JEE Main Physics Sample Paper-16

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. In a photoelectric effect experiment, the stopping potential V_0 varies with the frequency ν of the incident light. The slope of the V_0 vs ν graph is $4.12 \times 10^{-15}\, V \cdot s$. The value of Planck's constant h is: [JEE Main 2021]

(A) $6.4 \times 10^{-34}\, J \cdot s$

(B) $6.6 \times 10^{-34}\, J \cdot s$

(C) $6.0 \times 10^{-34}\, J \cdot s$

(D) $6.2 \times 10^{-34}\, J \cdot s$

Q2. A radioactive nucleus A has a half-life of 8 years. At $t = 0$, the activity is $10\, mCi$. The activity after 12 years will be: [JEE Main 2023]

(A) $2.5\, mCi$

(B) $5\, mCi$

(C) $3.5\, mCi$

(D) $3.125\, mCi$

Q3. The wavelength of the first line of the Lyman series for hydrogen is λ. The wavelength of the first line of the Balmer series for the same atom is: [JEE Main 2022]

(A) $\frac{5}{27}\lambda$

(B) $\frac{27}{5}\lambda$

(C) $\frac{9}{5}\lambda$

(D) $\frac{5}{9}\lambda$

Q4. A nucleus with mass number 240 breaks into two fragments of mass number 120 each. The binding energy per nucleon (BE/A) of the unfragmented nucleus is 7.6 MeV, while that of fragments is 8.5 MeV. The total gain in binding energy is: [JEE Main 2020]

(A) 216 MeV

(B) 0.9 MeV

(C) 120 MeV

(D) 80 MeV

Q5. Three concentric metallic shells A, B, and C of radii a, b, c $(a < b < c)$ have surface charge densities $\sigma, -\sigma, \sigma$ respectively. The potential of shell B is: [JEE Main 2019]

(A) $\frac{\sigma}{\epsilon_0}\left[\frac{a^2-b^2}{b}+c\right]$

(B) $\frac{\sigma}{\epsilon_0}\left[\frac{a^2+b^2}{b}+c\right]$

(C) $\frac{\sigma}{\epsilon_0}[a+b+c]$

(D) $\frac{\sigma}{\epsilon_0}\left[\frac{b^2-c^2}{c}+a\right]$

Q6. A capacitor of capacitance C is charged to a potential V and then connected in parallel to an uncharged capacitor of capacitance $2C$. The percentage loss of energy is: [JEE Main 2024]

(A) 33%

(B) 50%

(C) 67%

(D) 75%

Q7. A charge Q is distributed over two concentric hollow spheres of radii r and R $(R > r)$ such that their surface charge densities are equal. The potential at the common centre is: [JEE Main 2021]

(A) $\frac{1}{4\pi\epsilon_0}\frac{Q(r+R)}{r^2+R^2}$

(B) $\frac{1}{4\pi\epsilon_0}\frac{Q}{r+R}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{Q(r+R)}{2(r^2+R^2)}$

(D) Zero

Q8. A wire of resistance R is stretched to twice its original length. The new resistance is: [JEE Main 2020]

(A) $2R$

(B) $4R$

(C) $R/2$

(D) $R/4$

Q9. In a Wheatstone bridge, three resistances P, Q, R are connected in three arms and the fourth arm is formed by two resistances S_1 and S_2 in parallel. The condition for bridge balance is: [JEE Main 2022]

(A) $\frac{P}{Q} = \frac{R(S_1+S_2)}{S_1S_2}$

(B) $\frac{P}{Q} = \frac{R}{S_1+S_2}$

(C) $\frac{P}{Q} = \frac{R(S_1S_2)}{S_1+S_2}$

(D) $\frac{P}{Q} = R$

Q10. The current sensitivity of a galvanometer is increased by 20%. If its resistance also increases by 25%, the voltage sensitivity will: [JEE Main 2023]

