JEE Main Physics Sample Paper-11

Duration: 1 Hour **Maximum Marks: 100**

Instructions

- This paper contains TWO sections: **Section A** (MCQs) and **Section B** (Numerical).
- Section A contains 20 Multiple Choice Questions.
- Section B contains 5 Numerical Value Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Section A — Multiple Choice Questions

Q1. The frequency of revolution of the electron in Bohr's orbit varies with n, the principal quantum number, as per the relation: [JEE Main 2022]

(A) $1/n$

(B) $1/n^3$

(C) $1/n^4$

(D) $1/n^2$

Q2. In a Young's double slit experiment, the source is white light. One of the slits is covered by a red filter and another by a green filter. Which of the following describes the result on the screen? [JEE Main 2020]

(A) There shall be an interference pattern for red distinct from that for green

(B) There shall be no interference fringes

(C) There shall be alternate interference fringes of red and green

(D) There shall be an interference pattern where the center is green and edges are red

Q3. A coil of area A and N turns is rotating with angular velocity ω in a uniform magnetic field $\vec{B}$ about an axis perpendicular to $\vec{B}$. At the instant when $\vec{B}$ is parallel to the plane of the coil, the magnetic flux ϕ and induced emf ϵ are: [JEE Main 2022]

(A) $\phi = AB, \epsilon = 0$

(B) $\phi = 0, \epsilon = NAB\omega$

(C) $\phi = 0, \epsilon = 0$

(D) $\phi = AB, \epsilon = NAB\omega$

Q4. A plane electromagnetic wave propagates along the $+x$ direction in free space. The components of the electric field $\vec{E}$ and magnetic field $\vec{B}$ vectors associated with the wave in a Cartesian frame are: [JEE Main 2021]

(A) E_y, B_x

(B) E_y, B_z

(C) E_x, B_y

(D) E_z, B_y

Q5. The difference in temperature in a material can convert heat energy into electrical energy. To harvest the heat energy efficiently, the material should possess: [JEE Main 2023]

(A) Low thermal conductivity and low electrical conductivity

(B) High thermal conductivity and low electrical conductivity

(C) Low thermal conductivity and high electrical conductivity

(D) High thermal conductivity and high electrical conductivity

Q6. Ice and water are placed in a closed container at a pressure of 1 atm and temperature 273.15 K. If the pressure of the system is increased to 2 atm while keeping the temperature constant, which of the following happens? [JEE Main 2021]

(A) Volume of the system increases

(B) The liquid phase disappears completely

(C) The amount of ice decreases

(D) The total mass of the system increases

Q7. There are two vessels filled with an ideal gas where the volume of one is double the volume of the other ($V_1 = 2V_2$). The larger vessel contains gas at 8 kPa and 1000 K, while the smaller vessel contains gas at 7 kPa and 500 K. If the vessels are connected and the temperature of both is maintained at 600 K, the steady-state pressure (in kPa) will be: [JEE Main 2022]

(A) 18

(B) 6

(C) 4

(D) 15

Q8. Two vessels A and B are connected via a stopcock. Vessel A is filled with a gas, while vessel B is evacuated. The assembly is immersed in a water bath. After opening the stopcock, the gas expands into vessel B and no change in temperature is observed. Which statement is true? [JEE Main 2020]

(A) $dw \neq 0$

(B) $dq \neq 0$

(C) $dU \neq 0$

(D) The pressure in vessel B before opening the stopcock was zero

Q9. The ratio of vapour densities of two gases at the same temperature is 4/25. The ratio of their root mean square (r.m.s.) velocities will be: [JEE Main 2023]

(A) 25/4

(B) 2/5

(C) 5/2

(D) 4/25

Q10. Identify the correct pair of statements regarding thermodynamic variables: (A) Internal energy and volume are extensive. (B) Pressure and temperature are intensive. (C) Volume and density are intensive. (D) Mass and temperature are extensive. [JEE Main 2021]

