JEE Main — Physics Sample Paper 3

Collegedunia Test Series | Class 11 & 12 NCERT Syllabus

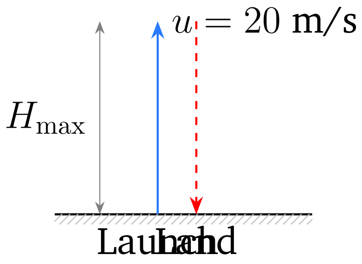
Duration: 60 min **Max Marks:** 100 **Section A:** Q1–Q20 (MCQ) **Section B:** Q21–Q30 (Numerica

Instructions

- **Section A** (Q1–Q20): Single Correct MCQ. **+4** for correct, **−1** for incorrect, **0** for unattempted.
- **Section B** (Q21–Q30): Numerical Value Questions. Attempt **any 5**. **+4** for correct, **0** for incorrect/unattempted.
- Use of calculators is **not** permitted. Take $g = 10$ m/s^2 unless stated otherwise.
- Constants: $h = 6.63 \times 10^{-34}$ J·s, $c = 3 \times 10^8$ m/s, $e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $m_p = 1.67 \times 10^{-27}$ kg, $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m, $\mu_0 = 4\pi \times 10^{-7}$ T·m/A, $R = 8.31$ J/(mol·K), $N_A = 6.02 \times 10^{23}$ mol^{-1}.

SECTION A — Single Correct MCQ (+4 / −1)

Q1. A ball is thrown **vertically upward** from the ground with an initial speed $u = 20$ m/s. Neglecting air resistance and taking $g = 10$ m/s^2, what is the **total time of flight** (the time the ball takes to return to the ground)?



(A) 2 s

(B) 3 s

(C) 4 s

(D) 5 s

Q2. A coin rests on the horizontal dashboard of a car that is accelerating forward at $a = 5$ m/s^2. What is the **minimum coefficient of static friction** (μ_s) required to prevent the coin from sliding?

(A) 0.2

(B) 0.3

(C) 0.4

(D) 0.5

Q3. A machine delivers **constant power** P to a body of mass m that starts from rest. Assuming no energy loss, the speed v of the body after time t is proportional to:

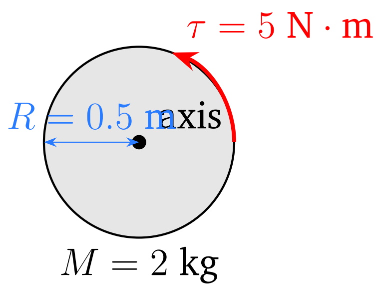
(A) $\sqrt{t}$

(B) t

(C) t^2

(D) $t^{3/2}$

Q4. A uniform disc of mass $M = 2$ kg and radius $R = 0.5$ m is free to rotate about its central axis. A net torque $\tau = 5$ N $\cdot$ m is applied to it. What is the **angular acceleration** of the disc?



(A) 10 rad/s^2

(B) 20 rad/s^2

(C) 40 rad/s^2

(D) 5 rad/s^2

Q5. A planet orbits the Sun at an orbital radius $r_2 = 4r_1$, where r_1 is Earth's orbital radius. Earth's orbital period is $T_1 = 1$ year. Using Kepler's Third Law ($T^2 \propto r^3$), the orbital period T_2 of the planet is:

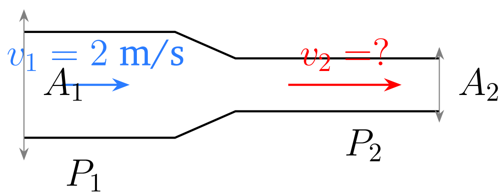
(A) 4 years

(B) 2 years

(C) 8 years

(D) 16 years

Q6. Water ($\rho = 1000$ kg/m^3) flows horizontally through a pipe whose cross-section narrows from $A_1 = 4$ cm^2 to $A_2 = 1$ cm^2. The velocity in the wider section is $v_1 = 2$ m/s. What is the **pressure difference** $(P_1 - P_2)$ between the two sections?



(A) 15 kPa

(B) 20 kPa

(C) 10 kPa

(D) 30 kPa

Q7. One mole of an ideal gas undergoes **isothermal expansion** at $T = 300$ K from volume $V_1 = 1$ L to $V_2 = 2$ L. The work done by the gas is approximately ($\ln 2 \approx 0.693$, $R = 8.31$ J/(mol $\cdot$ K)):

(A) 1.73 kJ

(B) 2.49 kJ

(C) 0.83 kJ

(D) 3.46 kJ

Q8. A particle in SHM has displacement $x = A\sin(\omega t + \varphi)$. At $t = 0$, the displacement is $x_0 = A/2$ and the velocity is **positive** (the particle is moving toward positive maximum). The initial phase φ is:

(A) $\frac{\pi}{3}$

(B) $\frac{\pi}{6}$

(C) $\frac{\pi}{4}$

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

Q9. A **closed organ pipe** (closed at one end) vibrates with fundamental frequency f. Which of the following frequencies is **absent** in its harmonic spectrum?