(A) Decrease by 4%

(B) Increase by 4%

(C) Increase by 45%

(D) Decrease by 1%

Q11. A circular coil of radius $10\,cm$ and 100 turns carries a current of $1\,A$. The magnetic moment of the coil is: [JEE Main 2021]

(A) $3.14\,A \cdot m^2$

(B) $1.57\,A \cdot m^2$

(C) $6.28\,A \cdot m^2$

(D) $10\,A \cdot m^2$

Q12. An alternating voltage $V = 200\sqrt{2}\sin(100t)$ is applied to a $1\,\mu F$ capacitor through an AC ammeter. The reading of the ammeter is: [JEE Main 2024]

(A) $20\,mA$

(B) $2\,mA$

(C) $10\sqrt{2}\,mA$

(D) $80\,mA$

Q13. A conducting rod of length l is rotated with constant angular velocity ω about one end in a uniform magnetic field B perpendicular to the plane of rotation. The induced EMF between the ends is: [JEE Main 2022]

(A) $B\omega l^2$

(B) $\frac{1}{2}B\omega l^2$

(C) $2B\omega l^2$

(D) $\frac{1}{4}B\omega l^2$

Q14. In Young's Double Slit Experiment, the fringe width is $0.4\,mm$. If the whole apparatus is immersed in water of refractive index $4/3$, the new fringe width will be: [JEE Main 2021]

(A) $0.3\,mm$

(B) $0.4\,mm$

(C) $0.53\,mm$

(D) $0.2\,mm$

Q15. A convex lens of focal length $20\,cm$ and a concave mirror of focal length $10\,cm$ are placed coaxially $50\,cm$ apart. An object is placed $30\,cm$ in front of the lens. The final image is formed at: [JEE Main 2023]

(A) $20\,cm$ from mirror

(B) $25\,cm$ from mirror

(C) $30\,cm$ from mirror

(D) infinity

Q16. A beam of unpolarized light is incident on a glass surface at the polarizing angle of $57°$. The angle of refraction is: [JEE Main 2019]

(A) $33°$

(B) $57°$

(C) $90°$

(D) $43°$

Q17. Two Carnot engines A and B are operated in series. Engine A receives heat at $900\,K$ and rejects to a reservoir at $T\,K$. Engine B receives heat rejected by A and rejects to a reservoir at $400\,K$. If the efficiencies are equal, T is: [JEE Main 2022]

(A) $600\,K$

(B) $650\,K$

(C) $700\,K$

(D) $500\,K$

Q18. The root mean square speed of molecules of an ideal gas at $27°C$ is v. If the temperature is raised to $927°C$, the rms speed becomes: [JEE Main 2021]

(A) $2v$

(B) $4v$

(C) $3v$

(D) $v/2$

Q19. A particle executes SHM with an amplitude A. At what displacement from the mean position is the kinetic energy equal to the potential energy? [JEE Main 2020]

(A) $A/2$

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

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

(D) $A/4$

Q20. A string of length L fixed at both ends vibrates in its third harmonic. The distance between adjacent nodes is: [JEE Main 2021]

(A) $L/3$

(B) $L/6$

(C) $2L/3$

(D) $L/2$

Section B — Numerical Questions

Q21. A block of mass 2 kg slides down a rough incline of 30° with a constant speed. The coefficient of kinetic friction between the block and the incline is $\frac{1}{\sqrt{x}}$. Find x. [JEE Main 2023]

Q22. A body of mass m is projected vertically upwards from the surface of the earth with a velocity equal to half the escape velocity. The maximum height attained by the body is R/x, where R is the radius of the earth. Find x. [JEE Main 2022]

Q23. A solid sphere of mass M and radius R rolls without slipping down an incline of height h. The linear velocity of the sphere at the bottom is $\sqrt{\frac{xgh}{7}}$. Find x. [JEE Main 2024]

Q24. The time period of a simple pendulum is $T = 2\pi\sqrt{L/g}$. The measured value of L is 20.0 cm known to 1 mm accuracy and the time for 100 oscillations is found to be 90 s using a watch of 1 s resolution. The percentage error in g is approximately ____%. (Round off to nearest integer). [JEE Main 2021]

Q25. Two moles of a monoatomic ideal gas occupy a volume V at 27°C. The gas is expanded adiabatically to $8V$. The work done by the gas is ____ R. (Take $2^{1/3} = 1.25$ and $\gamma = 5/3$). [JEE Main 2025]

Detailed Solutions

Q1.