(A) (C) and (D) only

(B) (D) and (A) only

(C) (A) and (B) only

(D) (B) and (C) only

Q11. A solid sphere of mass M and radius R rotates about its diameter. A solid cylinder of the same mass and radius rotates about its geometrical axis with an angular speed twice that of the sphere. The ratio of their rotational kinetic energies $(E_{sphere}/E_{cylinder})$ is: [JEE Main 2021]

(A) 1:5

(B) 2:5

(C) 1:4

(D) 5:2

Q12. A body is projected vertically upwards from Earth's surface with a velocity equal to half the escape velocity. If R is the radius of the Earth, the maximum height attained from the surface is: [JEE Main 2022]

(A) $R/2$

(B) $R/3$

(C) $R/4$

(D) $2R$

Q13. A particle moves in a straight line with constant acceleration. Its velocity changes from 10 m/s to 20 m/s over a distance of 135 m. The time t taken is: [JEE Main 2020]

(A) 12 s

(B) 9 s

(C) 10 s

(D) 1.8 s

Q14. Two planets have radii r_1, r_2 and densities d_1, d_2. The ratio of the accelerations due to gravity on their surfaces (g_1/g_2) is: [JEE Main 2021]

(A) $\frac{r_1 d_1}{r_2 d_2}$

(B) $\frac{r_1^2 d_1}{r_2^2 d_2}$

(C) $\frac{r_2 d_1}{r_1 d_2}$

(D) $\frac{r_1 d_2}{r_2 d_1}$

Q15. A particle of mass m moves in a horizontal circle of radius r under a centripetal force $F = -K/r^2$. The total energy of the particle is: [JEE Main 2023]

(A) $K/2r$

(B) $-K/2r$

(C) $-K/r$

(D) K/r

Q16. A particle is executing Simple Harmonic Motion (SHM) with an amplitude A. At what displacement from the mean position is the kinetic energy of the particle equal to three times its potential energy? [JEE Main 2021]

(A) $A/2$

(B) $A/\sqrt{2}$

(C) $A\sqrt{3}/2$

(D) $A/4$

Q17. A string of length L is fixed at both ends and is vibrating in its third harmonic. The distance between two consecutive nodes in this case is: [JEE Main 2022]

(A) $L/3$

(B) $L/2$

(C) $L/6$

(D) $2L/3$

Q18. A block of mass m is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally with an acceleration a so that the block remains stationary relative to the wedge. The value of a is: [JEE Main 2020]

(A) $g \sin\theta$

(B) $g\cos\theta$

(C) $g\tan\theta$

(D) $g/\tan\theta$

Q19. A force $F = (5\hat{i} + 3\hat{j} + 2\hat{k})$ N is applied to a particle which displaces it from its origin to the point $r = (2\hat{i} - \hat{j})$ m. The work done on the particle (in Joules) is: [JEE Main 2023]

(A) 7 J

(B) 13 J

(C) 10 J

(D) 11 J

Q20. The density of a material in the shape of a cube is determined by measuring its mass and the length of its side. If the maximum errors in the measurement of mass and length are 3% and 2% respectively, the maximum error in the measurement of density is: [JEE Main 2021]

(A) 5%

(B) 7%

(C) 9%

(D) 1%

Section B — Numerical Questions

Q21. A hydrogen-like atom (atomic number Z) is in a higher excited state n. This atom can transition to the first excited state by emitting a photon of energy 10.20 eV, or to the second excited state by emitting a photon of energy 4.25 eV. Determine the value of the principal quantum number n. Answer: [JEE Main 2021]

Q22. A parallel plate capacitor with plate area A and separation d is filled with two dielectric slabs of constants $K_1 = 3$ and $K_2 = 6$. Each slab has a thickness $d/2$. If the capacitance of the original empty capacitor was 10 μF, find the new capacitance in μF. Answer (in μF): [JEE Main 2021]

Q23. In a Young's Double Slit Experiment ($d = 1$ mm, $D = 1.33$ m), the entire apparatus is immersed in a liquid of refractive index $4/3$. If the wavelength of light in vacuum is 630 nm, find the fringe width on the screen in micrometers (μm). Answer (in μm): [JEE Main 2022]

Q24. A Carnot engine operates between 600 K and 300 K. If the engine receives 4000 J of heat from the hot reservoir in each cycle, find the amount of work done by the engine per cycle in Joules. Answer (in J): [JEE Main 2023]

Q25. A solid sphere of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal surface with a velocity of 4 m/s. Calculate the total kinetic energy of the sphere in Joules. (Round off to the nearest integer). Answer (in J): [JEE Main 2024]

Detailed Solutions

Q1.

