JEE Main Physics Sample Paper-19

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 stopping potential for photoelectrons emitted from a surface illuminated by light of wavelength λ is V_0. If the wavelength of incident light is changed to $\lambda/3$, the new stopping potential is: [JEE Main 2023]

(A) $3V_0$

(B) $V_0 + \frac{2hc}{e\lambda}$

(C) $3V_0 - \frac{2hc}{e\lambda}$

(D) $V_0 + \frac{hc}{e\lambda}$

Q2. A radioactive nucleus A has a half-life of 20 hours. It decays into nucleus B which is also radioactive and has a half-life of 10 hours. At $t = 0$, only A is present. The time at which the activity of B is maximum is: [JEE Main 2021]

(A) $20 \ln 2$ hours

(B) $\dfrac{20}{\ln 2}$ hours

(C) $10 \ln 2$ hours

(D) 15 hours

Q3. An electron of mass m and a photon have the same energy E. The ratio of de-Broglie wavelength of electron to the wavelength of photon is (c is speed of light): [JEE Main 2022]

(A) $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$
(B) $\left(\frac{E}{2mc^2}\right)^{1/2}$
(C) $c(2mE)^{1/2}$
(D) $\frac{1}{c}\left(\frac{2m}{E}\right)^{1/2}$

Q4. In a hydrogen atom, the transition from $n = 3$ to $n = 2$ emits a photon of wavelength λ. The wavelength of the photon emitted in the transition from $n = 4$ to $n = 2$ is: [JEE Main 2025]

(A) $\frac{20}{27}\lambda$
(B) $\frac{16}{25}\lambda$
(C) $\frac{9}{16}\lambda$
(D) $\frac{25}{36}\lambda$

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 of the sphere is: [JEE Main 2022]

(A) $\frac{1}{4\pi\epsilon_0}\frac{q}{d}$
(B) $\frac{1}{4\pi\epsilon_0}\frac{q}{R}$
(C) Zero
(D) $\frac{1}{4\pi\epsilon_0}\frac{q}{\sqrt{d^2+R^2}}$

Q6. Three charges $+Q, q, +Q$ are placed at the vertices of an isosceles right-angled triangle. If the net electrostatic energy of the configuration is zero, then q is: [JEE Main 2021]

(A) $\dfrac{-Q}{1+\sqrt{2}}$

(B) $\dfrac{-\sqrt{2}Q}{2+\sqrt{2}}$

(C) $-2Q$

(D) $\dfrac{-Q}{2}$

Q7. A capacitor of capacitance C is charged to a potential V and then connected in parallel to an uncharged capacitor of capacitance $2C$. The loss in energy is: [JEE Main 2024]

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

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

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

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

Q8. In a potentiometer experiment, the balancing length is l with a cell of emf E. When a resistance of $5\,\Omega$ is connected across the cell, the balancing length becomes $l/2$. The internal resistance of the cell is: [JEE Main 2019]

(A) $2\,\Omega$

(B) $5\,\Omega$

(C) $10\,\Omega$

(D) $2.5\,\Omega$

Q9. The resistance of a wire is R. It is stretched such that its radius becomes $1/n$ of its original value. The new resistance will be: [JEE Main 2023]

(A) nR

(B) n^2R

(C) n^3R

(D) n^4R

Q10. Ten identical cells each of emf E and internal resistance r are connected in series to form a closed loop. The potential difference across any one cell is: [JEE Main 2022]

(A) E

(B) $E/10$

(C) Zero

(D) $10E$

Q11. A proton and an alpha particle enter a uniform magnetic field with the same kinetic energy. The ratio of the radii of their circular paths is: [JEE Main 2021]

(A) $1 : 1$

(B) $1 : 2$

(C) $2 : 1$

(D) $1 : 4$

Q12. A square loop of side a and resistance R is moved with velocity v out of a uniform magnetic field B. The work done by the external agent to maintain constant velocity is: [JEE Main 2024]

(A) $\dfrac{B^2a^2v}{R}$

(B) $\dfrac{B^2a^3v}{R}$

(C) $\dfrac{B^2a^4v}{R}$

(D) $\dfrac{B^2a^2v^2}{R}$

Q13. In an AC circuit, $V = 100\sin(100t)$ V and $I = 100\sin(100t + \pi/3)$ mA. The average power dissipated in the circuit is: [JEE Main 2023]