Solution

Concept: The photoelectric effect describes how electrons are ejected from a metal surface when it is exposed to light. The stopping potential V_0 is related to the frequency ν of the incident light by the equation:

$$eV_0 = h\nu - \phi$$

where h is Planck's constant, ν is the frequency of the incident light, and ϕ is the work function of the material. The slope of the V_0 vs ν graph gives h/e.

Formula: The slope of the graph is given by:

$$\text{slope} = \frac{h}{e}$$

Solution: Given that the slope of the graph is $4.12 \times 10^{-15}\,\text{V}\cdot\text{s}$, we can calculate h as:

$$h = (4.12 \times 10^{-15}\,\text{V}\cdot\text{s}) \times (1.602 \times 10^{-19}\,\text{C}) = 6.6 \times 10^{-34}\,\text{J}\cdot\text{s}$$

Final Answer: The value of Planck's constant is $6.6 \times 10^{-34}\,\text{J}\cdot\text{s}$.

Answer: (B)

Q2.

Solution

Concept: The activity of a radioactive substance decreases over time according to the half-life formula:

$$A = A_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

where A_0 is the initial activity, t is the time elapsed, and $T_{1/2}$ is the half-life of the substance.

Formula:

$$A = A_0 \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

Solution: For this problem, we have $A_0 = 10\,\text{mCi}$, $T_{1/2} = 8\,\text{years}$, and $t = 12\,\text{years}$. The activity after 12 years is:

$$A = 10\left(\frac{1}{2}\right)^{12/8} = 10\left(\frac{1}{2}\right)^{1.5} = 10 \times 0.3536 = 3.536\,\text{mCi}$$

Final Answer: The activity after 12 years will be $3.5\,\text{mCi}$.

Answer: (D)

Q3.

Solution

Concept: The wavelength of light in the Lyman series and the Balmer series can be derived from the Rydberg formula. For hydrogen, the wavelength of the first line of the Lyman series λ is related to the first line of the Balmer series λ' by a ratio based on the transition levels.

Formula:

$$\frac{\lambda'}{\lambda} = \frac{27}{5}$$

Solution: The wavelength of the first line of the Lyman series is λ, and the wavelength of the first line of the Balmer series is given by:

$$\lambda' = \frac{27}{5}\lambda$$

Final Answer: The wavelength of the first line of the Balmer series is $\frac{27}{5}\lambda$.

Answer: (B)

Q4.

Solution

Concept: The binding energy per nucleon (BE/A) of a nucleus is a measure of the energy required to separate a nucleus into its constituent nucleons. The total gain in binding energy when a nucleus breaks into two smaller nuclei is the difference in their binding energies.

Formula:

$$\text{Gain in binding energy} = A\times(\text{Binding energy per nucleon of fragments})-A\times(\text{Binding energy per nucle}$$

Solution: For the nucleus with mass number 240, the initial binding energy is $BE/A = 7.6\,\text{MeV}$, and for each of the two fragments (with mass number 120), $BE/A = 8.5\,\text{MeV}$. The total gain in binding energy is:

$$\text{Gain} = 240 \times (8.5 - 7.6) = 240 \times 0.9 = 216\,\text{MeV}$$

Final Answer: The total gain in binding energy is $216\,\text{MeV}$.

Answer: (A)

Q5.

Solution

Concept: The potential at a point due to a system of concentric shells is the sum of the potentials from each shell. The potential at shell B is influenced by the other shells and their charges.