Solution

Concept:

In Bohr's model: - Radius of orbit: $r_n \propto n^2$ - Velocity of electron: $v_n \propto \frac{1}{n}$

Time period:

$$T = \frac{2\pi r}{v}$$

Frequency:

$$f = \frac{1}{T}$$

Solution:

Using proportional relations:

$$T \propto \frac{r}{v} \propto \frac{n^2}{1/n} = n^3$$

Thus:

$$f = \frac{1}{T} \propto \frac{1}{n^3}$$

Hence, frequency varies as:

$$f \propto \frac{1}{n^3}$$

Answer: (B)

Q2.

Solution

Concept:

For sustained interference: - Sources must be **coherent** - Same frequency (same wavelength) - Constant phase difference

Solution:

Here: - One slit $\rightarrow$ red light - Other slit $\rightarrow$ green light

Since:

$$\lambda_{red} \neq \lambda_{green}$$

Thus: - Frequencies are different - Phase difference changes continuously - Sources become **incoherent**

Therefore: - No stable interference pattern is formed

Only intensity addition occurs.

Answer: (B)

Q3.

Solution

Concept:

Magnetic flux:

$$\phi = NBA\cos\theta$$

Induced emf:

$$\epsilon = NBA\omega\sin\theta$$

where θ is angle between $\vec{B}$ and area vector.

Solution:

Given: - Magnetic field parallel to plane - Area vector is perpendicular to plane

So:

$$\theta = 90^\circ$$

Flux:

$$\phi = NBA\cos 90^\circ = 0$$

EMF:

$$\epsilon = NBA\omega\sin 90^\circ = NBA\omega$$

Thus: - Flux is zero - EMF is maximum

Answer: (B)

Q4.

Solution

Concept:

In electromagnetic waves: - $\vec{E} \perp \vec{B} \perp$ direction of propagation - Direction given by:

$$\vec{E} \times \vec{B}$$

Solution:

Wave propagates along $+x$-axis.

So: - $E_x = 0$, $B_x = 0$

We need:

$$\vec{E} \times \vec{B} = \hat{i}$$

Using vector relation:

$$\hat{j} \times \hat{k} = \hat{i}$$

Thus: - Electric field along y-axis $\rightarrow E_y$ - Magnetic field along z-axis $\rightarrow B_z$

Answer: (B)

Q5.

Solution

Concept:

Thermoelectric efficiency depends on: - High electrical conductivity → easy flow of charges - Low thermal conductivity → maintain temperature gradient

Solution:

If thermal conductivity is high: - Heat flows quickly → temperature difference reduces → efficiency decreases

If electrical conductivity is low: - Current cannot flow efficiently

Thus ideal material: - Low thermal conductivity - High electrical conductivity

Answer: (C)

Q6.

Solution

Concept:

At constant temperature, phase change depends on pressure. For water: - Ice has **larger volume** than water - Increasing pressure favors phase with **smaller volume**

Solution:

Given: - Ice + water at 273.15 K - Pressure increased from 1 atm → 2 atm

Since: - Water occupies less volume than ice - Increasing pressure shifts equilibrium towards liquid phase

Thus: - Ice melts partially - Amount of ice decreases

Answer: (C)

Q7.

