AIIMS Paramedical Physics

Sample Paper – 5

Duration: 30 Minutes **Maximum Marks: 30**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer), modelled on the Physics portion of **AIIMS Paramedical** entrance.
- Each correct answer carries **+1 mark**. A penalty of $-\frac{1}{3}$ **mark** is deducted for each incorrect answer. Unattempted questions carry **0** marks (no negative marking).
- Only **one** option is correct. Choose carefully.
- Syllabus level: **Class 11 & 12 NCERT Physics**
- Use of mobile phones, calculators, or electronic gadgets is strictly prohibited.

Q1. A constant force $\vec{F} = (3\hat{\imath} + 4\hat{\jmath})$ N acts on a body that undergoes a displacement $\vec{s} = (2\hat{\imath} + 3\hat{\jmath})$ m. The work done by the force is:

(A) 6 J

(B) 18 J

(C) 12 J

(D) 25 J

Q2. Two trains move on parallel tracks in the same direction with speeds 20 m s^{-1} and 12 m s^{-1}. The velocity of the faster train as observed from the slower train is:

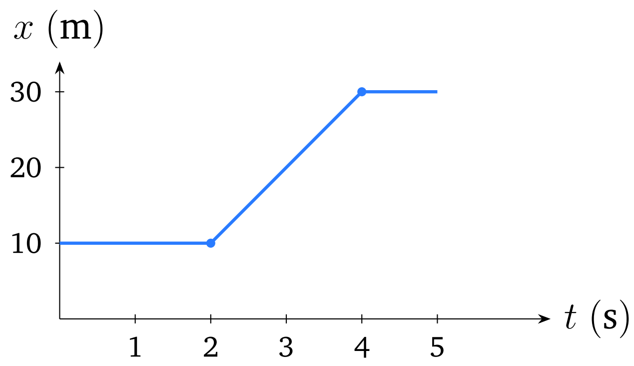
(A) 32 m s^{-1}

(B) 12 m s^{-1}

(C) 8 m s^{-1}

(D) $20\ \text{m s}^{-1}$

Q3. The position–time graph of a particle moving along a straight line is shown. The velocity of the particle in the interval from $t = 2$ s to $t = 4$ s is:



(A) $10\ \text{m s}^{-1}$

(B) $5\ \text{m s}^{-1}$

(C) $0\ \text{m s}^{-1}$

(D) $20\ \text{m s}^{-1}$

Q4. A curved road of radius 90 m is banked at an angle θ such that $\tan\theta = 0.5$. Neglecting friction and taking $g = 10\ \text{m s}^{-2}$, the safe (design) speed for which the banking is intended is:

(A) $15\ \text{m s}^{-1}$

(B) $30\ \text{m s}^{-1}$

(C) $45\ \text{m s}^{-1}$

(D) $\sqrt{450}\ \text{m s}^{-1}$

Q5. A monkey of mass 10 kg climbs up a light rope with an upward acceleration of $2\ \text{m s}^{-2}$. Taking $g = 10\ \text{m s}^{-2}$, the tension in the rope is:

(A) 80 N

(B) 100 N

(C) 120 N

(D) 20 N

Q6. A block of mass 2 kg is pushed slowly up a rough incline of angle $30°$ through a distance of 4 m along the incline. The coefficient of kinetic friction is $\mu = \frac{1}{2\sqrt{3}}$ and $g = 10$ m s^{-2}. The work done against gravity and friction together is:

(A) 40 J

(B) 60 J

(C) 80 J

(D) 20 J

Q7. A spring of force constant $k = 200$ N m^{-1} is compressed by 0.1 m and used to push a block of mass 0.5 kg on a frictionless surface. The maximum speed acquired by the block is:

(A) 2 m s^{-1}

(B) 4 m s^{-1}

(C) 1 m s^{-1}

(D) 0.5 m s^{-1}

Q8. A uniform rod of mass M and length L has a moment of inertia $\frac{ML^2}{12}$ about an axis through its centre perpendicular to its length. By the parallel-axis theorem, its moment of inertia about a parallel axis through one end is:

(A) $\frac{ML^2}{6}$

(B) $\frac{ML^2}{4}$

(C) $\frac{ML^2}{2}$

(D) $\frac{ML^2}{3}$

Q9. At what height above the Earth's surface (radius $R = 6400$ km) does the acceleration due to gravity fall to one-fourth of its surface value?