(A) f

(B) $3f$

(C) $4f$

(D) $5f$

Q10. A thin spherical shell of radius R carries a total charge Q uniformly distributed over its surface. The electric field at a point $r = R/2$ (inside the shell) is:

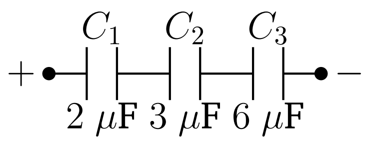
(A) $\frac{kQ}{R^2}$

(B) $\frac{2kQ}{R^2}$

(C) $\frac{kQ}{4R^2}$

(D) Zero

Q11. Three capacitors $C_1 = 2\ \mu$F, $C_2 = 3\ \mu$F, and $C_3 = 6\ \mu$F are connected in **series**. What is the equivalent capacitance?



(A) 1 μF

(B) 11 μF

(C) 2 μF

(D) 3 μF

Q12. A battery of EMF $\varepsilon = 12$ V and internal resistance $r = 2\ \Omega$ is connected to an external resistance $R = 4\ \Omega$. What is the **terminal voltage** across the battery?

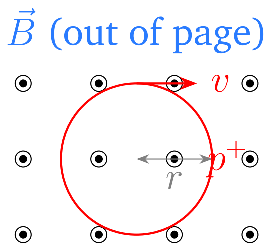
(A) 12 V

(B) 8 V

(C) 6 V

(D) 10 V

Q13. A proton ($m_p = 1.67 \times 10^{-27}$ kg, $q = 1.6 \times 10^{-19}$ C) enters a uniform magnetic field $B = 0.1$ T with speed $v = 10^6$ m/s, directed **perpendicular** to the field. What is the radius of its circular path?



(A) 0.05 m

(B) 0.20 m

(C) 0.10 m

(D) 1.0 m

Q14. A solenoid has self-inductance L. If the number of turns is **doubled** and the length is **halved** (cross-sectional area kept constant), the new inductance L' is:

(A) $2L$

(B) $4L$

(C) $L/2$

(D) $8L$

Q15. An ideal step-up transformer has $N_1 = 100$ primary turns and $N_2 = 500$ secondary turns. If the primary voltage is $V_1 = 220$ V, what is the **secondary voltage**?

(A) 1100 V

(B) 220 V

(C) 44 V

(D) 550 V

Q16. An electromagnetic wave of intensity $I = 1000$ W/m^2 is incident on a **perfectly absorbing** surface. The radiation pressure exerted on the surface is:

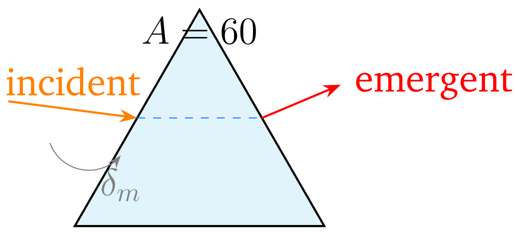
(A) 1.00×10^{-6} Pa

(B) 3.33×10^{-6} Pa

(C) 1.00×10^{-5} Pa

(D) 3.33×10^{-5} Pa

Q17. A glass prism has apex angle $A = 60$ and refractive index $n = \sqrt{3}$. What is the angle of **minimum deviation** δ_m?



(A) 30

(B) 45

(C) 60

(D) 90

Q18. A compound microscope has an objective of focal length $f_o = 1$ cm and an eyepiece of focal length $f_e = 5$ cm. The object is placed 1.2 cm from the objective, which forms an intermediate image 6 cm beyond the objective. Taking the least distance of distinct vision $D = 25$ cm, the **total magnification** is:

(A) 25

(B) 20

(C) 40

(D) 30

Q19. In Compton scattering, an X-ray photon is scattered by a free electron at an angle $\theta = 90$ to its original direction. The **shift in wavelength** $\Delta\lambda$ is (Compton wavelength $\lambda_c = 0.0243$ Å):

(A) 0.0243 Å

(B) 0.0486 Å

(C) 0.01215 Å

(D) 0.0972 Å

Q20. In a p-n junction diode, the **depletion layer** is formed primarily due to:

(A) Accumulation of majority carriers at the junction

(B) Diffusion of majority carriers across the junction, leaving behind fixed space charges

(C) Application of an external forward-bias voltage

(D) Thermal excitation of electrons into the conduction band only

SECTION B — Numerical Value Questions (Attempt any 5, +4 / 0)

Q21. A ball is thrown **vertically upward** with initial speed $u = 30$ m/s. Taking $g = 10$ m/s^2, find the **maximum height** (in metres) reached by the ball.