Solution

Concept:

Use ideal gas law:

$$PV = nRT$$

Total moles conserved:

$$n_{total} = n_1 + n_2$$

Final pressure:

$$P_f = \frac{(n_1 + n_2)RT}{V_1 + V_2}$$

Solution:

Given:

$$V_1 = 2V_2$$

Moles:

$$n_1 = \frac{P_1 V_1}{RT_1} = \frac{8 \cdot 2V_2}{R \cdot 1000}$$

$$n_2 = \frac{7 \cdot V_2}{R \cdot 500}$$

Simplify:

$$n_1 = \frac{16V_2}{1000R}, \quad n_2 = \frac{7V_2}{500R} = \frac{14V_2}{1000R}$$

Total moles:

$$n = \frac{30V_2}{1000R}$$

Final volume:

$$V = 3V_2$$

Final pressure:

$$P_f = \frac{nRT}{V} = \frac{30V_2}{1000R} \cdot \frac{R \cdot 600}{3V_2}$$

$$P_f = \frac{30 \times 600}{3000} = 6 \text{ kPa}$$

Answer: (B)

Q8.

Solution

Concept:

This is **free expansion**: - Gas expands into vacuum - No external pressure

Thus:

$$W = 0$$

For ideal gas:

$$\Delta U = nC_v\Delta T$$

Solution:

Given: - No temperature change $\rightarrow \Delta T = 0$

Thus:

$$\Delta U = 0$$

Also:

$$Q = \Delta U + W = 0$$

Hence: - No work done - No heat exchanged - Internal energy unchanged

Important fact: - Vessel B is evacuated $\rightarrow$ initial pressure $= 0$

Answer: (D)

Q9.

Solution

Concept:

Relation:

$$v_{rms} \propto \frac{1}{\sqrt{M}}$$

Vapour density:

$$VD \propto M$$

Thus:

$$v_{rms} \propto \frac{1}{\sqrt{VD}}$$

Solution:

Given:

$$\frac{VD_1}{VD_2} = \frac{4}{25}$$

So:

$$\frac{v_1}{v_2} = \sqrt{\frac{VD_2}{VD_1}} = \sqrt{\frac{25}{4}} = \frac{5}{2}$$

Answer: (C)

Q10.

Solution

Concept:

Thermodynamic variables: - Extensive → depend on mass (e.g., volume, internal energy) - Intensive → independent of mass (e.g., pressure, temperature)

Solution:

Check statements:

(A) Internal energy, volume → extensive (B) Pressure, temperature → intensive (C) Volume is not intensive (D) Temperature is not extensive

Correct pair:

$$(A) \text{ and } (B)$$

Answer: (C)

Q11.

Solution

Concept:

Rotational kinetic energy:

$$E = \frac{1}{2} I\omega^2$$

Moment of inertia: - Solid sphere about diameter:

$$I_s = \frac{2}{5} MR^2$$

- Solid cylinder about axis:

$$I_c = \frac{1}{2} MR^2$$

Solution:

Given: - Cylinder angular speed $= 2\omega$

Energy of sphere:

$$E_s = \frac{1}{2} \cdot \frac{2}{5} MR^2 \cdot \omega^2 = \frac{1}{5} MR^2\omega^2$$

Energy of cylinder:

$$E_c = \frac{1}{2} \cdot \frac{1}{2} MR^2 \cdot (2\omega)^2$$

$$E_c = \frac{1}{4} MR^2 \cdot 4\omega^2 = MR^2\omega^2$$

Ratio:

$$\frac{E_s}{E_c} = \frac{1/5}{1} = \frac{1}{5}$$

Answer: (A)

Q12.

Solution

Concept:

Escape velocity:

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

Using energy conservation:

$$\frac{1}{2}mv^2 - \frac{GMm}{R} = -\frac{GMm}{R+h}$$

Solution:

Given:

$$v = \frac{v_e}{2}$$

So:

$$v^2 = \frac{1}{4} \cdot \frac{2GM}{R} = \frac{GM}{2R}$$

Initial energy:

$$E = \frac{1}{2}m \cdot \frac{GM}{2R} - \frac{GMm}{R}$$

$$E = \frac{GMm}{4R} - \frac{GMm}{R} = -\frac{3GMm}{4R}$$

At maximum height:

$$E = -\frac{GMm}{R+h}$$

Equate:

$$\frac{GMm}{R+h} = \frac{3GMm}{4R}$$

$$R + h = \frac{4R}{3}$$

$$h = \frac{R}{3}$$

Answer: (B)

Q13.