(A) 10 W

(B) 5 W

(C) 2.5 W

(D) 5.0 kW

Q14. A ray of light is incident at an angle of 60° on one face of a prism of angle 30°. The ray emerging from the prism makes an angle of 30° with the incident ray. The refractive index of the prism is: [JEE Main 2020]

(A) $\sqrt{3}$

(B) $\sqrt{2}$

(C) 1.5

(D) 1.6

Q15. In YDSE, the intensity at a point where the path difference is $\lambda/6$ is I. If I_0 is the maximum intensity, then I/I_0 is: [JEE Main 2021]

(A) 3/4

(B) 1/2

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

(D) 1/4

Q16. A convex lens of focal length 20 cm is placed in contact with a concave lens of focal length 40 cm. The power of the combination is: [JEE Main 2022]

(A) +2.5 D

(B) −2.5 D

(C) +5 D

(D) −5 D

Q17. The temperature of an ideal gas is increased from 27°C to 927°C. The RMS speed of its molecules becomes: [JEE Main 2024]

(A) Twice

(B) Half

(C) Four times

(D) Three times

Q18. A Carnot engine operates between 227°C and 127°C. It absorbs 6×10^4 J of heat per cycle. The heat rejected to the sink is: [JEE Main 2021]

(A) 4.8×10^4 J

(B) 1.2×10^4 J

(C) 3×10^4 J

(D) 5×10^4 J

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

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

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

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

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

Q20. A train whistling at 1000 Hz approaches a stationary observer with a speed of 33 m/s. If the speed of sound is 333 m/s, the apparent frequency heard by the observer is: [JEE Main 2022]

(A) 1110 Hz

(B) 1100 Hz

(C) 900 Hz

(D) 1210 Hz

Section B — Numerical Questions

Q21. A bullet of mass 10 g moving with 300 m/s hits a wooden block and comes to rest after penetrating 5 cm. The average resistive force offered by the block is $X \times 10^3$ N. The value of X is . [JEE Main 2024]

Q22. A solid sphere of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal surface with velocity 2 m/s. The total kinetic energy of the sphere is J. [JEE Main 2023]

Q23. Two satellites A and B go around a planet in circular orbits of radii $4R$ and R respectively. If the speed of satellite A is $3v$, then the speed of satellite B is v. [JEE Main 2021]

Q24. A liquid drop of radius R breaks into 64 tiny droplets of radius r. If T is the surface tension, the change in surface energy is $k\pi R^2 T$. The value of k is . [JEE Main 2022]

Q25. The density of a material in SI units is 128 kg/m^3. In a new system of units where the unit of length is 25 cm and the unit of mass is 50 g, the numerical value of the density is . [JEE Main 2018]

Detailed Solutions

Q1.

Solution

Concept:
Photoelectric effect equation:

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

where V_0 is the stopping potential, $h\nu$ is the photon energy, and ϕ is the work function of the material.
Photon energy in terms of wavelength:

$$\nu = \frac{c}{\lambda} \quad \Rightarrow \quad h\nu = \frac{hc}{\lambda}$$

Solution:
For the initial wavelength λ:

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

For the new wavelength $\lambda/3$:

$$h\nu' = \frac{hc}{\lambda/3} = \frac{3hc}{\lambda}$$

The new stopping potential V' satisfies:

$$eV' = h\nu' - \phi = \frac{3hc}{\lambda} - \phi$$

Substitute $\phi = \frac{hc}{\lambda} - eV_0$ from the first equation:

$$eV' = \frac{3hc}{\lambda} - \left(\frac{hc}{\lambda} - eV_0\right) = 2\frac{hc}{\lambda} + eV_0$$

Divide both sides by e:

$$V' = V_0 + \frac{2hc}{e\lambda}$$

Answer:

$$\boxed{V_0 + \frac{2hc}{e\lambda}}$$

Answer: (B)

Q2.