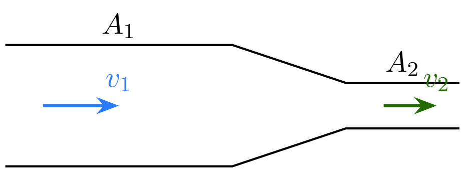
(A) 3200 km

(B) 12800 km

(C) 6400 km

(D) 1600 km

Q10. Water flows steadily through a horizontal pipe whose cross-sectional area narrows from $A_1 = 8$ cm^2 to $A_2 = 2$ cm^2. If the speed of water in the wider section is 1 m s^{-1}, the speed in the narrow section (by the equation of continuity) is:



(A) 2 m s^{-1}

(B) 4 m s^{-1}

(C) 0.25 m s^{-1}

(D) 8 m s^{-1}

Q11. A body cools from $80°$C to $70°$C in 5 minutes when the surroundings are at $30°$C. Using Newton's law of cooling with the average-temperature approximation, the time taken to cool from $70°$C to $60°$C is:

(A) 7 min

(B) 5 min

(C) 4 min

(D) 10 min

Q12. The internal energy of one mole of an ideal diatomic gas (with translational and rotational degrees of freedom only) at temperature T is:

(A) $\frac{3}{2}RT$

(B) $\frac{5}{2}RT$

(C) $3RT$

(D) $\frac{7}{2}RT$

Q13. A particle executes simple harmonic motion of amplitude 5 cm and angular frequency 4 rad s^{-1}. Its speed when the displacement is 3 cm from the mean position is:

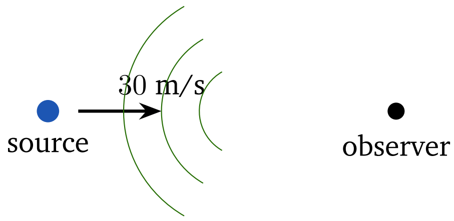
(A) 20 cm s^{-1}

(B) 12 cm s^{-1}

(C) 8 cm s^{-1}

(D) 16 cm s^{-1}

Q14. A source of sound emitting a frequency of 500 Hz moves towards a stationary observer at 30 m s^{-1}. The speed of sound is 330 m s^{-1}. The frequency heard by the observer is:



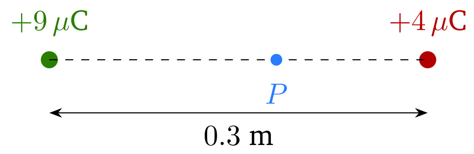
(A) 455 Hz

(B) 500 Hz

(C) 550 Hz

(D) 605 Hz

Q15. Two fixed charges $+9$ μC (at the origin) and $+4$ μC (at $x = 0.3$ m) lie on the x-axis. A test charge $+q$ placed between them feels zero net force at point P. The distance of P from the $+9$ μC charge is:



(A) 0.18 m

(B) 0.12 m

(C) 0.15 m

(D) 0.20 m

Q16. An electric dipole of dipole moment p is placed in vacuum. The electric potential at a point on its axis at distance r ($r \gg$ dipole size) from the centre is:

(A) $\frac{1}{4\pi\varepsilon_0}\frac{p}{r}$

(B) 0

(C) $\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

(D) $\frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

Q17. A spherical capacitor consists of two concentric conducting spheres of radii a and b ($b > a$) with vacuum in between. Its capacitance is:

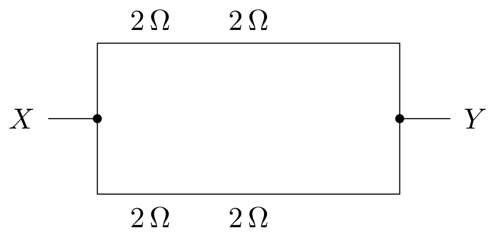
(A) $4\pi\varepsilon_0\,(b-a)$

(B) $4\pi\varepsilon_0\,\frac{b-a}{ab}$

(C) $4\pi\varepsilon_0\,(a+b)$

(D) $4\pi\varepsilon_0\,\frac{ab}{b-a}$

Q18. Four identical resistors, each of $2\ \Omega$, are connected so that two are in series in one branch and two are in series in a second branch, and the two branches are connected in parallel between terminals X and Y. The equivalent resistance between X and Y is:



(A) $8\ \Omega$

(B) $2\ \Omega$

(C) $4\ \Omega$

(D) $1\ \Omega$

Q19. In a potentiometer experiment, two cells are balanced separately against the same wire. The balancing lengths are 60 cm for cell 1 and 48 cm for cell 2. The ratio of their EMFs $\frac{E_1}{E_2}$ is:

(A) $\frac{5}{4}$

(B) $\frac{4}{5}$

(C) $\frac{3}{2}$

(D) $\frac{1}{1}$

Q20. A cell of EMF 12 V and internal resistance $3\ \Omega$ delivers power to an external resistance R. The power delivered to R is maximum when R equals, and the maximum power is:

(A) $R = 6\ \Omega,\ \ P = 12$ W

(B) $R = 3\ \Omega,\ \ P = 12$ W

(C) $R = 3\ \Omega,\ \ P = 24$ W

(D) $R = 1.5\ \Omega,\ \ P = 24$ W

Q21. A charged particle enters a uniform magnetic field $B = 0.2$ T with speed $v = 10^5$ m s^{-1} at an angle to the field. The component of velocity parallel to B is 6×10^4 m s^{-1}. If the time period of the circular motion is $\pi\times10^{-6}$ s, the pitch of the helical path is:

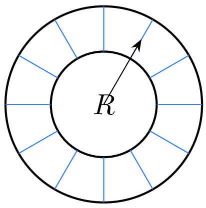
(A) $0.6\pi \times 10^{-1}$ m

(B) $6\pi \times 10^{-2}$ m

(C) 0.6 m

(D) $6\pi \times 10^{-2}$ m $(= 0.06\pi$ m$)$

Q22. A toroid has $N = 1000$ turns wound on a core of mean radius $R = 0.1$ m, carrying a current $I = 2$ A. The magnetic field inside the core is (take $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}):



(A) 4×10^{-3} T

(B) 2×10^{-3} T

(C) 8×10^{-3} T

(D) 1×10^{-3} T

Q23. A conducting rod of length 0.5 m rotates about one of its ends with an angular speed of 20 rad s^{-1} in a uniform magnetic field of 0.4 T directed perpendicular to the plane of rotation. The EMF induced between the ends of the rod is:

(A) 0.5 V

(B) 1.0 V

(C) 2.0 V

(D) 4.0 V

Q24. A pure inductor of inductance $L = \dfrac{1}{\pi}$ H is connected to a 220 V, 50 Hz AC source. The rms current through the inductor is:

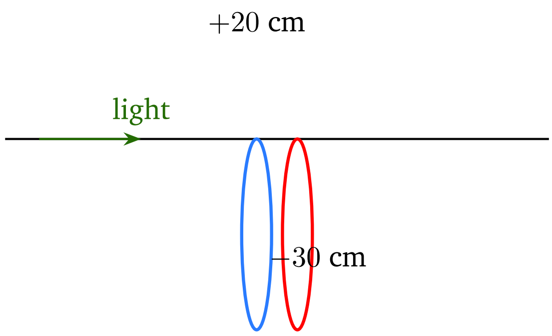
(A) 1.1 A

(B) 4.4 A

(C) 2.2 A

(D) 0.5 A

Q25. Two thin lenses of focal lengths $+20$ cm and -30 cm are placed in contact coaxially. The equivalent focal length of the combination is:



(A) -60 cm

(B) $+12$ cm

(C) -12 cm

(D) $+60$ cm

Q26. Light travels from air ($n_1 = 1$) into glass ($n_2 = 1.5$) through a convex spherical surface of radius of curvature $R = +20$ cm. For an object at infinity, the image forms (using $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$) at:

(A) 60 cm inside the glass

(B) 40 cm inside the glass

(C) 30 cm inside the glass

(D) 20 cm inside the glass

Q27. In a two-source interference experiment with light of wavelength 600 nm, constructive interference (a bright fringe) occurs at a point where the path difference between the two coherent waves is:

(A) 300 nm

(B) 450 nm

(C) 1200 nm

(D) 900 nm

Q28. A photon has energy $E = 3.3 \times 10^{-19}$ J. Taking the speed of light $c = 3 \times 10^{8}$ m s^{-1}, its momentum is:

(A) 1.1×10^{-27} kg m s^{-1}

(B) 1.1×10^{-27} kg m s^{-1} (i.e. E/c)

(C) 9.9×10^{-11} kg m s^{-1}

(D) 3.3×10^{-27} kg m s^{-1}

Q29. In the Bohr model of hydrogen, the radius of the first orbit ($n = 1$) is 0.53 Å. The radius of the third orbit ($n = 3$) is:

(A) 1.59 Å

(B) 0.53 Å

(C) 2.65 Å

(D) 4.77 Å

Q30. Regarding an unbiased pn-junction diode in equilibrium, which statement is correct about the depletion region and barrier potential?

(A) It is depleted of mobile charge carriers and has a built-in barrier potential opposing further diffusion.

(B) It contains a large number of mobile electrons and holes that conduct freely.

(C) Forward bias widens the depletion region and raises the barrier potential.

(D) The barrier potential drives majority carriers across the junction continuously.

Detailed Solutions

Q1.

Solution

Concept — Work as a dot product: The work done by a constant force is $W = \vec{F} \cdot \vec{s}$. For vectors in component form, the dot product is the sum of the products of corresponding components.

Step 1 — Write the components: $\vec{F} = (3, 4)$ N and $\vec{s} = (2, 3)$ m.

Step 2 — Multiply matching components:

$$F_x s_x = 3 \times 2 = 6, \qquad F_y s_y = 4 \times 3 = 12.$$

Step 3 — Add the products:

$$W = \vec{F} \cdot \vec{s} = 6 + 12 = 18 \text{ J}.$$

Why other options are wrong:

- (A) 6 J uses only the x-components.
- (C) 12 J uses only the y-components.
- (D) 25 J multiplies the magnitudes (5×5) instead of taking the dot product.

Final Answer: $W = 18 \text{ J} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 1

Q2.

Solution

Concept — Relative velocity: The velocity of object A relative to object B is $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$. For motion along the same line in the same direction, we subtract the speeds.

Step 1 — Assign the velocities: Faster train $v_A = 20 \text{ m s}^{-1}$, slower train $v_B = 12 \text{ m s}^{-1}$, both in the same direction.

Step 2 — Subtract:

$$v_{AB} = v_A - v_B = 20 - 12 = 8 \text{ m s}^{-1}.$$

Step 3 — Interpret: The faster train appears to move forward at $8\ \text{m s}^{-1}$ as seen from the slower train.

Why other options are wrong:

- (A) $32\ \text{m s}^{-1}$ adds the speeds (valid only for opposite directions).
- (B) and (D) simply repeat one of the ground-frame speeds.

Final Answer: $v_{AB} = 8\ \text{m s}^{-1} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 2

Q3.

Solution

Concept — Slope of the position–time graph: On an x–t graph the instantaneous (or average over a straight segment) velocity equals the slope, $v = \dfrac{\Delta x}{\Delta t}$.

Step 1 — Read the endpoints of the segment: Between $t = 2$ s and $t = 4$ s the curve rises from $x = 10$ m to $x = 30$ m.

