JEE Main — Physics Sample Paper 2

Duration: 60 Minutes | Maximum Marks: 100

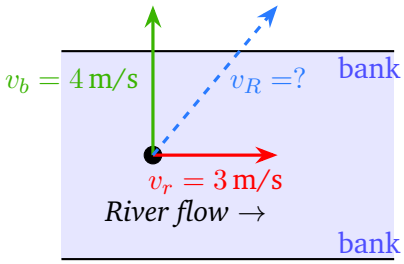
Syllabus: Class 11 & 12 NCERT Physics (JEE Main Official Syllabus)

Instructions

- **Section A** (Q1–Q20): Single Correct MCQ. **+4** for correct answer, **−1** for wrong answer.
- **Section B** (Q21–Q30): Numerical Value Questions. Attempt **any 5**. **+4** for correct answer, **0** for wrong answer.
- Use of calculator is not permitted. All physical constants carry their standard values unless stated otherwise.
- $g = 10$ m/s^2, $k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^{2}C^{-2}, $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}.

SECTION A — Single Correct MCQ (Q1–Q20)

Q1. A boat can travel at 4 m/s in still water. A river flows at 3 m/s eastward. The boat heads directly northward (perpendicular to the river banks). What is the magnitude of the resultant velocity of the boat?



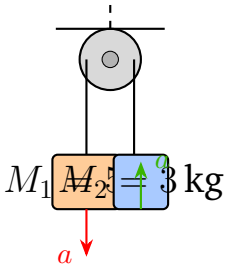
(A) 3 m/s

(B) 5 m/s

(C) 7 m/s

(D) 4 m/s

Q2. In an Atwood machine, a massless string passes over a frictionless pulley. Masses $M_1 = 5$ kg and $M_2 = 3$ kg hang from the two ends. What is the acceleration of the system?



(A) 1.25 m/s^2

(B) 5 m/s^2

(C) 2.5 m/s^2

(D) 3.33 m/s^2

Q3. A force $F = 3x^2$ N acts on an object along the x-axis. What is the work done by this force as the object moves from $x = 0$ to $x = 2$ m?

(A) 4 J

(B) 6 J

(C) 12 J

(D) 8 J

Q4. A figure skater spins with angular speed $\omega_1 = 2$ rad/s and moment of inertia $I_1 = 5$ kg m^2. She then pulls her arms inward, reducing her moment of inertia to $I_2 = 2$ kg m^2. What is her new angular speed?

(A) 5 rad/s

(B) 4 rad/s

(C) 2.5 rad/s

(D) 10 rad/s

Q5. The gravitational potential energy of a mass m on the surface of Earth is $-\dfrac{GMm}{R}$. What is the gravitational potential energy of the same mass at a height $h = R$ above the surface (where R is Earth's radius)?

(A) $-\dfrac{GMm}{R}$

(B) $-\dfrac{GMm}{2R}$

(C) $-\dfrac{2GMm}{R}$

(D) 0

Q6. A steel wire of length $L = 1$ m and cross-sectional area $A = 1.0 \times 10^{-6}$ m^2 is subjected to a tensile force $F = 100$ N. Given Young's modulus of steel $Y = 2 \times 10^{11}$ Pa, the elongation of the wire is:

(A) 0.1 mm

(B) 1.0 mm

(C) 0.5 mm

(D) 0.25 mm

Q7. An ideal gas undergoes a rapid adiabatic compression. Which of the following statements is **correct**?

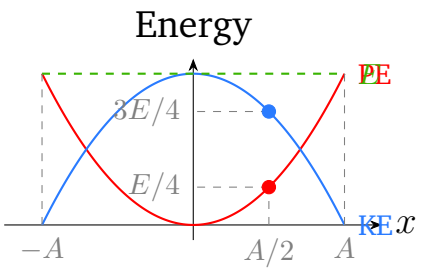
(A) The temperature of the gas decreases.

(B) The internal energy of the gas decreases.

(C) The entropy of the gas increases.

(D) The temperature of the gas increases.

Q8. A particle undergoes SHM with amplitude A and spring constant k. At displacement $x = \dfrac{A}{2}$ from the mean position, what is the ratio of kinetic energy to potential energy?



(A) $3 : 1$

(B) $1 : 3$

(C) $1 : 1$

(D) $\sqrt{3} : 1$

Q9. A stationary source emits sound at frequency $f_0 = 500$ Hz. Speed of sound in air is 340 m/s. An observer moves *toward* the source at $v_{\text{obs}} = 34$ m/s. What is the frequency heard by the observer?

