JEE Main Physics Sample Paper-14

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. A hydrogen-like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by emitting a photon of energy 27.2 eV. Alternatively, the atom may make a transition to the second excited state by emitting a photon of energy 10.2 eV. The value of n and Z are: [JEE Main 2022]

(A) $n = 3, Z = 2$

(B) $n = 4, Z = 3$

(C) $n = 6, Z = 3$

(D) $n = 4, Z = 2$

Q2. The stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength 400 nm is V_0. When the incident wavelength is changed to 300 nm, the stopping potential becomes V_1. If $V_1 - V_0 = 0.8$ V, the work function of the surface is approximately: [JEE Main 2023]

(A) 1.1 eV

(B) 2.3 eV

(C) 1.5 eV

(D) 0.8 eV

Q3. A radioactive nucleus A has a half-life of T. At $t = 0$, there are N_0 nuclei. After a time $t = T/2$, the number of nuclei decayed is: [JEE Main 2021]

(A) $N_0/2$

(B) $N_0\left(1-\frac{1}{\sqrt{2}}\right)$

(C) $\frac{N_0}{\sqrt{2}}$

(D) $N_0\left(1-e^{-1/2}\right)$

Q4. In a Davisson-Germer experiment, the maximum intensity is observed at a scattering angle of 50° for an accelerating voltage of 54 V. If the voltage is increased to 100 V, the new Bragg angle for the first-order maximum is nearly: [JEE Main 2024]

(A) 65°

(B) 45°

(C) 35°

(D) 25°

Q5. A point charge q is placed at a distance d from the center of an uncharged conducting sphere of radius R $(d > R)$. The potential at any point on the surface of the sphere is: [JEE Main 2022]

(A) Zero

(B) $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{d}$

(C) $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{R}$

(D) $\frac{1}{4\pi\epsilon_0} \cdot \frac{q}{\sqrt{d^2-R^2}}$

Q6. Three concentric metallic shells A, B, and C of radii a, b, c $(a < b < c)$ have surface charge densities $+\sigma, -\sigma, +\sigma$ respectively. If the shells A and C are at the same potential, the relation between the radii is: [JEE Main 2021]

(A) $c = a + b$

(B) $a^2 + b^2 = c^2$

(C) $c = b - a$

(D) $a + b + c = 0$

Q7. A capacitor of capacitance C is charged to a potential V and then connected in parallel with an uncharged capacitor of capacitance $2C$. The loss of energy in the process is: [JEE Main 2023]

(A) $\frac{1}{2}CV^2$

(B) $\frac{1}{3}CV^2$

(C) $\frac{1}{4}CV^2$

(D) $\frac{1}{6}CV^2$

Q8. In a Wheatstone bridge circuit, the four arms have resistances $P = 10\Omega, Q = 20\Omega, R = 30\Omega$, and $S = R_x$. If the bridge is balanced, and then P and Q are interchanged, the new value of S to keep the bridge balanced is: [JEE Main 2022]

(A) 15Ω

(B) 60Ω

(C) 120Ω

(D) 30Ω

Q9. A potentiometer wire of length 10 m has a resistance of 20Ω. It is connected in series with a battery of 3 V and a resistance of 10Ω. The potential gradient along the wire is: [JEE Main 2024]

(A) 0.1 V/m

(B) 0.2 V/m

(C) 0.3 V/m

(D) 0.5 V/m

Q10. A copper wire is stretched to make it 0.1% longer. The percentage change in its resistance, assuming the density remains constant, is: [JEE Main 2021]

(A) 0.1%

(B) 0.2%

(C) 0.05%

(D) 0.4%

Q11. A square loop of side L carrying current I is placed in a uniform magnetic field B such that the plane of the loop makes an angle of 30° with the field. The torque acting on the loop is: [JEE Main 2022]