(Enter the exact numerical value as your answer.)

Q22. An electric heater of resistance $R = 300\ \Omega$ carries a current $I = 2$ A for a time $t = 0.5$ s. Find the **heat generated** (in joules).

(Enter the exact numerical value as your answer.)

Q23. Two large parallel conducting plates are separated by $d = 2$ cm and maintained at a potential difference of $V = 100$ V. Find the magnitude of the **electric field** between the plates in kV/m.

(Enter the exact numerical value as your answer.)

Q24. A convex lens of focal length $f = 4$ cm has an object placed 5 cm in front of it. Find the **magnitude of the linear magnification** produced by the lens.

(Enter the exact numerical value as your answer.)

Q25. The mutual inductance between two coils is $M = 4$ H. If the current in the primary coil changes at a rate of 3 A/s, find the magnitude of the **induced EMF** (in volts) in the secondary coil.

(Enter the exact numerical value as your answer.)

Q26. A resistor of resistance $R = 25\ \Omega$ has a potential difference of $V = 25$ V maintained across it. Find the **power dissipated** (in watts) in the resistor.

(Enter the exact numerical value as your answer.)

Q27. A radioactive sample decays to $\frac{1}{8}$ of its original activity. How many **half-lives** have elapsed?

(Enter the exact numerical value as your answer.)

Q28. A spring-mass system has spring constant $k = 400\pi^2$ N/m and mass $m = 1$ kg. Find the **frequency of oscillation** (in Hz).

(Enter the exact numerical value as your answer.)

Q29. A transverse wave travels along a stretched string under tension $T = 225$ N. The mass per unit length of the string is $\mu = 1$ kg/m. Find the **wave speed** (in m/s).

(Enter the exact numerical value as your answer.)

Q30. In Simple Harmonic Motion, the acceleration a and displacement x are related by $a = -\omega^2 x$. The **phase difference** between a and x is π radians. Express this phase difference as a **multiple of** $\pi/2$. (i.e., find n such that the phase difference $= n \times \frac{\pi}{2}$.)

(Enter the exact numerical value as your answer.)

Answer Key

Click any answer to jump to the solution.

Section A

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
C	D	A	B	C	D	A	B	C	D
Q11	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
A	B	C	D	A	B	C	D	A	B

Section B

Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30
45	600	5	4	12	25	3	10	15	2

Detailed Solutions

Solution

Q1 — Kinematics: Vertical Motion

For a body thrown vertically upward with initial speed u:

$$T = \frac{2u}{g} = \frac{2 \times 20}{10} = \mathbf{4}\ \text{s}$$

The ball takes $t_{\text{up}} = u/g = 2$ s to reach the apex and an equal time to return.

Answer: (C)

Solution

Q2 — Newton's Laws: Pseudo Force on a Coin

In the non-inertial (accelerating) frame of the car, a pseudo-force $F_{\text{pseudo}} = ma$ acts backward on the coin. For the coin not to slide, static friction must balance it:

$$f_s = \mu_s mg \geq ma \implies \mu_s \geq \frac{a}{g} = \frac{5}{10} = \mathbf{0.5}$$

Answer: (D)

Solution

Q3 — Work and Energy: Constant Power

At any instant, $P = Fv = m\dfrac{dv}{dt} \cdot v$. With constant P:

$$mv\,dv = P\,dt \implies m\frac{v^2}{2} = Pt \implies v = \sqrt{\frac{2Pt}{m}} \propto \sqrt{t}$$

The speed grows as $\sqrt{t}$ (option A).