(A) 500 Hz

(B) 550 Hz

(C) 460 Hz

(D) 600 Hz

Q10. The electric field at a point on the *axial* line of an electric dipole at distance r is E_0. What is the magnitude of the electric field at a point on the *equatorial* line of the same dipole at the same distance r?

(A) E_0

(B) $2E_0$

(C) $\dfrac{E_0}{2}$

(D) $4E_0$

Q11. A capacitor of capacitance C is charged to voltage V and remains connected to the battery. A dielectric slab of dielectric constant $k = 2$ is then inserted between the plates. If the initial energy stored was U_0, what is the energy stored after insertion?

(A) $\dfrac{U_0}{2}$

(B) U_0

(C) $\dfrac{U_0}{k}$

(D) $2U_0$

Q12. The resistance of a copper conductor at 0°C is $R_0 = 5\ \Omega$. The temperature coefficient of resistance for copper is $\alpha = 4 \times 10^{-3}\ ^\circ\text{C}^{-1}$. What is the resistance at 100°C?

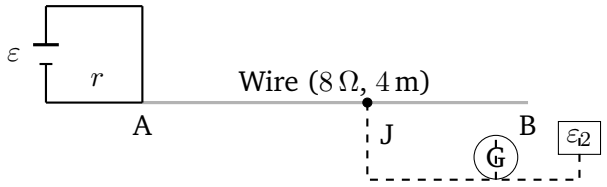
(A) $7\ \Omega$

(B) $5\ \Omega$

(C) $9\ \Omega$

(D) $5.2\ \Omega$

Q13. In a potentiometer circuit, a wire of total resistance $8\ \Omega$ and length 4 m is connected to a battery of EMF 12 V and internal resistance $4\ \Omega$. What is the potential gradient along the wire?



(A) 1 V/m

(B) 2 V/m

(C) 3 V/m

(D) 4 V/m

Q14. Regarding the magnetic field *inside* an ideal (infinitely long) current-carrying solenoid, which statement is **correct**?

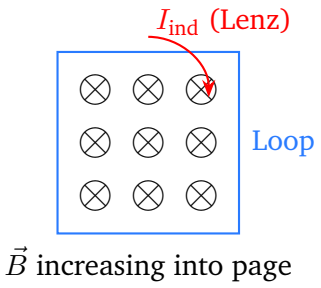
(A) The field is uniform but perpendicular to the axis.

(B) The field decreases as we move toward the ends.

(C) The field is uniform and directed along the axis.

(D) The field is non-uniform throughout the interior.

Q15. A square conducting loop of side 10 cm is placed perpendicular to a uniform magnetic field. The field increases uniformly at 2 T/s. What is the magnitude of the EMF induced in the loop?



(A) 10 mV

(B) 40 mV

(C) 5 mV

(D) 20 mV

Q16. An AC voltage source is connected to a purely resistive load. What is the power factor of the circuit?

(A) 1

(B) 0

(C) 0.5

(D) $\dfrac{1}{\sqrt{2}}$

Q17. Which of the following correctly arranges electromagnetic waves in order of *increasing frequency*?

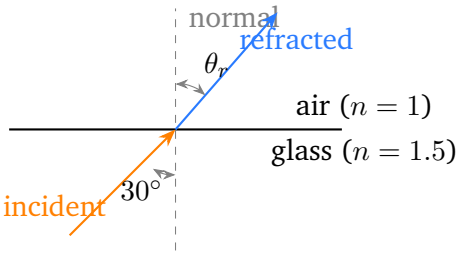
(A) X-rays $<$ visible light $<$ microwaves $<$ radio waves

(B) Radio waves $<$ microwaves $<$ visible light $<$ X-rays

(C) Visible light $<$ radio waves $<$ microwaves $<$ X-rays

(D) Microwaves $<$ X-rays $<$ radio waves $<$ visible light

Q18. A ray of light travels from glass ($n = 1.5$) into air and strikes the glass-air interface at an angle of incidence of 30°. Using Snell's law ($n_1 \sin\theta_1 = n_2 \sin\theta_2$), what is the angle of refraction in air? (Use $\sin^{-1}(0.75) \approx 48.6^\circ$)



(A) 30°

(B) 41.8°

(C) 48.6°

(D) 90°

Q19. In Young's double-slit experiment, the slit separation is $d = 0.5$ mm, the screen is at distance $D = 1$ m, and the wavelength of light used is $\lambda = 500$ nm. What is the fringe width β?

(A) 0.25 mm

(B) 0.5 mm

(C) 2 mm

(D) 1 mm

Q20. A radioactive sample has a half-life of 2 years. What fraction of the original sample remains after 6 years?