(A) IL^2B

(B) $\frac{1}{2}IL^2B$

(C) $\frac{\sqrt{3}}{2}IL^2B$

(D) Zero

Q12. In an LCR series circuit, the resonance frequency is f. If the capacitance is made 4 times and inductance is made $1/4$ times, the new resonance frequency will be: [JEE Main 2023]

(A) $4f$

(B) $2f$

(C) f

(D) $f/2$

Q13. A conducting rod of length l is rotated with a constant angular velocity ω about one of its ends in a magnetic field B perpendicular to the plane of rotation. The induced emf between the ends of the rod is: [JEE Main 2021]

(A) $Bl\omega$

(B) $Bl^2\omega$

(C) $\frac{1}{2}Bl^2\omega$

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

Q14. A biconvex lens of focal length f is cut into two identical plano-convex lenses by a plane passing through the optical center. The focal length of each part is: [JEE Main 2024]

(A) f

(B) $2f$

(C) $f/2$

(D) ∞

Q15. In Young's double slit experiment, the intensity at a point where path difference is $\lambda/6$ (λ being the wavelength of light) is I. If I_0 denotes the maximum intensity, then I/I_0 is: [JEE Main 2022]

(A) $1/2$

(B) $3/4$

(C) 1/4

(D) 2/3

Q16. A ray of light is incident at an angle i on one face of a prism of small angle A and emerges normally from the other face. If the refractive index of the material is μ, then the angle of incidence i is nearly: [JEE Main 2023]

(A) μA

(B) A/μ

(C) $(\mu - 1)A$

(D) μ/A

Q17. Two Carnot engines A and B are operated in series. The first one A receives heat at 900 K and rejects to a reservoir at temperature T. The second engine B receives heat rejected by the first engine and in turn rejects to a heat reservoir at 400 K. If the efficiencies of the two engines are equal, then the temperature T is: [JEE Main 2021]

(A) 650 K

(B) 600 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 327°C, the new rms speed is: [JEE Main 2022]

(A) $2v$

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

(C) $\sqrt{2}v$

(D) $4v$

Q19. A particle executing SHM has a maximum velocity v_m and maximum acceleration a_m. The amplitude of oscillation is: [JEE Main 2023]

(A) $\frac{v_m^2}{a_m}$

(B) $\frac{a_m^2}{v_m}$

(C) $\frac{v_m}{a_m}$

(D) $\dfrac{v_m^2}{a_m^2}$

Q20. A pipe open at both ends has a fundamental frequency f in air. The pipe is dipped vertically in water so that half of it is in water. The fundamental frequency of the air column is now: [JEE Main 2024]

(A) f

(B) $f/2$

(C) $2f$

(D) $3f/2$

Section B — Numerical Questions

Q21. A block of mass 2 kg is placed on a smooth horizontal surface. Two forces $F_1 = 10\,\text{N}$ and $F_2 = 5\,\text{N}$ act on it in opposite directions. The work done by the net force in moving the block a distance of 4 m is ________ Joules. [JEE Main 2021]

Q22. A body of mass 5 kg is moving in a straight line with a velocity $v = 3s^2 + 2$, where s is the displacement. The work done by the net force during the displacement from $s = 0$ to $s = 2\,\text{m}$ is ________ Joules. [JEE Main 2023]

Q23. A solid sphere of mass M and radius R rolls without slipping down an inclined plane of inclination θ. The acceleration of the center of mass of the sphere is $\frac{x}{7} g \sin\theta$. The value of x is ______. [JEE Main 2022]

Q24. The escape velocity from the surface of Earth is 11.2 km/s. If a planet has a radius twice that of Earth and the same mean density, the escape velocity from its surface is ______ km/s. [JEE Main 2024]

Q25. The density of a material in SI units is $128\,\text{kg/m}^3$. In a unit system where the unit of length is 25 cm and the unit of mass is 50 g, the numerical value of the density of the material is ______. [JEE Main 2021]

Detailed Solutions

Q1.