Answer: (A)

Solution

Q4 — Rotational Mechanics: Torque and Angular Acceleration

Moment of inertia of a disc about its central axis:

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

Angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{5}{0.25} = \mathbf{20\ rad/s^2}$$

Answer: (B)

Solution

Q5 — Gravitation: Kepler's Third Law

By Kepler's Third Law, $T^2 \propto r^3$:

$$\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^3 = 4^3 = 64 \implies \frac{T_2}{T_1} = 8 \implies T_2 = \mathbf{8\ years}$$

Answer: (C)

Solution

Q6 — Fluid Mechanics: Bernoulli's Principle

Step 1 — Continuity equation:

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

Step 2 — Bernoulli's equation (horizontal pipe, same height):

$$P_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \tfrac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(1000)(64 - 4) = 500 \times 60 = \mathbf{30{,}000\ Pa} = \mathbf{30\ kPa}$$

Answer: (D)

Solution

Q7 — Thermodynamics: Isothermal Work

For an ideal gas undergoing isothermal expansion:

$$W = nRT \ln\frac{V_2}{V_1} = (1)(8.31)(300)\ln 2 = 2493 \times 0.693 \approx \mathbf{1727\ J} \approx \mathbf{1.73\ kJ}$$

Answer: (A)

Solution

Q8 — Oscillations: Initial Phase in SHM

Given $x = A\sin(\omega t + \varphi)$. At $t = 0$:

$$x_0 = A\sin\varphi = \frac{A}{2} \implies \sin\varphi = \frac{1}{2} \implies \varphi = \frac{\pi}{6} \text{ or } \frac{5\pi}{6}$$

Velocity at $t = 0$: $v_0 = A\omega\cos\varphi > 0 \implies \cos\varphi > 0$.
Since $\cos(\pi/6) = \sqrt{3}/2 > 0$ and $\cos(5\pi/6) < 0$, we take:

$$\varphi = \frac{\pi}{\mathbf{6}}$$

Answer: (B)

Solution

Q9 — Waves: Harmonics of a Closed Organ Pipe

A pipe closed at one end supports only **odd harmonics**: f, $3f$, $5f$, $7f, \ldots$ Even harmonics $(2f, 4f, 6f, \ldots)$ are absent. Therefore, **4f** is the frequency that is **not produced**.

Answer: (C)

Solution

Q10 — Electrostatics: Electric Field Inside a Charged Shell

By Gauss's Law, a Gaussian surface of radius $r < R$ encloses **zero net charge** (all charge Q sits on the outer surface). Therefore:

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{\text{enc}}}{\varepsilon_0} = 0 \implies E = \mathbf{0}$$

Answer: (D)

Solution

Q11 — Capacitors: Series Combination

For capacitors in series:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{3+2+1}{6} = 1 \implies C_{\text{eq}} = \mathbf{1}\ \mu\text{F}$$

Answer: (A)

Solution

Q12 — Current Electricity: Terminal Voltage

Current in the circuit:

$$I = \frac{\varepsilon}{R+r} = \frac{12}{4+2} = 2 \text{ A}$$

Terminal voltage (voltage drop across internal resistance subtracted from EMF):

$$V_T = \varepsilon - Ir = 12 - (2)(2) = \mathbf{8} \text{ V}$$

Answer: (B)

Solution

Q13 — Magnetism: Radius of Circular Motion

The magnetic Lorentz force provides centripetal force:

$$qvB = \frac{mv^2}{r} \implies r = \frac{mv}{qB} = \frac{(1.67 \times 10^{-27})(10^6)}{(1.6 \times 10^{-19})(0.1)} = \frac{1.67 \times 10^{-21}}{1.6 \times 10^{-20}} \approx \mathbf{0.10 \text{ m}}$$

Answer: (C)

Solution

Q14 — Electromagnetic Induction: Self-Inductance of a Solenoid

Self-inductance of a solenoid:

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

New parameters: $N' = 2N$, $l' = l/2$:

$$L' = \mu_0 \frac{(2N)^2}{l/2} A = \mu_0 \frac{4N^2 \times 2}{l} A = 8\mu_0 \frac{N^2}{l} A = \mathbf{8L}$$

Answer: (D)

Solution

Q15 — AC Circuits: Ideal Transformer

For an ideal transformer, the voltage ratio equals the turns ratio:

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \implies V_2 = 220 \times \frac{500}{100} = \mathbf{1100} \text{ V}$$

Answer: (A)

Solution

Q16 — Electromagnetic Waves: Radiation Pressure

For a perfectly absorbing surface, radiation pressure is:

$$P_{\text{rad}} = \frac{I}{c} = \frac{1000}{3 \times 10^8} = \mathbf{3.33 \times 10^{-6}} \text{ Pa}$$

Answer: (B)

Solution

Q17 — Ray Optics: Minimum Deviation in a Prism

At minimum deviation, the ray travels symmetrically; the refraction angle $r = A/2 = 30$. Applying Snell's law at the first face:

$$n = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin(A/2)} \implies \sqrt{3} = \frac{\sin\left(\frac{60+\delta_m}{2}\right)}{\sin 30} = \frac{\sin\left(\frac{60+\delta_m}{2}\right)}{0.5}$$

$$\sin\left(\frac{60+\delta_m}{2}\right) = \frac{\sqrt{3}}{2} \implies \frac{60+\delta_m}{2} = 60 \implies \delta_m = \mathbf{60}$$