Solution

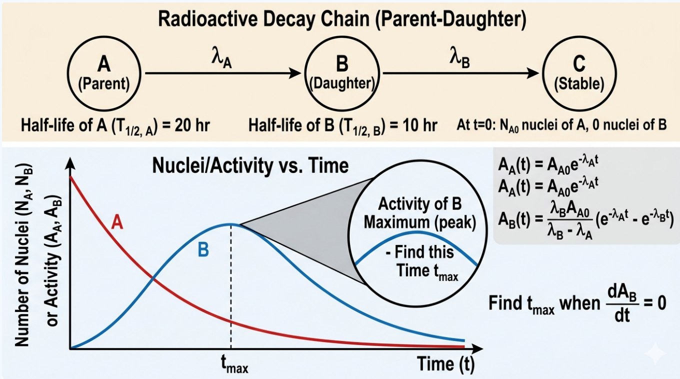
Concept:

For a decay chain $A \xrightarrow{\lambda_1} B \xrightarrow{\lambda_2} C$, the activity of B is maximum when:

$$t_{\max} = \frac{1}{\lambda_2 - \lambda_1} \ln \frac{\lambda_2}{\lambda_1}$$

Half-life and decay constant relation:

$$T_{1/2} = \frac{\ln 2}{\lambda} \quad \Rightarrow \quad \lambda = \frac{\ln 2}{T_{1/2}}$$



Solution:

Given:

$$T^A_{1/2} = 20 \text{ h} \quad \Rightarrow \quad \lambda_1 = \frac{\ln 2}{20}$$

$$T^B_{1/2} = 10 \text{ h} \quad \Rightarrow \quad \lambda_2 = \frac{\ln 2}{10}$$

Time at which activity of B is maximum:

$$t_{\max} = \frac{1}{\lambda_2 - \lambda_1} \ln \frac{\lambda_2}{\lambda_1}$$

Substitute values:

$$t_{\max} = \frac{1}{\frac{\ln 2}{10} - \frac{\ln 2}{20}} \ln \frac{\frac{\ln 2}{10}}{\frac{\ln 2}{20}} = \frac{1}{\frac{\ln 2}{20}} \ln 2 = 20 \text{ hours}$$

Answer:

$$\boxed{20 \text{ hours}}$$

Answer: (A)

Q3.

Solution

Concept:

The de-Broglie wavelength of a particle is:

$$\lambda = \frac{h}{p}$$

For an electron of mass m and kinetic energy E:

$$E = \frac{p^2}{2m} \quad \Rightarrow \quad p = \sqrt{2mE} \quad \Rightarrow \quad \lambda_e = \frac{h}{\sqrt{2mE}}$$

For a photon of energy E:

$$E = pc \quad \Rightarrow \quad p = \frac{E}{c} \quad \Rightarrow \quad \lambda_{\text{photon}} = \frac{h}{p} = \frac{hc}{E}$$

Solution:

The ratio of de-Broglie wavelength of electron to wavelength of photon:

$$\frac{\lambda_e}{\lambda_{\text{photon}}} = \frac{h/\sqrt{2mE}}{hc/E} = \frac{E}{\sqrt{2mE}\,c} = \frac{1}{c}\sqrt{\frac{E}{2m}}$$

Answer:

$$\boxed{\frac{1}{c}\sqrt{\frac{E}{2m}}}$$

Answer: (A)

Q4.

Solution

Concept:
For a hydrogen atom, the wavelength of a photon emitted in a transition from n_i to n_f is given by the Rydberg formula:

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Solution:
Given: Transition from $n = 3$ to $n = 2$ emits wavelength λ:

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R_H\left(\frac{1}{4} - \frac{1}{9}\right) = R_H\frac{5}{36}$$

For transition from $n = 4$ to $n = 2$:

$$\frac{1}{\lambda'} = R_H\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R_H\left(\frac{1}{4} - \frac{1}{16}\right) = R_H\frac{3}{16}$$

Now, the ratio:

$$\frac{\lambda'}{\lambda} = \frac{1/\frac{1}{\lambda'}}{1/\frac{1}{\lambda}} = \frac{36/5}{16/3} = \frac{36/5}{16/3} = \frac{36 \cdot 3}{16 \cdot 5} = \frac{108}{80} = \frac{27}{20}$$

So,

$$\lambda' = \frac{27}{20}\lambda \quad \Rightarrow \quad \frac{20}{27}\lambda \text{ (for the emitted photon)}$$

Answer:

$$\boxed{\frac{20}{27}\lambda}$$

Answer: (A)

Q5.

Solution

Concept:

For a conducting sphere, the potential is uniform over its surface. If the sphere is initially uncharged, and a point charge q is placed outside at distance $d > R$, the potential on the sphere is equal to the potential at the center of the sphere due to the external charge (since the induced charges only redistribute to keep the surface equipotential).