Solution

Concept: Energy levels of a hydrogen-like atom are

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

and emitted photon energy equals the difference of levels.

Formula:

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

Solution: For transition from higher state n to first excited state ($n_f = 2$),

$$13.6Z^2 \left(\frac{1}{4} - \frac{1}{n^2}\right) = 27.2$$

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

For transition from same higher state n to second excited state ($n_f = 3$),

$$13.6Z^2 \left(\frac{1}{9} - \frac{1}{n^2}\right) = 10.2$$

$$Z^2 \left(\frac{1}{9} - \frac{1}{n^2}\right) = \frac{3}{4} \qquad ...(2)$$

Subtracting (2) from (1),

$$Z^2 \left(\frac{1}{4} - \frac{1}{9}\right) = 2 - \frac{3}{4} = \frac{5}{4}$$

$$Z^2 \cdot \frac{5}{36} = \frac{5}{4}$$

$$Z^2 = 9 \Rightarrow Z = 3$$

Now using (2),

$$9\left(\frac{1}{9} - \frac{1}{n^2}\right) = \frac{3}{4}$$

$$1 - \frac{9}{n^2} = \frac{3}{4}$$

$$\frac{9}{n^2} = \frac{1}{4} \Rightarrow n^2 = 36 \Rightarrow n = 6$$

Final Answer: (C)

Answer: (C)

Q2.

Solution

Concept: Einstein's photoelectric equation:

$$eV_s = \frac{hc}{\lambda} - \phi$$

Formula:

$$V_s = \frac{1}{e}\left(\frac{hc}{\lambda} - \phi\right)$$

Solution: For wavelength 400 nm,

$$eV_0 = \frac{hc}{400} - \phi$$

For wavelength 300 nm,

$$eV_1 = \frac{hc}{300} - \phi$$

Subtracting,

$$e(V_1 - V_0) = hc\left(\frac{1}{300} - \frac{1}{400}\right)$$

Using

$$hc \approx 1240 \text{ eV nm}$$

we get

$$V_1 - V_0 \approx 1240\left(\frac{1}{300} - \frac{1}{400}\right) \approx 1.03 \text{ V}$$

So, as written, the given condition

$$V_1 - V_0 = 0.8 \text{ V}$$

is not consistent, because the difference is independent of work function.
The standard intended version of this question is usually:

$$V_0 = 0.8 \text{ V for } \lambda = 400 \text{ nm}$$

Then

$$\phi = \frac{1240}{400} - 0.8 = 3.1 - 0.8 = 2.3 \text{ eV}$$

Hence the intended answer is
Final Answer: (B)

Answer: (B)

Q3.

Solution

Concept: Radioactive decay law.

Formula:

$$N = N_0 \left(\frac{1}{2}\right)^{t/T}$$

Solution: Given

$$t = \frac{T}{2}$$

Hence,

$$N = N_0 \left(\frac{1}{2}\right)^{1/2} = \frac{N_0}{\sqrt{2}}$$

So number of nuclei decayed is

$$N_0 - N = N_0 - \frac{N_0}{\sqrt{2}} = N_0 \left(1 - \frac{1}{\sqrt{2}}\right)$$

Final Answer: (B)

Answer: (B)

Q4.

Solution

Concept: In Davisson-Germer experiment,

$$n\lambda = 2d\sin\theta$$

where θ is the Bragg angle. For first order maximum, $n = 1$.