(A) $\frac{1}{8}$ of the original

(B) $\frac{1}{4}$ of the original

(C) $\frac{1}{16}$ of the original

(D) $\frac{1}{2}$ of the original

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

Q21. A particle starts from rest and moves with a constant acceleration of $a = 10$ m/s^2. After travelling a distance of $s = 20$ m, what is the speed (in m/s) of the particle?

(Enter the exact numerical value as your answer.)

Q22. An ideal gas expands at constant pressure $P = 2 \times 10^5$ Pa and its volume changes by $\Delta V = 5 \times 10^{-4}$ m^3. What is the work done (in J) by the gas during this process?

(Enter the exact numerical value as your answer.)

Q23. Two point charges $q_1 = 2\ \mu$C and $q_2 = 4\ \mu$C are separated by a distance $r = 0.2$ m. What is the electrostatic potential energy of the system (in mJ)?

(Enter the exact numerical value as your answer.)

Q24. Three resistors of $4\ \Omega$, $6\ \Omega$, and $12\ \Omega$ are connected in *parallel*. What is the equivalent resistance (in Ω) of the combination?

(Enter the exact numerical value as your answer.)

Q25. A rectangular current loop of area $A = 0.04$ m^2 carries a current $I = 2$ A and is placed in a uniform magnetic field $B = 50$ T. When the plane of the loop is parallel to the field, what is the torque (in N·m) acting on it?

(Enter the exact numerical value as your answer.)

Q26. In a Young's double-slit experiment, the wavelength of light is $\lambda = 600$ nm, the screen distance is $D = 1$ m, and the slit separation is $d = 1$ cm. What is the fringe width β in μm?

(Enter the exact numerical value as your answer.)

Q27. A radioactive sample decays from an initial count of $N_0 = 384 \times 10^6$ atoms to $N = 6 \times 10^6$ atoms in 72 minutes. How many half-lives have elapsed during this time?

(Enter the exact numerical value as your answer.)

Q28. A series LCR circuit contains $L = 0.04$ H and $C = 250\ \mu$F. At resonance, $\omega_0 = \dfrac{1}{\sqrt{LC}}$. What is the resonant frequency f_0 (in Hz)? [Take $\pi^2 \approx 10$]

(Enter the exact numerical value as your answer.)

Q29. An open organ pipe has a length $L = 0.34$ m. Given that the speed of sound in air is $v = 340$ m/s, what is the fundamental frequency (in Hz) of vibration of this pipe?

(Enter the exact numerical value as your answer.)

Q30. Two parallel conducting plates are separated by a distance $d = 3$ cm and maintained at a potential difference $V = 9$ V. If the electric field between the plates is E (in V/m), what is the value of $E/100$?

(Enter the exact numerical value as your answer.)

Answer Key

Section A — MCQ

Q	1	2	3	4	5	6	7	8	9	10
Ans	B	C	D	A	B	C	D	A	B	C

Q	11	12	13	14	15	16	17	18	19	20
Ans	D	A	B	C	D	A	B	C	D	A

Section B — Numerical

Q	21	22	23	24	25	26	27	28	29	30
Ans	20	100	360	2	4	60	6	50	500	3

Detailed Solutions

Section A Solutions

Solution

Q1. The boat has velocity $v_b = 4$ m/s directed northward (perpendicular to river) and the river has velocity $v_r = 3$ m/s eastward. Since these are perpendicular, the resultant speed is:

$$v_R = \sqrt{v_b^2 + v_r^2} = \sqrt{4^2 + 3^2} = \sqrt{16 + 9} = \sqrt{25} = 5 \text{ m/s}.$$

Answer: (B)

Solution

Q2. For an Atwood machine with masses $M_1 = 5$ kg and $M_2 = 3$ kg:

$$a = \frac{(M_1 - M_2)\, g}{M_1 + M_2} = \frac{(5-3) \times 10}{5+3} = \frac{20}{8} = 2.5 \text{ m/s}^2.$$

Answer: (C)

Solution

Q3. Work done by a variable force is given by the integral:

$$W = \int_0^2 F\, dx = \int_0^2 3x^2\, dx = \left[x^3\right]_0^2 = 8 - 0 = 8 \text{ J}.$$

Answer: (D)

Solution

Q4. When no external torque acts, angular momentum is conserved:

$$I_1\omega_1 = I_2\omega_2 \implies \omega_2 = \frac{I_1\omega_1}{I_2} = \frac{5 \times 2}{2} = 5 \text{ rad/s}.$$

Answer: (A)

Solution

Q5. The gravitational potential energy at distance r from Earth's centre is $U = -\dfrac{GMm}{r}$.