Formula:

$$V_B = \frac{\sigma}{\epsilon_0}\left[\frac{a^2 - b^2}{b} + c\right]$$

Solution: Using the provided radii and surface charge densities, we calculate the potential at shell B, considering the contributions from the inner shell and the outer shell.

Final Answer: The potential at shell B is $\frac{\sigma}{\epsilon_0}\left[\frac{a^2-b^2}{b} + c\right]$.

Answer: (A)

Q6.

Solution

Concept: When a capacitor of capacitance C is charged to a potential V and then connected in parallel to an uncharged capacitor of capacitance $2C$, the total energy loss can be calculated from the difference between initial and final energy stored.

Formula:

$$U_{\text{initial}} = \frac{1}{2}CV^2, \quad U_{\text{final}} = \frac{1}{2}(3C)V_f^2$$

Solution: Since the total charge is conserved, $Q = CV = 3CV_f$, so $V_f = \frac{V}{3}$. The final energy is:

$$U_{\text{final}} = \frac{1}{2}(3C)\left(\frac{V}{3}\right)^2 = \frac{1}{6}CV^2$$

The energy loss is:

$$\Delta U = \frac{1}{2}CV^2 - \frac{1}{6}CV^2 = \frac{1}{3}CV^2$$

The percentage loss is:

$$\frac{\Delta U}{U_{\text{initial}}} \times 100 = 33\%$$

Final Answer: The percentage loss of energy is 33%.

Answer: (A)

Q7.

Solution

Concept: The potential at the center of two concentric spheres with equal surface charge densities depends on the radii and the charge distribution.

Formula:

$$V_{\text{center}} = \frac{Q(r+R)}{4\pi\epsilon_0(r^2+R^2)}$$

Solution: Using the formula for the potential due to spherical charge distributions, we find the total potential at the center of the spheres.

Final Answer: The potential at the center is $\frac{Q(r+R)}{4\pi\epsilon_0(r^2+R^2)}$.

Answer: (A)

Q8.

Solution

Concept: When a wire is stretched, its length doubles, and the area of cross-section is halved. This results in an increase in resistance.

Formula:

$$R' = 4R$$

Solution: When the length is doubled, the area is halved, and the resistance increases by a factor of four.

Final Answer: The new resistance is $4R$.

Answer: (B)

Q9.

Solution

Concept: The condition for a balanced Wheatstone bridge is the ratio of resistances in the arms. When the fourth arm is composed of two resistances in parallel, the condition becomes:

$$\frac{P}{Q} = \frac{R(S_1+S_2)}{S_1S_2}$$

Solution: Using the Wheatstone bridge balance condition, we derive the relationship between the resistances in the bridge.

Final Answer: The condition for balance is $\frac{P}{Q} = \frac{R(S_1+S_2)}{S_1S_2}$.

Answer: (A)

Q10.

Solution

Concept: Voltage sensitivity is proportional to the current sensitivity and the resistance of the galvanometer.

Formula:

$$S_v = S_i \times R$$

Solution: If the current sensitivity increases by 20

Final Answer: The voltage sensitivity will increase by 45

Answer: (C)

Q11.

Solution

Concept: The magnetic moment of a coil is given by:

$$\mu = NIA$$

where N is the number of turns, I is the current, and A is the area of the coil.

Formula:

$$\mu = NIA = 100 \times 1 \times \pi(0.1)^2 = 3.14\,\mathrm{A} \cdot \mathrm{m}^2$$

Solution: Using the formula, we find the magnetic moment of the coil.

Final Answer: The magnetic moment is $3.14\,\mathrm{A} \cdot \mathrm{m}^2$.

Answer: (A)

Q12.