Formula:

$$\lambda = \frac{12.27}{\sqrt{V}}\ \text{Å}$$

Solution: For accelerating voltage

$$V_1 = 54\ \text{V}$$

$$\lambda_1 = \frac{12.27}{\sqrt{54}} \approx 1.67\ \text{Å}$$

Given scattering angle is 50°, so Bragg angle is

$$\theta_1 = \frac{50^\circ}{2} = 25^\circ$$

Using Bragg condition,

$$d = \frac{\lambda_1}{2\sin 25^\circ} = \frac{1.67}{2\sin 25^\circ} \approx 1.98\ \text{Å}$$

Now for

$$V_2 = 100\ \text{V}$$

$$\lambda_2 = \frac{12.27}{10} = 1.227\ \text{Å}$$

Again for first order,

$$\lambda_2 = 2d\sin\theta_2$$

$$1.227 = 2(1.98)\sin\theta_2$$

$$\sin\theta_2 \approx 0.31 \Rightarrow \theta_2 \approx 18^\circ$$

Hence new scattering angle is

$$2\theta_2 \approx 36^\circ$$

which is nearly

$$35^\circ$$

Final Answer: (C)

Answer: (C)

Q5.

Solution

Concept: An external charge induces charges on the conducting sphere, but the sphere remains an equipotential surface.

Solution: Since the sphere is uncharged, induced charges appear on its surface such that net induced charge is zero.

For an isolated uncharged conducting sphere in presence of an external charge q at distance d, the whole sphere comes to a uniform potential equal to the potential at its center due to the external charge, i.e.

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{d}$$

Thus every point on the surface of the sphere is at the same potential

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q}{d}$$

Final Answer: (B)

Answer: (B)

Q6.

Solution

Concept: Potential at a point due to a charged spherical shell is:

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{R} \quad \text{(on or outside shell)}$$

and inside a shell it remains constant equal to surface potential.
Solution: Charges on the shells are

$$Q_A = 4\pi a^2\sigma, \qquad Q_B = -4\pi b^2\sigma, \qquad Q_C = 4\pi c^2\sigma$$

Potential of shell A:

$$V_A = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_A}{a} + \frac{Q_B}{b} + \frac{Q_C}{c}\right)$$

$$V_A = \frac{\sigma}{\epsilon_0}(a - b + c)$$

Potential of shell C:

$$V_C = \frac{1}{4\pi\epsilon_0}\left(\frac{Q_A + Q_B + Q_C}{c}\right)$$

$$V_C = \frac{\sigma}{\epsilon_0}\cdot\frac{a^2 - b^2 + c^2}{c}$$

Given

$$V_A = V_C$$

so

$$a - b + c = \frac{a^2 - b^2 + c^2}{c}$$

Multiplying by c,

$$ac - bc + c^2 = a^2 - b^2 + c^2$$

$$c(a - b) = a^2 - b^2 = (a - b)(a + b)$$

Hence

$$c = a + b$$

Final Answer: (A)

Answer: (A)

Q7.

Solution

Concept: When capacitors are connected in parallel, charge redistributes and some energy is lost as heat.

Formula:

$$U = \frac{1}{2}CV^2$$

Solution: Initially, only capacitor C is charged:

$$Q = CV$$

Initial energy,

$$U_i = \frac{1}{2}CV^2$$

Now it is connected in parallel with an uncharged capacitor $2C$.

Total capacitance:

$$C_{\text{eq}} = C + 2C = 3C$$

Final common potential:

$$V_f = \frac{Q}{C_{\text{eq}}} = \frac{CV}{3C} = \frac{V}{3}$$

Final energy:

$$U_f = \frac{1}{2}(3C)\left(\frac{V}{3}\right)^2 = \frac{1}{2}(3C)\frac{V^2}{9} = \frac{1}{6}CV^2$$

Loss of energy:

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

Final Answer: (B)

Answer: (B)

Q8.

Solution

Concept: Wheatstone bridge is balanced when

$$\frac{P}{Q} = \frac{R}{S}$$

Solution: Initially,

$$P = 10\Omega, \quad Q = 20\Omega, \quad R = 30\Omega, \quad S = R_x$$

For balance,

$$\frac{10}{20} = \frac{30}{R_x}$$

$$\frac{1}{2} = \frac{30}{R_x} \Rightarrow R_x = 60\Omega$$

Now P and Q are interchanged, so

$$P = 20\Omega, \quad Q = 10\Omega$$

Again for balance,

$$\frac{20}{10} = \frac{30}{S}$$

$$2 = \frac{30}{S} \Rightarrow S = 15\Omega$$

Final Answer: (A)

Answer: (A)

Q9.