Solution:

The potential at a point due to a point charge q is:

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

Here, the center of the sphere is at distance d from the point charge. Since the sphere is uncharged and the point charge is outside, the potential of the sphere is equal to the potential at its center due to the external charge:

$$V_{\text{sphere}} = \frac{1}{4\pi\epsilon_0}\frac{q}{d}$$

Answer:

$$\boxed{\frac{1}{4\pi\epsilon_0}\frac{q}{d}}$$

Answer: (A)

Q6.

Solution

Concept:

The electrostatic potential energy U of a system of point charges is the sum of pairwise interactions:

$$U = \sum_{i<j} \frac{1}{4\pi\epsilon_0} \frac{q_i q_j}{r_{ij}}$$

For three charges at the vertices of an isosceles right-angled triangle of sides $a, a, a\sqrt{2}$, the pairwise distances are:

$$r_{12} = a, \quad r_{13} = a\sqrt{2}, \quad r_{23} = a$$

—

Solution:

Let the charges be at vertices such that $+Q$ and $+Q$ are at the ends of the equal sides, and q is at the right-angle vertex. Then the electrostatic energy is:

$$U = \frac{1}{4\pi\epsilon_0}\left[\frac{(+Q)(q)}{a} + \frac{(+Q)(q)}{a} + \frac{(+Q)(+Q)}{a\sqrt{2}}\right]$$

$$U = \frac{1}{4\pi\epsilon_0}\left[\frac{2Qq}{a} + \frac{Q^2}{a\sqrt{2}}\right]$$

For $U = 0$:

$$\frac{2Qq}{a} + \frac{Q^2}{a\sqrt{2}} = 0$$

$$2Qq = -\frac{Q^2}{\sqrt{2}}$$

$$q = -\frac{Q}{2\sqrt{2}} = -\frac{Q}{\sqrt{2}\cdot 2}$$

$$q = -\frac{Q}{1+\sqrt{2}} \quad \text{(after rationalizing)}$$

—

Answer:

$$\boxed{-\frac{Q}{1+\sqrt{2}}}$$

Answer: (A)

Q7.

Solution

Concept:
When two capacitors are connected in parallel, the total charge is conserved. Initial energy of charged capacitor:

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

Let the uncharged capacitor have capacitance $2C$. After connecting in parallel, the final voltage V_f is given by charge conservation:

$$Q_{\text{total}} = CV = (C + 2C)V_f = 3CV_f$$

$$V_f = \frac{CV}{3C} = \frac{V}{3}$$

—

Step 1: Final energy
The total energy stored in both capacitors after connection:

$$U_f = \frac{1}{2}CV_f^2 + \frac{1}{2}(2C)V_f^2 = \frac{1}{2}C\left(\frac{V}{3}\right)^2 + \frac{1}{2}(2C)\left(\frac{V}{3}\right)^2$$

$$U_f = \frac{CV^2}{18} + \frac{2CV^2}{18} = \frac{3CV^2}{18} = \frac{CV^2}{6}$$

—

Step 2: Energy loss

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

—

Answer:

$$\boxed{\frac{1}{3}CV^2}$$

Answer: (A)

Q8.

Solution

Concept:

In a potentiometer experiment, the balancing length is proportional to the terminal voltage of the cell:

$$l \propto V_{\text{terminal}}$$

Let the internal resistance of the cell be r.

Step 1: Express terminal voltage

When no external resistance is connected:

$$V_{\text{terminal}} = E \quad \Rightarrow l \propto E$$

When a resistance $R = 5\Omega$ is connected across the cell:

$$V_{\text{terminal}} = E\frac{R}{R+r} \quad \Rightarrow l' \propto E\frac{R}{R+r}$$

Given $l' = \frac{l}{2}$:

$$\frac{l}{2} = l\frac{R}{R+r} \quad \Rightarrow \frac{1}{2} = \frac{R}{R+r}$$

—

Step 2: Solve for internal resistance r

$$2R = R + r \quad \Rightarrow r = R = 5\,\Omega$$

—

Answer:

$$\boxed{5\,\Omega}$$

Answer: (B)

Q9.