Solution

Concept: An alternating voltage applied to a capacitor creates a current. The current through a capacitor is related to the voltage by:

$$I = C\frac{dV}{dt}$$

Solution: For the given AC voltage $V = 200\sqrt{2}\sin(100t)$, we calculate the RMS current. The amplitude of the voltage is $200\sqrt{2}$, and using the relationship for a capacitor:

$$I_{\mathrm{rms}} = \frac{V_{\mathrm{rms}}}{Z} \quad \text{where} \quad Z = \frac{1}{C\omega}$$

After calculating, the RMS current is $20\,\mathrm{mA}$.

Final Answer: The ammeter reading is $20\,\mathrm{mA}$.

Answer: (A)

Q13.

Solution

Concept: A conducting rod moving with constant angular velocity in a magnetic field induces an EMF between its ends.
Formula:

$$\mathcal{E} = \frac{1}{2}B\omega l^2$$

Solution: Using the given values for B, ω, and l, we calculate the induced EMF.
Final Answer: The induced EMF is $\frac{1}{2}B\omega l^2$.

Answer: (B)

Q14.

Solution

Concept: In Young's double-slit experiment, the fringe width depends on the wavelength of the light and the refractive index of the medium.
Formula:

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

Solution: The fringe width in water is:

$$\beta_{\text{new}} = \beta \times \frac{3}{4} = 0.3\,\text{mm}$$

Final Answer: The new fringe width is 0.3 mm.

Answer: (A)

Q15.

Solution

Concept: The combination of a convex lens and a concave mirror forms a complex imaging system. The final image position is calculated by considering the object and image formed by the lens, followed by the mirror.
Solution: The image formed by the lens at 30 cm is 60 cm from the lens. The image formed by the mirror is at 20 cm.
Final Answer: The final image is formed 20 cm from the mirror.

Answer: (A)

Q16.

Solution

Concept: Brewster's angle is the angle at which light is perfectly polarized upon reflection. It is related to the refractive index of the material by:

$$\tan(\theta_B) = n$$

Solution: Given $\theta_B = 57°$, we find that the refractive index is $n = \tan(57°) \approx 1.54$.
Final Answer: The angle of refraction is $33°$.

Answer: (A)

Q17.

Solution

Concept: The efficiency of a Carnot engine is given by:

$$\eta = 1 - \frac{T_{\text{cold}}}{T_{\text{hot}}}$$

Solution: For two Carnot engines operating in series, the efficiencies must be equal, so $T = 600\,\text{K}$.
Final Answer: $T = 600\,\text{K}$.

Answer: (A)

Q18.

Solution

Concept: The root mean square speed of molecules is proportional to the square root of temperature.
Solution: If the temperature increases from $T_1 = 300\,\text{K}$ to $T_2 = 1200\,\text{K}$, the RMS speed becomes $2v$.
Final Answer: The RMS speed is $2v$.

Answer: (A)

Q19.

Solution

Concept: The kinetic energy and potential energy in simple harmonic motion are equal when the displacement is $\frac{A}{\sqrt{2}}$.
Solution:

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

Final Answer: The displacement is $\frac{A}{\sqrt{2}}$.

Answer: (B)

Q20.

Solution

Concept: The distance between adjacent nodes in a standing wave is $\lambda/2$. For the third harmonic, the distance is $L/3$.
Solution: The distance between adjacent nodes is $L/3$.
Final Answer: The distance is $L/3$.

Answer: (A)

Q21.

Solution

Concept: The block slides down the incline with constant speed, meaning the net force along the incline is zero. The frictional force balances the component of gravitational force parallel to the incline. We can use the following equation for kinetic friction:

$$f_k = \mu_k N$$

where N is the normal force, and $\mu_k = \frac{1}{\sqrt{x}}$ is the coefficient of kinetic friction. The normal force is given by:

$$N = mg\cos(\theta)$$

where $m = 2\,\text{kg}$ and $\theta = 30^\circ$. The frictional force is equal to the parallel component of the gravitational force:

$$f_k = mg\sin(\theta)$$

Formula:

$$\mu_k mg\cos(\theta) = mg\sin(\theta)$$

Substitute $\mu_k = \frac{1}{\sqrt{x}}$ and solve for x.
Solution: Substituting the values into the equation:

$$\frac{1}{\sqrt{x}} \cdot 2 \cdot 9.8 \cdot \cos(30^\circ) = 2 \cdot 9.8 \cdot \sin(30^\circ)$$

Solving for x, we find:

$$\frac{1}{\sqrt{x}} \cdot 9.8 \cdot \frac{\sqrt{3}}{2} = 9.8 \cdot \frac{1}{2}$$

$$\frac{1}{\sqrt{x}} = \frac{1}{\sqrt{3}}$$

$$x = 3$$

Final Answer: $x = 3$.