Solution

Concept: Potential gradient along potentiometer wire is

$$k = \frac{V_{\text{wire}}}{L}$$

Solution: Resistance of wire

$$R_w = 20\Omega$$

Series resistance

$$R = 10\Omega$$

Battery voltage

$$V = 3 \text{ V}$$

Total resistance:

$$R_{\text{total}} = 20 + 10 = 30\Omega$$

Current in the circuit:

$$I = \frac{V}{R_{\text{total}}} = \frac{3}{30} = 0.1 \text{ A}$$

Potential drop across the potentiometer wire:

$$V_{\text{wire}} = IR_w = 0.1 \times 20 = 2 \text{ V}$$

Length of wire:

$$L = 10 \text{ m}$$

Hence potential gradient:

$$k = \frac{2}{10} = 0.2 \text{ V/m}$$

Final Answer: (B)

Answer: (B)

Q10.

Solution

Concept: Resistance of a wire is

$$R = \rho \frac{L}{A}$$

If density remains constant, volume remains constant:

$$AL = \text{constant} \Rightarrow A \propto \frac{1}{L}$$

Solution: Since

$$A \propto \frac{1}{L}$$

therefore

$$R = \rho \frac{L}{A} \propto L^2$$

Hence fractional change in resistance is

$$\frac{\Delta R}{R} = 2\frac{\Delta L}{L}$$

Given increase in length is

$$0.1\%$$

So

$$\%\Delta R = 2 \times 0.1\% = 0.2\%$$

Final Answer: (B)

Answer: (B)

Q11.

Solution

Concept: Torque on a current loop:

$$\tau = MB\sin\theta$$

where

$$M = IA$$

and θ is the angle between magnetic moment and magnetic field.
Solution: Area of square loop:

$$A = L^2$$

So magnetic moment is

$$M = IL^2$$

The plane of the loop makes angle 30° with the field, hence the normal to the loop makes angle

$$\theta = 90^\circ - 30^\circ = 60^\circ$$

Therefore torque is

$$\tau = IL^2B\sin 60^\circ = IL^2B \cdot \frac{\sqrt{3}}{2}$$

$$\tau = \frac{\sqrt{3}}{2}IL^2B$$

Final Answer: (C)

Answer: (C)

Q12.

Solution

Concept: Resonance frequency of an LCR series circuit is

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Solution: Initially,

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Now

$$C' = 4C, \qquad L' = \frac{L}{4}$$

So new resonance frequency is

$$f' = \frac{1}{2\pi\sqrt{L'C'}} = \frac{1}{2\pi\sqrt{\left(\frac{L}{4}\right)(4C)}}$$

$$f' = \frac{1}{2\pi\sqrt{LC}} = f$$

Final Answer: (C)

Answer: (C)

Q13.

Solution

Concept: Motional emf induced in a rod rotating in a uniform magnetic field.
Formula:

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

Solution: A small element at distance r from the axis has speed

$$v = \omega r$$

So small emf across element dr is

$$d\mathcal{E} = Bv\,dr = B\omega r\,dr$$

Integrating from

$$r = 0 \text{ to } r = l$$

$$\mathcal{E} = \int_0^l B\omega r\,dr = B\omega\left[\frac{r^2}{2}\right]_0^l$$

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

Final Answer: (C)

Answer: (C)

Q14.

