{2\pi}{\pi} = 2 \text{ s}$$

Answer: (D)

Solution

Q7. By the equation of continuity for an incompressible fluid:

$$A_1 v_1 = A_2 v_2 \implies v_2 = \frac{A_1 v_1}{A_2} = \frac{4 \times 2}{1} = 8 \text{ m/s}$$

Answer: (C)

Solution

Q8. Efficiency of a Carnot engine:

$$\eta = 1 - \frac{T_C}{T_H} = 1 - \frac{400}{800} = 1 - 0.5 = 0.5 = 50\%$$

Answer: (B)

Solution

Q9. For a diatomic ideal gas with $f = 5$ degrees of freedom:

$$\gamma = \frac{C_p}{C_v} = \frac{f+2}{f} = \frac{5+2}{5} = \frac{7}{5} = 1.4$$

Answer: (A)

Solution

Q10. When the source moves toward a stationary observer, the Doppler formula gives:

$$f' = f_0 \cdot \frac{v}{v - v_s} = 500 \times \frac{340}{340 - 34} = 500 \times \frac{340}{306} \approx 500 \times 1.111 \approx 556 \text{ Hz}$$

Answer: (C)

Solution

Q11. The electric dipole moment is defined as $p = q \cdot d$:

$$p = 2 \times 10^{-6} \text{ C} \times 4 \times 10^{-2} \text{ m} = 8 \times 10^{-8} \text{ C} \cdot \text{m}$$

Answer: (D)

Solution

Q12. Balanced Wheatstone bridge condition: $\frac{P}{Q} = \frac{R}{S}$

$$S = \frac{Q \cdot R}{P} = \frac{4 \times 3}{2} = \frac{12}{2} = 6\,\Omega$$

Answer: (B)

Solution

Q13. In a velocity selector, the electric force balances the magnetic force for undeflected motion:

$$qE = qvB \implies v = \frac{E}{B} = \frac{2 \times 10^4 \text{ V/m}}{0.2 \text{ T}} = 10^5 \text{ m/s}$$

Answer: (C)

Solution

Q14. By Faraday's law, the magnitude of the induced EMF is:

$$\varepsilon = N\left|\frac{\Delta\Phi}{\Delta t}\right| = 200 \times \frac{|0.05 - 0.01|}{0.2} = 200 \times \frac{0.04}{0.2} = 200 \times 0.2 = 40 \text{ V}$$

Answer: (A)

Solution

Q15. The angular frequency at resonance in a series LCR circuit:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.5 \times 50 \times 10^{-6}}} = \frac{1}{\sqrt{25 \times 10^{-6}}} = \frac{1}{5 \times 10^{-3}} = 200 \text{ rad/s}$$

Answer: (D)

Solution

Q16. At minimum deviation, applying the prism formula:

$$\sin\left(\frac{A + \delta_m}{2}\right) = n \sin\left(\frac{A}{2}\right) = 1.5 \times \sin 30 = 1.5 \times 0.5 = 0.75$$

$$\frac{A + \delta_m}{2} = \sin^{-1}(0.75) \approx 48.59$$

$$A + \delta_m \approx 97.18 \implies \delta_m \approx 97.18 - 60 \approx 37$$

Answer: (B)

Solution

Q17. After the first Polaroid, the intensity of unpolarised light is halved:

$$I_1 = \frac{I_0}{2}$$

By Malus's law, after the second Polaroid (at 60 to the first):

$$I_2 = I_1 \cos^2 60 = \frac{I_0}{2} \times \left(\frac{1}{2}\right)^2 = \frac{I_0}{2} \times \frac{1}{4} = \frac{I_0}{8}$$

Answer: (C)

Solution

Q18. De Broglie wavelength of the proton:

$$\lambda = \frac{h}{m_p v} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 10^6} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-21}} \approx 3.97 \times 10^{-13}\ \text{m} \approx 4 \times 10^{-13}\ \text{m}$$

Answer: (A)

Solution

Q19. Energy of the hydrogen atom at quantum number n: $E_n = -13.6/n^2$ eV

$$E_2 = -\frac{13.6}{4} = -3.4\ \text{eV}, \qquad E_3 = -\frac{13.6}{9} \approx -1.511\ \text{eV}$$