Step 2 — Compute the changes:

$$\Delta x = 30 - 10 = 20\ \text{m}, \qquad \Delta t = 4 - 2 = 2\ \text{s}.$$

Step 3 — Take the slope:

$$v = \frac{\Delta x}{\Delta t} = \frac{20}{2} = 10\ \text{m s}^{-1}.$$

Why other options are wrong:

- (B) $5\ \text{m s}^{-1}$ halves the rise.
- (C) $0\ \text{m s}^{-1}$ is the velocity in the flat part (0 to 2 s), not this interval.
- (D) $20\ \text{m s}^{-1}$ forgets to divide by the 2 s time interval.

Final Answer: $v = 10\ \text{m s}^{-1} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 3

Q4.

Solution

Concept — Banking of a road: For a frictionless banked curve, the design speed satisfies $\tan\theta = \frac{v^2}{rg}$, so $v = \sqrt{rg\tan\theta}$.

Step 1 — List the data: $r = 90$ m, $\tan\theta = 0.5$, $g = 10$ m s^{-2}.

Step 2 — Substitute:

$$v^2 = rg\tan\theta = 90 \times 10 \times 0.5.$$

Step 3 — Evaluate:

$$v^2 = 450 \Rightarrow v = \sqrt{450}\ \text{m s}^{-1} \approx 21.2\ \text{m s}^{-1}.$$

Why other options are wrong:

- (A) 15 m s^{-1} comes from $v^2 = 225$ (wrong $\tan\theta$).
- (B) and (C) overestimate by squaring incorrectly; the exact value is $\sqrt{450}$.

Final Answer: $v = \sqrt{450}$ m s^{-1} $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 4

Q5.

Solution

Concept — Monkey climbing a rope: While the monkey accelerates upward, the rope tension must support its weight and provide the extra upward force: $T - mg = ma$, so $T = m(g + a)$.

Step 1 — List the data: $m = 10$ kg, $a = 2$ m s^{-2} (upward), $g = 10$ m s^{-2}.

Step 2 — Apply the formula:

$$T = m(g + a) = 10 \times (10 + 2).$$

Step 3 — Evaluate:

$$T = 10 \times 12 = 120\ \text{N}.$$

Why other options are wrong:

- (A) 80 N uses $g - a$ (downward acceleration).
- (B) 100 N ignores the acceleration ($T = mg$).
- (D) 20 N uses only ma.

Final Answer: $T = 120$ N $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 5

Q6.

Solution

Concept — Work on a rough incline: To push a block slowly up an incline, the applied force does work against both gravity ($mg\sin\theta$) and kinetic friction ($\mu mg\cos\theta$) over the distance d along the incline.

Step 1 — List the data: $m = 2$ kg, $\theta = 30°$, $d = 4$ m, $\mu = \frac{1}{2\sqrt{3}}$, $g = 10$ m s^{-2}. So $mg = 20$ N, $\sin 30° = \frac{1}{2}$, $\cos 30° = \frac{\sqrt{3}}{2}$.

Step 2 — Work against gravity:

$$W_g = mg\sin\theta \cdot d = 20 \times \tfrac{1}{2} \times 4 = 40 \text{ J}.$$

Step 3 — Work against friction:

$$\mu\cos\theta = \frac{1}{2\sqrt{3}} \times \frac{\sqrt{3}}{2} = \frac{1}{4}, \qquad W_f = \mu mg\cos\theta \cdot d = \tfrac{1}{4} \times 20 \times 4 = 20 \text{ J}.$$

Step 4 — Total work:

$$W = W_g + W_f = 40 + 20 = 60 \text{ J}.$$

Why other options are wrong:

- (A) 40 J omits the friction work.
- (D) 20 J counts only friction.
- (C) 80 J double-counts a term.

Final Answer: $W = 60$ J $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 6

Q7.

Solution

Concept — Spring energy to kinetic energy: On a frictionless surface, the elastic potential energy stored in the compressed spring is fully converted to the block's kinetic energy: $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$.