Solution

Concept: Lens maker's formula:

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Solution: Let the original biconvex lens be symmetrical with radii

$$R_1 = R, \qquad R_2 = -R$$

Then

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{-R}\right) = (\mu - 1)\left(\frac{2}{R}\right)$$

$$\frac{1}{f} = \frac{2(\mu - 1)}{R}$$

After cutting through the optical center, each part becomes a plano-convex lens. For each plano-convex part,

$$R_1 = R, \qquad R_2 = \infty$$

Hence

$$\frac{1}{f'} = (\mu - 1)\left(\frac{1}{R} - 0\right) = \frac{(\mu - 1)}{R}$$

Comparing,

$$\frac{1}{f'} = \frac{1}{2} \cdot \frac{1}{f} \Rightarrow f' = 2f$$

Final Answer: (B)

Answer: (B)

Q15.

Solution

Concept: In YDSE, intensity at phase difference ϕ is

$$I = I_{\max} \cos^2 \frac{\phi}{2}$$

for equal intensities.
Solution: Given path difference

$$\Delta x = \frac{\lambda}{6}$$

Hence phase difference is

$$\phi = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{6} = \frac{\pi}{3}$$

Therefore

$$\frac{I}{I_0} = \cos^2 \frac{\phi}{2} = \cos^2 \frac{\pi}{6}$$

$$\frac{I}{I_0} = \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}$$

Final Answer: (B)

Answer: (B)

Q16.

Solution

Concept: For a prism,

$$r_1 + r_2 = A$$

Solution: The ray emerges normally from the second face, so angle of emergence is zero. Therefore inside the prism at second face,

$$r_2 = 0$$

Hence

$$r_1 + r_2 = A \Rightarrow r_1 = A$$

Now applying Snell's law at first face,

$$\sin i = \mu \sin r_1 = \mu \sin A$$

For a small angle prism,

$$\sin A \approx A, \qquad \sin i \approx i$$

Thus

$$i \approx \mu A$$

Final Answer: (A)

Answer: (A)

Q17.

Solution

Concept: Efficiency of a Carnot engine:

$$\eta = 1 - \frac{T_2}{T_1}$$

Solution: For engine A:

$$T_1 = 900\text{ K}, \qquad T_2 = T$$

So

$$\eta_A = 1 - \frac{T}{900}$$

For engine B:

$$T_1 = T, \qquad T_2 = 400\text{ K}$$

So

$$\eta_B = 1 - \frac{400}{T}$$

Given

$$\eta_A = \eta_B$$

Therefore

$$1 - \frac{T}{900} = 1 - \frac{400}{T}$$

$$\frac{T}{900} = \frac{400}{T}$$

$$T^2 = 900 \times 400 = 360000$$

$$T = 600\text{ K}$$

Final Answer: (B)

Answer: (B)

Q18.

Solution

Concept: RMS speed of gas molecules varies as square root of absolute temperature:

$$v_{\text{rms}} \propto \sqrt{T}$$

Solution: Initial temperature:

$$27^\circ\text{C} = 300\ \text{K}$$

Final temperature:

$$327^\circ\text{C} = 600\ \text{K}$$

Hence

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{600}{300}} = \sqrt{2}$$

Therefore

$$v_2 = \sqrt{2}\,v$$

Final Answer: (C)

Answer: (C)

Q19.

Solution

Concept: For SHM,

$$v_m = \omega A, \qquad a_m = \omega^2 A$$

Solution: From

$$v_m = \omega A$$

we get

$$\omega = \frac{v_m}{A}$$

Now

$$a_m = \omega^2 A$$

Substituting $\omega = \dfrac{v_m}{A}$,

$$a_m = \left(\frac{v_m}{A}\right)^2 A = \frac{v_m^2}{A}$$

Hence

$$A = \frac{v_m^2}{a_m}$$

Final Answer: (A)

Answer: (A)

Q20.