Solution

Concept:

Equation:

$$v^2 = u^2 + 2as$$

Then:

$$t = \frac{v - u}{a}$$

Solution:

Given:

$$u = 10, \quad v = 20, \quad s = 135$$

From:

$$v^2 = u^2 + 2as$$

$$400 = 100 + 2a(135)$$

$$300 = 270a$$

$$a = \frac{10}{9}$$

Now:

$$t = \frac{20 - 10}{10/9} = \frac{10 \times 9}{10} = 9 \text{ s}$$

Answer: (B)

Q14.

Solution

Concept:

Acceleration due to gravity:

$$g = \frac{GM}{R^2}$$

Mass:

$$M = \frac{4}{3}\pi R^3 d$$

Thus:

$$g \propto Rd$$

Solution:

$$\frac{g_1}{g_2} = \frac{R_1 d_1}{R_2 d_2}$$

Answer: (A)

Q15.

Solution

Concept:

Given force:

$$F = -\frac{K}{r^2}$$

Potential energy:

$$U = -\frac{K}{r}$$

For circular motion:

$$\frac{mv^2}{r} = \frac{K}{r^2} \Rightarrow mv^2 = \frac{K}{r}$$

Kinetic energy:

$$K.E. = \frac{1}{2}mv^2 = \frac{K}{2r}$$

Solution:

Total energy:

$$E = K.E. + U = \frac{K}{2r} - \frac{K}{r}$$

$$E = -\frac{K}{2r}$$

Answer: (B)

Q16.

Solution

Concept:

In SHM:

$$\text{Total Energy} = \frac{1}{2}kA^2$$

At displacement x:

$$\text{P.E.} = \frac{1}{2}kx^2$$

$$\text{K.E.} = \frac{1}{2}k(A^2 - x^2)$$

Solution:

Given:

$$\text{K.E.} = 3 \times \text{P.E.}$$

$$\frac{1}{2}k(A^2 - x^2) = 3 \cdot \frac{1}{2}kx^2$$

Cancel $\frac{1}{2}k$:

$$A^2 - x^2 = 3x^2$$

$$A^2 = 4x^2$$

$$x = \frac{A}{2}$$

Answer: (A)

Q17.

Solution

Concept:

For a string fixed at both ends:

$$\text{Distance between two consecutive nodes} = \frac{\lambda}{2}$$

For n^{th} harmonic:

$$L = \frac{n\lambda}{2} \Rightarrow \lambda = \frac{2L}{n}$$

Solution:

Given: - Third harmonic $\rightarrow n = 3$

$$\lambda = \frac{2L}{3}$$

Distance between nodes:

$$= \frac{\lambda}{2} = \frac{1}{2} \cdot \frac{2L}{3} = \frac{L}{3}$$

Answer: (A)

Q18.

Solution

Concept:

In non-inertial frame (accelerating wedge): - Pseudo force acts opposite to acceleration - Resolve forces along incline

For equilibrium along incline:

$$mg \sin\theta = ma \cos\theta$$

Solution:

$$a = g \tan\theta$$

Thus, horizontal acceleration needed is:

$$a = g \tan\theta$$

Answer: (C)

Q19.

Solution

Concept:

Work done:

$$W = \vec{F} \cdot \vec{r}$$

Dot product:

$$\vec{F} \cdot \vec{r} = (F_x r_x + F_y r_y + F_z r_z)$$

Solution:

Given:

$$\vec{F} = (5\hat{i} + 3\hat{j} + 2\hat{k})$$

$$\vec{r} = (2\hat{i} - \hat{j} + 0\hat{k})$$

Dot product:

$$W = (5 \cdot 2) + (3 \cdot -1) + (2 \cdot 0)$$

$$W = 10 - 3 = 7 \text{ J}$$

Answer: (A)

Q20.

Solution

Concept:

Density:

$$\rho = \frac{m}{l^3}$$

Error formula:

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3\frac{\Delta l}{l}$$

Solution:

Given:

$$\frac{\Delta m}{m} = 3\%, \quad \frac{\Delta l}{l} = 2\%$$

$$\frac{\Delta\rho}{\rho} = 3 + 3(2) = 3 + 6 = 9\%$$

Answer: (C)

Q21.