Answer: (C)

Solution

Q18 — Optics: Compound Microscope Magnification

Objective magnification (image at $v_o = 6$ cm, object at $u_o = 1.2$ cm):

$$m_o = \frac{v_o}{u_o} = \frac{6}{1.2} = 5$$

Eyepiece magnification (image at least distance of distinct vision $D = 25$ cm):

$$m_e = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 6$$

Total magnification:

$$M = m_o \times m_e = 5 \times 6 = \mathbf{30}$$

Answer: (D)

Solution

Q19 — Modern Physics: Compton Scattering

The Compton wavelength shift is:

$$\Delta\lambda = \lambda_c(1 - \cos\theta)$$

For $\theta = 90$: $\cos 90 = 0$, so:

$$\Delta\lambda = \lambda_c(1 - 0) = \lambda_c = \mathbf{0.0243}\ \text{Å}$$

Answer: (A)

Solution

Q20 — Semiconductors: Depletion Layer Formation

When a p-n junction is formed, majority carriers (holes in p-type, electrons in n-type) **diffuse** across the junction. Holes leave behind negatively charged acceptor ions in the p-region; electrons leave behind positively charged donor ions in the n-region. These immobile space charges create the **depletion layer** — option B.

Answer: (B)

Section B — Solutions

Solution

Q21 — Maximum Height of Vertical Throw

Using $v^2 = u^2 - 2gH$ at maximum height ($v = 0$):

$$H = \frac{u^2}{2g} = \frac{(30)^2}{2 \times 10} = \frac{900}{20} = \mathbf{45}\ \text{m}$$

Answer: (45)

Solution

Q22 — Joule Heating

Heat generated by current in a resistor:

$$Q = I^2Rt = (2)^2 \times 300 \times 0.5 = 4 \times 150 = \mathbf{600}\ \text{J}$$

Answer: (600)

Solution

Q23 — Uniform Electric Field Between Parallel Plates

The electric field between ideal parallel plates:

$$E = \frac{V}{d} = \frac{100\ \text{V}}{0.02\ \text{m}} = 5000\ \text{V/m} = \mathbf{5}\ \text{kV/m}$$

Answer: (5)

Solution

Q24 — Linear Magnification by a Convex Lens

Using the lens formula ($f = +4$ cm, $u = -5$ cm with sign convention):

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \implies \frac{1}{v} = \frac{1}{4} + \frac{1}{-5} = \frac{1}{4} - \frac{1}{5} = \frac{1}{20} \implies v = 20\ \text{cm}$$

Magnification:

$$|m| = \left|\frac{v}{u}\right| = \frac{20}{5} = \mathbf{4}$$

Answer: (4)

Solution

Q25 — Induced EMF via Mutual Inductance

By Faraday's law of mutual induction:

$$\mathcal{E}_2 = M\frac{dI_1}{dt} = 4 \times 3 = \mathbf{12}\ \text{V}$$

Answer: (12)

Solution

Q26 — Power Dissipated in a Resistor

$$P = \frac{V^2}{R} = \frac{(25)^2}{25} = \frac{625}{25} = \mathbf{25}\ \text{W}$$

Answer: (25)

Solution

Q27 — Number of Half-Lives

After n half-lives, the remaining fraction is $\left(\frac{1}{2}\right)^n$. Setting this equal to $\frac{1}{8}$:

$$\left(\frac{1}{2}\right)^n = \frac{1}{8} = \left(\frac{1}{2}\right)^3 \implies n = \mathbf{3}$$

Answer: (3)

Solution

Q28 — Frequency of a Spring-Mass System

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{400\pi^2}{1}} = 20\pi \text{ rad/s}$$

$$f = \frac{\omega}{2\pi} = \frac{20\pi}{2\pi} = \mathbf{10}\text{ Hz}$$

Answer: (10)

Solution

Q29 — Transverse Wave Speed on a String

The speed of a transverse wave on a stretched string:

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{225}{1}} = \sqrt{225} = \mathbf{15}\text{ m/s}$$

Answer: (15)

Solution

Q30 — Phase Difference Between Acceleration and Displacement in SHM

In SHM: $a = -\omega^2 x$. The negative sign means a is always **opposite** in direction to x, corresponding to a phase difference of π radians $= 180$.

Expressed as a multiple of $\frac{\pi}{2}$:

$$\pi = n \times \frac{\pi}{2} \implies n = \mathbf{2}$$

Answer: (2)