Solution

Concept: Fundamental frequency of an open pipe:

$$f = \frac{v}{2L}$$

Fundamental frequency of a closed pipe:

$$f = \frac{v}{4L}$$

Solution: Initially the pipe is open at both ends, so

$$f = \frac{v}{2L}$$

Now the pipe is dipped in water so that half of it is in water. Hence the air column length becomes

$$L' = \frac{L}{2}$$

and the lower end behaves as a closed end.
So the air column is now a closed pipe of length $L/2$.
Therefore new fundamental frequency is

$$f' = \frac{v}{4(L/2)} = \frac{v}{2L}$$

Thus

$$f' = f$$

Final Answer: (A)

Answer: (A)

Q21.

Solution

Concept: Work done by constant force:

$$W = F_{\text{net}} \cdot s$$

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Solution: Given forces are opposite:

$$F_1 = 10 \text{ N}, \quad F_2 = 5 \text{ N}$$

Net force:

$$F_{\text{net}} = 10 - 5 = 5 \text{ N}$$

Displacement:

$$s = 4 \text{ m}$$

So work done:

$$W = F_{\text{net}} \cdot s = 5 \times 4 = 20 \text{ J}$$

Final Answer: $W = 20$ J

Answer: (20)

Q22.

Solution

Concept: Work done by variable force:

$$W = \int F\,ds$$

Also,

$$F = m\frac{dv}{dt} = mv\frac{dv}{ds}$$

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Solution: Given

$$v = 3s^2 + 2$$

So

$$\frac{dv}{ds} = 6s$$

Thus force:

$$F = mv\frac{dv}{ds} = 5(3s^2 + 2)(6s) = 30s(3s^2 + 2)$$

Work done:

$$W = \int_0^2 F\,ds = \int_0^2 30s(3s^2 + 2)\,ds$$

$$= 30\int_0^2 (3s^3 + 2s)\,ds = 30\left[\frac{3s^4}{4} + s^2\right]_0^2$$

$$= 30\left(\frac{3 \times 16}{4} + 4\right) = 30(12 + 4) = 30 \times 16 = 480 \text{ J}$$

Final Answer: $W = 480$ J

Answer: (480)

Q23.

Solution

Concept: Acceleration of rolling body:

$$a = \frac{g \sin\theta}{1 + \frac{I}{mR^2}}$$

For solid sphere:

$$I = \frac{2}{5}mR^2$$

Solution:

$$a = \frac{g \sin\theta}{1 + \frac{2}{5}} = \frac{g \sin\theta}{\frac{7}{5}} = \frac{5}{7}g \sin\theta$$

Comparing with

$$a = \frac{x}{7}g \sin\theta$$

we get

$$x = 5$$

Final Answer: $x = 5$

Answer: (5)

Q24.

Solution

Concept: Escape velocity:

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

Also mass:

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

Solution:

$$v_e = \sqrt{\frac{2G \cdot \frac{4}{3}\pi R^3 \rho}{R}} = \sqrt{\frac{8}{3}\pi G \rho R^2}$$

Thus

$$v_e \propto R$$

If radius doubles:

$$v_e' = 2v_e$$

Given Earth escape velocity:

$$v_e = 11.2 \text{ km/s}$$

So

$$v_e' = 2 \times 11.2 = 22.4 \text{ km/s}$$

Final Answer: 22.4 km/s

Answer: (22.4)

Q25.

Solution

Concept: Density:

$$\rho = \frac{M}{L^3}$$

Solution: Given:

$$\rho = 128 \text{ kg/m}^3$$

New unit of mass:

$$1M' = 50 \text{ g} = 0.05 \text{ kg}$$

New unit of length:

$$1L' = 25 \text{ cm} = 0.25 \text{ m}$$

So

$$1L'^3 = (0.25)^3 = 0.015625 \text{ m}^3$$

Now numerical value:

$$\rho' = \rho \times \frac{(L')^3}{M'}$$

$$\rho' = 128 \times \frac{0.015625}{0.05}$$

$$= 128 \times 0.3125 = 40$$

Final Answer: 40

Answer: (40)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	20	22	480
23	5	24	22.4
25	40		