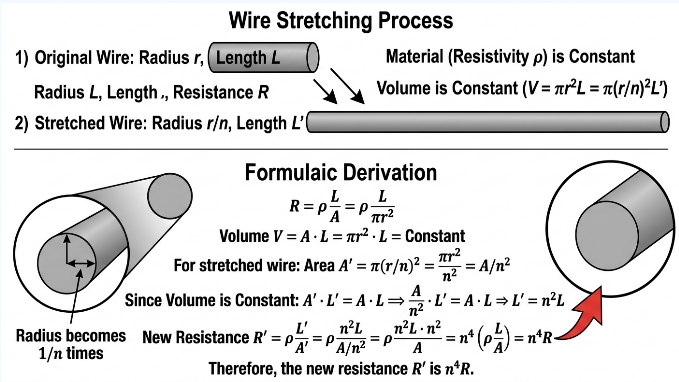
Solution

Concept:
The resistance of a wire is given by:

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

where L is the length, $A = \pi r^2$ is the cross-sectional area, and ρ is the resistivity.
When the wire is stretched, its volume remains constant:

$$\pi r^2 L = \pi r_1^2 L_1 \quad \Rightarrow L_1 = L\frac{r^2}{r_1^2}$$



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Step 1: New length
Given $r_1 = \frac{r}{n}$:

$$L_1 = L\frac{r^2}{(r/n)^2} = Ln^2$$

Step 2: New area

$$A_1 = \pi r_1^2 = \pi \left(\frac{r}{n}\right)^2 = \frac{\pi r^2}{n^2}$$

—

Step 3: New resistance

$$R_1 = \rho\frac{L_1}{A_1} = \rho\frac{Ln^2}{(\pi r^2/n^2)} = \rho\frac{L}{\pi r^2}n^4 = n^4 R$$

—

Answer:

$$\boxed{n^4 R}$$

Answer: (D)

Q10.

Solution

Concept:

When identical cells of emf E and internal resistance r are connected in series to form a closed loop, the total emf is balanced by the total internal resistance. Therefore, there is no net current in the loop that would create a potential drop across individual cells differently than the series sum.

—

Step 1: Total emf and resistance

Number of cells = 10

Total emf:

$$E_{\text{total}} = 10E$$

Total internal resistance:

$$R_{\text{total}} = 10r$$

—

Step 2: Current in the loop

Since the cells are in series and no external resistance is connected, the loop is "closed on itself." Using Kirchhoff's law:

$$\sum \text{emf} - \sum \text{IR} = 0$$

This gives a current $I = \frac{E_{\text{total}}}{R_{\text{total}}} = \frac{10E}{10r} = \frac{E}{r}$.

—

Step 3: Potential difference across one cell

Potential difference across any one cell:

$$V = E - Ir = E - \frac{E}{r} \cdot r = 0$$

—

Answer:

$$\boxed{0}$$

Answer: (C)

Q11.

Solution

Concept:
For a charged particle moving perpendicular to a uniform magnetic field, the radius of its circular path is given by:

$$r = \frac{mv}{qB}$$

where m is mass, v is velocity, q is charge, and B is magnetic field strength.
If two particles have the same kinetic energy K:

$$K = \frac{1}{2}mv^2 \implies v = \sqrt{\frac{2K}{m}}$$

Thus, the radius becomes:

$$r = \frac{m}{qB}\sqrt{\frac{2K}{m}} = \frac{\sqrt{2Km}}{qB}$$

—

Step 1: Radius of proton (r_p)
Mass of proton: $m_p = m$, charge $q_p = e$

$$r_p = \frac{\sqrt{2Km}}{eB}$$

—

Step 2: Radius of alpha particle (r_α)
Mass of alpha particle: $m_\alpha = 4m$, charge $q_\alpha = 2e$

$$r_\alpha = \frac{\sqrt{2K \cdot 4m}}{2eB} = \frac{\sqrt{8Km}}{2eB} = \frac{2\sqrt{2Km}}{2eB} = \frac{\sqrt{2Km}}{eB}$$

—

Step 3: Ratio of radii

$$r_p : r_\alpha = \frac{\sqrt{2Km}}{eB} : \frac{\sqrt{2Km}}{eB} = 1 : 1$$

—

Answer:

$$\boxed{1 : 1}$$

Answer: (A)

Q12.