Answer: (3)

Q22.

Solution

Concept: The escape velocity is the minimum velocity required for an object to escape from the Earth's gravitational field. The escape velocity is given by:

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

where M is the mass of the Earth and R is its radius. The problem states that the velocity is half of the escape velocity, and we are asked to find the maximum height attained by the body.

Formula:

$$v = \frac{1}{2}v_e = \frac{1}{2}\sqrt{\frac{2GM}{R}}$$

Solution: The maximum height attained by the body is related to the initial velocity by the following energy conservation equation:

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

Substitute $v = \frac{1}{2}\sqrt{\frac{2GM}{R}}$ and solve for h. We find that the maximum height attained by the body is:

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

Final Answer: $x = 4$.

Answer: (4)

Q23.

Solution

Concept: The solid sphere rolls without slipping, meaning both translational and rotational kinetic energy are involved. The total energy at the bottom of the incline is the sum of translational and rotational kinetic energy:

$$E_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For a solid sphere, $I = \frac{2}{5}mr^2$ and $\omega = \frac{v}{r}$.
Formula:

$$E_{\text{total}} = \frac{1}{2}mv^2 + \frac{1}{2} \times \frac{2}{5}mv^2 = \frac{7}{10}mv^2$$

Solution: Using conservation of energy, the potential energy lost by the sphere is converted into kinetic energy. At the top of the incline, the potential energy is mgh, and at the bottom, the total kinetic energy is:

$$mgh = \frac{7}{10}mv^2$$

Solving for v, we find:

$$v = \sqrt{\frac{7gh}{10}}$$

Since the problem states that the velocity is of the form $\sqrt{\frac{xgh}{7}}$, we find:

$$x = 10$$

Final Answer: $x = 10$.

Answer: (10)

Q24.

Solution

Concept: The time period of a simple pendulum is given by:

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

where L is the length of the pendulum and g is the acceleration due to gravity. The errors in L and time are propagated to calculate the error in g.
Formula: The error in the time period leads to an error in g:

$$\frac{\Delta g}{g} = 2\frac{\Delta L}{L} + \frac{\Delta T}{T}$$

Solution: The measured length is $L = 20.0\,\text{cm} = 0.20\,\text{m}$ with an uncertainty of $1\,\text{mm} = 0.001\,\text{m}$, and the time for 100 oscillations is $90\,\text{s}$, with a resolution of $1\,\text{s}$. The percentage error in g is calculated as:

$$\frac{\Delta g}{g} = 2 \times \frac{0.001}{0.20} + \frac{1}{90} \times 100 = 1\% + 1.11\% \approx 2\%$$

Final Answer: The percentage error in g is approximately 2%.

Answer: (2)

Q25.

Solution

Concept: In an adiabatic expansion, the work done by the gas is given by:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

where γ is the adiabatic index.

Formula: The work done in the adiabatic expansion is also given by:

$$W = nC_V\Delta T$$

Solution: For two moles of a monoatomic ideal gas with $\gamma = \frac{5}{3}$, we use the relation for the work done during an adiabatic process. The volume changes from V to $8V$. Using the equation for work done in an adiabatic process:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

Using the provided values $2^{1/3} = 1.25$, we calculate the work done:

$$W = 4R$$

Final Answer: The work done by the gas is $4R$.

Answer: (4)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	3	22	4
23	10	24	2
25	4		