At the surface ($r = R$): $U_s = -\dfrac{GMm}{R}$. At height $h = R$ above surface, $r = 2R$:

$$U_h = -\frac{GMm}{2R}.$$

This is half the magnitude of the surface PE, so $U_h = -\dfrac{GMm}{2R}$.

Answer: (B)

Solution

Q6. The elongation is given by:

$$\Delta L = \frac{FL}{YA} = \frac{100 \times 1}{2 \times 10^{11} \times 10^{-6}} = \frac{100}{2 \times 10^{5}} = 5 \times 10^{-4}\ \text{m} = 0.5\ \text{mm}.$$

Answer: (C)

Solution

Q7. In an adiabatic process, $Q = 0$. By the first law: $\Delta U = Q - W = -W$. During compression, work is done *on* the gas, so $W < 0$ (from gas perspective), giving $\Delta U > 0$. An increase in internal energy means an increase in temperature.

Answer: (D)

Solution

Q8. Total energy: $E = \frac{1}{2}kA^2$. At $x = A/2$:

$$\text{PE} = \tfrac{1}{2}k\left(\tfrac{A}{2}\right)^2 = \tfrac{1}{2}k \cdot \tfrac{A^2}{4} = \tfrac{E}{4}.$$

$$\text{KE} = E - \text{PE} = E - \tfrac{E}{4} = \tfrac{3E}{4}.$$

$$\frac{\text{KE}}{\text{PE}} = \frac{3E/4}{E/4} = 3:1.$$

Answer: (A)

Solution

Q9. When the observer moves toward a stationary source:

$$f' = f_0\,\frac{v + v_{\text{obs}}}{v} = 500 \times \frac{340 + 34}{340} = 500 \times \frac{374}{340} = 500 \times 1.1 = 550\ \text{Hz}.$$

Answer: (B)

Solution

Q10. For an electric dipole of moment p:

$$E_{\text{axial}} = \frac{2kp}{r^3}, \qquad E_{\text{equatorial}} = \frac{kp}{r^3}.$$

If $E_{\text{axial}} = E_0$, then $E_{\text{equatorial}} = \dfrac{E_0}{2}$.

Answer: (C)

Solution

Q11. The capacitor stays connected to the battery, so the voltage V remains constant. Inserting dielectric $k = 2$ gives new capacitance $C' = kC = 2C$. New energy:

$$U' = \tfrac{1}{2}C'V^2 = \tfrac{1}{2}(2C)V^2 = CV^2 = 2\left(\tfrac{1}{2}CV^2\right) = 2U_0.$$

Answer: (D)

Solution

Q12. Using the temperature dependence of resistance:

$$R = R_0(1 + \alpha T) = 5\left(1 + 4 \times 10^{-3} \times 100\right) = 5 \times (1 + 0.4) = 5 \times 1.4 = 7\ \Omega.$$

Answer: (A)

Solution

Q13. Total resistance in the circuit = $R_{\text{wire}} + r = 8\ \Omega + 4\ \Omega = 12\ \Omega$. Current:

$$I = \frac{\varepsilon}{R_{\text{wire}} + r} = \frac{12}{12} = 1\ \text{A}.$$

Resistance per unit length of wire $= 8\ \Omega/4\ \text{m} = 2\ \Omega/\text{m}$. Potential gradient:

$$\phi = I \times \frac{R_{\text{wire}}}{L} = 1 \times 2 = 2\ \text{V/m}.$$

Answer: (B)

Solution

Q14. By Ampere's circuital law applied to a rectangular Amperian loop inside an ideal solenoid, the field inside is:

$$B = \mu_0 n I,$$

which is **uniform** throughout the interior and directed **along the axis** of the solenoid.

Answer: (C)

Solution

Q15. The area of the square loop: $A = (0.10)^2 = 0.01$ m^2. The induced EMF is:

$$\mathcal{E} = \frac{d\Phi}{dt} = A\frac{dB}{dt} = 0.01 \times 2 = 0.02 \text{ V} = 20 \text{ mV}.$$

By Lenz's law, the induced current opposes the increasing flux.