Solution

Concept:

Energy levels of hydrogen-like atom:

$$E_n = -13.6Z^2\frac{1}{n^2}$$

Transition energy:

$$E = 13.6Z^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Solution:

Given:

$$10.20 = 13.6Z^2\left(\frac{1}{4} - \frac{1}{n^2}\right)$$

$$4.25 = 13.6Z^2\left(\frac{1}{9} - \frac{1}{n^2}\right)$$

Divide:

$$\frac{10.20}{4.25} = \frac{\frac{1}{4} - \frac{1}{n^2}}{\frac{1}{9} - \frac{1}{n^2}} \approx 2.4$$

Let $x = \frac{1}{n^2}$:

$$2.4 = \frac{\frac{1}{4} - x}{\frac{1}{9} - x}$$

Solving:

$$x \approx \frac{1}{84} \Rightarrow n^2 \approx 84 \Rightarrow n \approx 9$$

Final Answer: $n = 9$

Answer: (9)

Q22.

Solution

Concept:

Two dielectric slabs in series:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

Each capacitance:

$$C = \frac{K\epsilon_0 A}{d}$$

Solution:

Original capacitance:

$$C_0 = \frac{\epsilon_0 A}{d} = 10\mu F$$

Now slabs: - Thickness $= d/2$

$$C_1 = \frac{K_1\epsilon_0 A}{d/2} = 2K_1C_0 = 2 \cdot 3 \cdot 10 = 60\mu F$$

$$C_2 = 2K_2C_0 = 2 \cdot 6 \cdot 10 = 120\mu F$$

Series combination:

$$\frac{1}{C} = \frac{1}{60} + \frac{1}{120} = \frac{2+1}{120} = \frac{3}{120}$$

$$C = 40\mu F$$

Final Answer: $40\mu F$

Answer: (40)

Q23.

Solution

Concept:

Fringe width:

$$\beta = \frac{\lambda D}{d}$$

In medium:

$$\lambda' = \frac{\lambda}{\mu}$$

Solution:

Given:

$$\lambda = 630 \text{ nm}, \quad \mu = \frac{4}{3}$$

$$\lambda' = \frac{630}{4/3} = 630 \cdot \frac{3}{4} = 472.5 \text{ nm}$$

Convert:

$$472.5 \text{ nm} = 472.5 \times 10^{-9} \text{ m}$$

Now:

$$\beta = \frac{472.5 \times 10^{-9} \cdot 1.33}{1 \times 10^{-3}}$$

$$\beta = 628.4 \times 10^{-6} \text{ m}$$

$$\beta = 628.4\,\mu m$$

Final Answer: $628\,\mu m$

Answer: (628)

Q24.

Solution

Concept:

Efficiency of Carnot engine:

$$\eta = 1 - \frac{T_C}{T_H}$$

Work:

$$W = \eta Q_H$$

Solution:

Given:

$$T_H = 600K, \quad T_C = 300K$$

$$\eta = 1 - \frac{300}{600} = 1 - 0.5 = 0.5$$

$$W = 0.5 \times 4000 = 2000 \text{ J}$$

Final Answer: 2000 J

Answer: (2000)

Q25.

Solution

Concept:

Total kinetic energy (rolling):

$$K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For solid sphere:

$$I = \frac{2}{5}mR^2, \quad \omega = \frac{v}{R}$$

Solution:

Translational KE:

$$= \frac{1}{2} \cdot 2 \cdot 4^2 = 16 \text{ J}$$

Rotational KE:

$$= \frac{1}{2} \cdot \frac{2}{5} \cdot 2 \cdot (4^2)$$

$$= \frac{1}{2} \cdot \frac{4}{5} \cdot 16 = \frac{32}{5} = 6.4 \text{ J}$$

Total:

$$K = 16 + 6.4 = 22.4 \text{ J}$$

Rounded:

$$K \approx 22 \text{ J}$$

Final Answer: 22 J

Answer: (22)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	9	22	40
23	628	24	2000
25	22		