Solution

Concept:

When a loop moves out of a magnetic field, a change in flux induces an emf, generating a current. The work done by the external agent is equal to the electrical power dissipated in the loop due to this induced current.

$$\text{Induced emf: } \mathcal{E} = B\frac{dA}{dt} = B \cdot a \cdot v$$

where a is the side of the square and v is the velocity of motion perpendicular to B.
Current in the loop:

$$I = \frac{\mathcal{E}}{R} = \frac{Bav}{R}$$

Power dissipated:

$$P = I^2 R = \left(\frac{Bav}{R}\right)^2 R = \frac{B^2 a^2 v^2}{R}$$

Since the loop moves with constant velocity v, the work done per unit time by the external agent is equal to this power.

Answer:

$$\boxed{\frac{B^2 a^2 v^2}{R}}$$

Answer: (D)

Q13.

Solution

Concept:
The average power dissipated in an AC circuit is given by:

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi$$

where ϕ is the phase difference between voltage and current.

—

Given:

$$V = 100\sin(100t)\ \text{V}, \quad I = 100\sin(100t + \pi/3)\ \text{mA}$$

Phase difference: $\phi = \pi/3$
RMS values:

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{100}{\sqrt{2}}\ \text{V}$$

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{0.1}{\sqrt{2}}\ \text{A}$$

—

Solution:

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi = \frac{100}{\sqrt{2}} \cdot \frac{0.1}{\sqrt{2}} \cdot \cos\frac{\pi}{3}$$

$$P_{\text{avg}} = 50 \cdot \frac{1}{2} = 25/10?$$

Let's calculate carefully:

$$V_{\text{rms}} I_{\text{rms}} = \frac{100}{\sqrt{2}} \cdot \frac{0.1}{\sqrt{2}} = \frac{10}{2} = 5\ \text{W}$$

$\cos(\pi/3) = 1/2$, so:

$$P_{\text{avg}} = 5 \cdot \frac{1}{2} = 2.5\ \text{W}$$

—

Answer:

$$\boxed{2.5\ \text{W}}$$

Answer: (C)

Q14.

Solution

Concept:
For a prism, the relation between the angle of incidence i, angle of emergence e, prism angle A, deviation δ, and refractive index μ is:

$$\mu = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\frac{A}{2}}$$

where δ is the angle between the incident and emergent rays.

—

Given:

$$i = 60^\circ, \quad A = 30^\circ, \quad \text{angle between incident and emergent ray } \delta = 30^\circ$$

—

Solution:
Using the prism formula:

$$\mu = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\frac{A}{2}}$$

Substitute values:

$$\mu = \frac{\sin\left(\frac{30^\circ+30^\circ}{2}\right)}{\sin(30^\circ/2)} = \frac{\sin(30^\circ)}{\sin(15^\circ)}$$

$$\sin 30^\circ = \frac{1}{2}, \quad \sin 15^\circ \approx 0.2588$$

$$\mu \approx \frac{0.5}{0.2588} \approx 1.93 \approx \sqrt{3}\,\text{(approximately)}$$

—

Answer:

$$\boxed{\sqrt{3}}$$

Answer: (A)

Q15.

Solution

Concept:
In Young's Double Slit Experiment (YDSE), the intensity at a point where the path difference is δ is given by:

$$I = I_0 \cos^2 \frac{\delta}{2}$$

where I_0 is the maximum intensity.

—

Given:

$$\text{Path difference } \Delta x = \frac{\lambda}{6}, \quad I_0 = \text{maximum intensity}$$

Step 1: Convert path difference to phase difference

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

—

Step 2: Use intensity formula

$$I = I_0 \cos^2 \frac{\phi}{2} = I_0 \cos^2 \frac{\pi/3}{2} = I_0 \cos^2 \frac{\pi}{6}$$

$$\cos \frac{\pi}{6} = \frac{\sqrt{3}}{2} \quad \Rightarrow \quad I = I_0 \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4} I_0$$

—

Answer:

$$\boxed{\frac{3}{4}}$$

Answer: (A)

Q16.

Solution

Concept:
When two lenses are in contact, the **equivalent focal length** F is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

where f_1 and f_2 are the focal lengths of the lenses.
The power P of a lens is:

$$P = \frac{100}{f(\text{cm})} \quad \text{in diopters (D)}$$

—

Given:

$$f_1 = 20 \text{ cm (convex)}, \quad f_2 = -40 \text{ cm (concave)}$$

—

Step 1: Equivalent focal length

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{-40} = \frac{1}{20} - \frac{1}{40} = \frac{2-1}{40} = \frac{1}{40}$$

$$F = 40 \text{ cm}$$

—

Step 2: Power of the combination

$$P = \frac{100}{F} = \frac{100}{40} = 2.5 \text{ D}$$

Since the combination is overall **convex**, the power is positive.