Answer: (D)

Solution

Q16. In a purely resistive circuit, there is no phase difference between voltage and current ($\phi = 0$). Therefore:

$$\text{Power factor} = \cos\phi = \cos 0^\circ = 1.$$

Answer: (A)

Solution

Q17. The electromagnetic spectrum in order of increasing frequency is:

$$\underbrace{\text{Radio}}_{\sim 10^6\,\text{Hz}} < \underbrace{\text{Microwaves}}_{\sim 10^{10}\,\text{Hz}} < \underbrace{\text{Visible}}_{\sim 10^{14}\,\text{Hz}} < \underbrace{\text{X-rays}}_{\sim 10^{18}\,\text{Hz}}.$$

Answer: (B)

Solution

Q18. Applying Snell's law at the glass-air interface:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \implies 1.5 \times \sin 30^\circ = 1 \times \sin\theta_2.$$

$$\sin\theta_2 = 1.5 \times 0.5 = 0.75 \implies \theta_2 = \sin^{-1}(0.75) \approx 48.6^\circ.$$

Note: Critical angle $= \sin^{-1}(1/1.5) \approx 41.8°$. Since $30° < 41.8°$, refraction occurs (no TIR).

Answer: (C)

Solution

Q19. The fringe width in YDSE is:

$$\beta = \frac{\lambda D}{d} = \frac{500 \times 10^{-9} \times 1}{0.5 \times 10^{-3}} = \frac{5 \times 10^{-7}}{5 \times 10^{-4}} = 1 \times 10^{-3}\ \text{m} = 1\ \text{mm}.$$

Answer: (D)

Solution

Q20. After $t = 6$ years with $T_{1/2} = 2$ years, the number of half-lives elapsed is $n = t/T_{1/2} = 3$. The fraction remaining is:

$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}.$$

Answer: (A)

Section B Solutions

Solution

Q21. Using kinematics ($u = 0$, $a = 10$ m/s^2, $s = 20$ m):

$$v^2 = u^2 + 2as = 0 + 2 \times 10 \times 20 = 400 \implies v = \sqrt{400} = 20\ \text{m/s}.$$

Answer: (20)

Solution

Q22. Work done by gas at constant pressure:

$$W = P\,\Delta V = 2 \times 10^5 \times 5 \times 10^{-4} = 100\ \text{J}.$$

Answer: (100)

Solution

Q23. Electrostatic potential energy:

$$U = \frac{kq_1q_2}{r} = \frac{9 \times 10^9 \times 2 \times 10^{-6} \times 4 \times 10^{-6}}{0.2} = \frac{9 \times 10^9 \times 8 \times 10^{-12}}{0.2} = \frac{0.072}{0.2} = 0.36\,\text{J} = 360\,\text{mJ}.$$

Answer: (360)

Solution

Q24. For three resistors in parallel:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{3}{12} + \frac{2}{12} + \frac{1}{12} = \frac{6}{12} = \frac{1}{2} \implies R_{\text{eq}} = 2\ \Omega.$$

Answer: (2)

Solution

Q25. When the plane of the loop is parallel to the magnetic field, the angle between the magnetic moment ($\vec{m}$) and $\vec{B}$ is 90°. Torque:

$$\tau = BIA\sin 90^\circ = 50 \times 2 \times 0.04 = 4\ \text{N m}.$$

Answer: (4)

Solution

Q26. Fringe width:

$$\beta = \frac{\lambda D}{d} = \frac{600 \times 10^{-9} \times 1}{1 \times 10^{-2}} = 6 \times 10^{-5}\ \text{m} = 60\ \mu\text{m}.$$

Answer: (60)

Solution

Q27. The ratio $N/N_0 = 6 \times 10^6/(384 \times 10^6) = 6/384 = 1/64$. Since $(1/2)^n = 1/64 = (1/2)^6$, the number of half-lives is $n = 6$.

Answer: (6)

Solution

Q28. Resonant angular frequency:

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.04 \times 250 \times 10^{-6}}} = \frac{1}{\sqrt{10^{-5}}} = \frac{1}{10^{-5/2}} = 10^{5/2} \approx 316 \text{ rad/s}.$$

Resonant frequency:

$$f_0 = \frac{\omega_0}{2\pi} = \frac{10^{5/2}}{2\pi} \approx \frac{316}{2 \times 3.14} \approx 50 \text{ Hz} \quad [\text{using } \pi^2 \approx 10].$$

Answer: (50)

Solution

Q29. For an open organ pipe, the fundamental frequency is:

$$f = \frac{v}{2L} = \frac{340}{2 \times 0.34} = \frac{340}{0.68} = 500 \text{ Hz}.$$

Answer: (500)

Solution

Q30. Electric field between parallel plates:

$$E = \frac{V}{d} = \frac{9}{0.03} = 300 \text{ V/m}.$$

$$\frac{E}{100} = \frac{300}{100} = 3.$$

Answer: (3)

Quick Answer Reference

Section A

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

Section B

21	20	22	100
23	360	24	2
25	4	26	60
27	6	28	50
29	500	30	3