Energy required for excitation from $n = 2$ to $n = 3$:

$$\Delta E = E_3 - E_2 = -1.511 - (-3.4) = 1.889 \approx 1.9\ \text{eV}$$

Answer: (D)

Solution

Q20. In a common-emitter amplifier, the relationship between collector and base current changes:

$$\Delta I_C = \beta \cdot \Delta I_B = 100 \times 0.02\ \text{mA} = 2\ \text{mA}$$

Answer: (B)

SECTION B — Solutions (Q21–Q30)

Solution

Q21. For a block on a smooth inclined plane, the net force along the plane is $mg\sin\theta$:

$$a = g\sin 30 = 10 \times 0.5 = 5 \text{ m/s}^2$$

Answer: (5)

Solution

Q22. When the wire is stretched to double its length, volume is conserved: $A' = A/2$, $L' = 2L$.

New resistance:

$$R' = \rho\frac{L'}{A'} = \rho\frac{2L}{A/2} = 4\rho\frac{L}{A} = 4R = 4 \times 10 = 40\ \Omega$$

Answer: (40)

Solution

Q23. The RC time constant:

$$\tau = RC = 20\ \Omega \times 5 \times 10^{-6}\text{ F} = 10^{-4}\text{ s} = 100\ \mu\text{s}$$

Answer: (100)

Solution

Q24. By Faraday's law:

$$\varepsilon = N\left|\frac{\Delta\Phi}{\Delta t}\right| = 50 \times \frac{|0.08 - 0.02|}{0.1} = 50 \times \frac{0.06}{0.1} = 50 \times 0.6 = 30 \text{ V}$$

Answer: (30)

Solution

Q25. Wavelength of light from its frequency:

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8 \text{ m/s}}{6 \times 10^{14} \text{ Hz}} = 5 \times 10^{-7} \text{ m} = 500 \text{ nm}$$

Answer: (500)

Solution

Q26. Kinetic energy gained by an alpha particle (charge $q = 2e$) through potential difference V:

$$KE = qV = 2e \times 1000 \text{ V} = 2000 \text{ eV} = 2 \text{ keV}$$

Answer: (2)

Solution

Q27. Let $\sqrt{I_1} = 2k$ and $\sqrt{I_2} = k$ (since $I_1 : I_2 = 4 : 1$).

$$\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2} = \frac{(2+1)^2}{(2-1)^2} = \frac{9}{1} = 9$$

Answer: (9)

Solution

Q28. The maximum number of spectral lines emitted when atoms de-excite from level n is:

$$N_{\text{lines}} = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$$

These correspond to transitions: $4 \to 3$, $4 \to 2$, $4 \to 1$, $3 \to 2$, $3 \to 1$, $2 \to 1$.

Answer: (6)

Solution

Q29. Using the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ with $u = -15$ cm and $f = 25$ cm:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{25} + \frac{1}{-15} = \frac{3}{75} - \frac{5}{75} = -\frac{2}{75}$$

$$v = -37.5 \text{ cm}$$

Lateral magnification (magnitude):

$$|m| = \left|\frac{v}{u}\right| = \frac{37.5}{15} = 2.5$$

Answer: (2.5)

Solution

Q30. Fringe width in Young's double-slit experiment:

$$\beta = \frac{\lambda D}{d} = \frac{400 \times 10^{-9} \text{ m} \times 1 \text{ m}}{0.2 \times 10^{-3} \text{ m}} = \frac{4 \times 10^{-7}}{2 \times 10^{-4}} = 2 \times 10^{-3} \text{ m} = 2 \text{ mm}$$

Answer: (2)

Answer Key — Section A (MCQ)

Q No.	Answer	Q No.	Answer	Q No.					
1	A	2	C	3	D	4	B	5	A
6	D	7	C	8	B	9	A	10	C
11	D	12	B	13	C	14	A	15	D
16	B	17	C	18	A	19	D	20	B

Answer Key — Section B (Numerical)

Q No.	Answer	Q No.	Answer
21	5	22	40
23	100	24	30
25	500	26	2
27	9	28	6
29	2.5	30	2