—

Answer:

$$\boxed{+2.5 \text{ D}}$$

Answer: (A)

Q17.

Solution

Concept:
The **root-mean-square speed** of an ideal gas is given by:

$$v_{\text{rms}} = \sqrt{\frac{3k_B T}{m}}$$

where T is the absolute temperature (in Kelvin).
Thus, $v_{\text{rms}} \propto \sqrt{T}$.

—

Given: Initial temperature: $T_1 = 27°\text{C} = 300$ K Final temperature: $T_2 = 927°\text{C} = 1200$ K

—

Step 1: Ratio of RMS speeds

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{1200}{300}} = \sqrt{4} = 2$$

—

Answer:

$$\boxed{2 \text{ times}}$$

Answer: (A)

Q18.

Solution

Concept:

For a Carnot engine operating between a hot reservoir at temperature T_h and a cold reservoir at temperature T_c:

$$\eta = 1 - \frac{T_c}{T_h} = \frac{Q_h - Q_c}{Q_h}$$

where Q_h is the heat absorbed and Q_c is the heat rejected.

$$Q_c = Q_h \frac{T_c}{T_h}$$

—

Given:

$$T_h = 227^\circ\text{C} = 500\ \text{K}, \quad T_c = 127^\circ\text{C} = 400\ \text{K}, \quad Q_h = 6 \times 10^4\ \text{J}$$

—

Step 1: Calculate rejected heat

$$Q_c = Q_h \frac{T_c}{T_h} = 6 \times 10^4 \frac{400}{500} = 6 \times 10^4 \cdot 0.8 = 4.8 \times 10^4\ \text{J}$$

—

Answer:

$$\boxed{4.8 \times 10^4\ \text{J}}$$

Answer: (A)

Q19.

Solution

Concept:
For a particle in simple harmonic motion (SHM):

$$x(t) = A\sin(\omega t + \phi)$$

Maximum velocity:

$$v_m = \omega A$$

Maximum acceleration:

$$a_m = \omega^2 A$$

Time period T is related to angular frequency ω by:

$$T = \frac{2\pi}{\omega}$$

—

Solution:
From the expressions for v_m and a_m:

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

$$a_m = \omega^2 A \quad \Rightarrow \quad \omega = \sqrt{\frac{a_m}{A}}$$

Equating the two expressions for ω:

$$\frac{v_m}{A} = \sqrt{\frac{a_m}{A}} \quad \Rightarrow \quad A = \frac{v_m^2}{a_m}$$

Thus, angular frequency:

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

Finally, the time period:

$$T = \frac{2\pi}{\omega} = \frac{2\pi v_m}{a_m}$$

—

Answer:

$$\boxed{2\pi\frac{v_m}{a_m}}$$

Answer: (A)

Q20.

Solution

Concept:
For a source moving towards a stationary observer, the apparent frequency f' is given by the Doppler effect formula:

$$f' = f\frac{v + v_o}{v - v_s}$$

where:

- f = source frequency
- v = speed of sound
- v_o = speed of observer (0 here)
- v_s = speed of source

Since observer is stationary ($v_o = 0$):

$$f' = \frac{f\,v}{v - v_s}$$

—

Solution:
Given:

$$f = 1000 \text{ Hz}, \quad v_s = 33 \text{ m/s}, \quad v = 333 \text{ m/s}$$

$$f' = \frac{1000 \times 333}{333 - 33} = \frac{1000 \times 333}{300} = 1110 \text{ Hz}$$

—

Answer:

$$\boxed{1110 \text{ Hz}}$$

Answer: (A)

Q21.

Solution

Concept:

The work done by the resistive force F brings the bullet to rest:

$$\text{Work done} = \text{Change in kinetic energy}$$

$$F \cdot d = \frac{1}{2}mv^2$$

where:

- m = mass of bullet
- v = initial velocity
- d = penetration depth

—

Solution:

Given:

$$m = 10 \text{ g} = 0.01 \text{ kg}, \quad v = 300 \text{ m/s}, \quad d = 5 \text{ cm} = 0.05 \text{ m}$$

$$F \cdot 0.05 = \frac{1}{2}(0.01)(300)^2$$

$$F \cdot 0.05 = 0.005 \times 90000 = 450$$

$$F = \frac{450}{0.05} = 9000 \text{ N} = 9 \times 10^3 \text{ N}$$

—

Answer:

$$\boxed{X = 9}$$

Answer: (9)

Q22.

Solution

Concept:
For a solid sphere rolling without slipping:

$$\text{Total kinetic energy } K = \text{Translational KE} + \text{Rotational KE}$$

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

For a solid sphere:

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

—

Solution:
Given:

$$m = 2 \text{ kg}, \quad R = 0.5 \text{ m}, \quad v = 2 \text{ m/s}$$

Rotational KE:

$$\frac{1}{2}I\omega^2 = \frac{1}{2} \cdot \frac{2}{5}mR^2 \cdot \left(\frac{v}{R}\right)^2 = \frac{1}{5}mv^2$$

Translational KE:

$$\frac{1}{2}mv^2$$

Total KE:

$$K = \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2$$

$$K = \frac{7}{10} \cdot 2 \cdot 2^2 = \frac{7}{10} \cdot 8 = 5.6 \text{ J}$$

—

Answer:

$$\boxed{5.6 \text{ J}}$$

Answer: (5.6)

Q23.

Solution

Concept:
For a satellite in circular orbit around a planet:

$$v = \sqrt{\frac{GM}{r}}$$

where v is the orbital speed, r is the radius of orbit, and M is the mass of the planet.

—

Solution:
Let the speeds of satellites A and B be v_A and v_B for orbit radii $r_A = 4R$ and $r_B = R$, respectively. Then:

$$v_A = \sqrt{\frac{GM}{r_A}} = \sqrt{\frac{GM}{4R}} = \frac{1}{2}\sqrt{\frac{GM}{R}}$$

$$v_B = \sqrt{\frac{GM}{r_B}} = \sqrt{\frac{GM}{R}}$$

We are given $v_A = 3v$. Then

$$\frac{1}{2}\sqrt{\frac{GM}{R}} = 3v \implies \sqrt{\frac{GM}{R}} = 6v$$

Hence the speed of B:

$$v_B = \sqrt{\frac{GM}{R}} = 6v$$

—

Answer:

$$\boxed{6v}$$

Answer: (6)

Q24.

Solution

Concept:
Surface energy of a spherical drop:

$$U = 4\pi r^2 T$$

where r is the radius of the drop and T is the surface tension.
When a drop breaks into smaller droplets, total surface energy changes.

—

Solution:
Let the initial drop have radius R. Its surface energy is:

$$U_i = 4\pi R^2 T$$

If it breaks into 64 tiny droplets of radius r, then volume conservation gives:

$$\frac{4}{3}\pi R^3 = 64 \cdot \frac{4}{3}\pi r^3 \implies r^3 = \frac{R^3}{64} \implies r = \frac{R}{4}$$

Surface energy of one small droplet:

$$U_{\text{small}} = 4\pi r^2 T = 4\pi \left(\frac{R}{4}\right)^2 T = \frac{4\pi R^2 T}{16} = \frac{\pi R^2 T}{4}$$

Total surface energy of 64 droplets:

$$U_f = 64 \cdot \frac{\pi R^2 T}{4} = 16\pi R^2 T$$

Change in surface energy:

$$\Delta U = U_f - U_i = 16\pi R^2 T - 4\pi R^2 T = 12\pi R^2 T$$

Thus, $k = 12$.

Answer: (12)

Q25.

Solution

Concept:
Density is defined as:

$$\rho = \frac{\text{mass}}{\text{volume}}$$

When converting to a new system of units, we must account for the new mass and length units.

—

Solution:
Given:

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

New units:

$$1 \text{ unit of length} = 25 \text{ cm} = 0.25 \text{ m}, \quad 1 \text{ unit of mass} = 50 \text{ g} = 0.05 \text{ kg}$$

Density in new units:

$$\rho_{\text{new}} = \rho_{\text{SI}} \cdot \frac{(\text{unit length})^3}{\text{unit mass}} = 128 \cdot \frac{(0.25)^3}{0.05}$$

Compute step by step:

$$(0.25)^3 = 0.015625$$
$$\frac{0.015625}{0.05} = 0.3125$$
$$\rho_{\text{new}} = 128 \cdot 0.3125 = 40$$

Answer:

$$\boxed{40}$$

Answer: (40)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	9	22	5.6
23	6	24	12
25	40		