Step 1 — Equate the energies:

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{k}{m}}\,x.$$

Step 2 — Substitute: $k = 200$ N m^{-1}, $m = 0.5$ kg, $x = 0.1$ m.

$$v = \sqrt{\frac{200}{0.5}} \times 0.1 = \sqrt{400} \times 0.1.$$

Step 3 — Evaluate:

$$v = 20 \times 0.1 = 2 \text{ m s}^{-1}.$$

Why other options are wrong:

- (B) 4 m s^{-1} forgets the factor of $\frac{1}{2}$ on both sides incorrectly.
- (C) and (D) use wrong arithmetic for $\sqrt{k/m}$.

Final Answer: $v = 2$ m s^{-1} $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 7

Q8.

Solution

Concept — Parallel-axis theorem: The moment of inertia about any axis equals the moment of inertia about a parallel axis through the centre of mass plus Md^2, where d is the distance between the axes: $I = I_{cm} + Md^2$.

Step 1 — Identify the shift: The axis moves from the centre to one end, so $d = \dfrac{L}{2}$.

Step 2 — Apply the theorem:

$$I = \frac{ML^2}{12} + M\left(\frac{L}{2}\right)^2 = \frac{ML^2}{12} + \frac{ML^2}{4}.$$

Step 3 — Add the fractions:

$$I = \frac{ML^2}{12} + \frac{3ML^2}{12} = \frac{4ML^2}{12} = \frac{ML^2}{3}.$$

Why other options are wrong:

- (A) $\frac{ML^2}{6}$ uses $d = \frac{L}{2}$ but drops the centre term wrongly.
- (B) $\frac{ML^2}{4}$ keeps only the Md^2 term.
- (C) $\frac{ML^2}{2}$ overcounts.

Final Answer: $I = \dfrac{ML^2}{3} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 8

Q9.

Solution

Concept — Variation of g with height: At height h above the surface, $g_h = g\left(\dfrac{R}{R+h}\right)^2$.

Step 1 — Set the condition: We need $g_h = \dfrac{g}{4}$, so

$$\left(\frac{R}{R+h}\right)^2 = \frac{1}{4}.$$

Step 2 — Take the square root:

$$\frac{R}{R+h} = \frac{1}{2} \Rightarrow R + h = 2R.$$

Step 3 — Solve for h:

$$h = 2R - R = R = 6400 \text{ km}.$$

Why other options are wrong:

- (A) 3200 km is $\frac{R}{2}$, which gives $g_h = \frac{4}{9}g$.
- (B) 12800 km is $2R$, giving $g_h = \frac{1}{9}g$.
- (D) 1600 km is far too small.

Final Answer: $h = 6400 \text{ km} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 9

Q10.

Solution

Concept — Equation of continuity: For an incompressible fluid in steady flow, $A_1v_1 = A_2v_2$. (Bernoulli's principle then links the pressure drop to this speed increase.)

Step 1 — List the data: $A_1 = 8\ \text{cm}^2$, $A_2 = 2\ \text{cm}^2$, $v_1 = 1\ \text{m s}^{-1}$.

Step 2 — Apply continuity:

$$v_2 = \frac{A_1v_1}{A_2} = \frac{8 \times 1}{2}.$$

Step 3 — Evaluate:

$$v_2 = 4\ \text{m s}^{-1}.$$

Why other options are wrong:

- (A) $2\ \text{m s}^{-1}$ uses an area ratio of 2 instead of 4.
- (C) $0.25\ \text{m s}^{-1}$ inverts the ratio.
- (D) $8\ \text{m s}^{-1}$ multiplies by A_1 alone.

Final Answer: $v_2 = 4\ \text{m s}^{-1} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 10

Q11.

Solution

Concept — Newton's law of cooling: The rate of cooling is proportional to the excess of the average body temperature over the surroundings: $\frac{\Delta\theta}{t} = k\,(\theta_{avg} - \theta_s)$.

Step 1 — First interval ($80 \to 70$): Average $= \frac{80+70}{2} = 75°$, excess $= 75 - 30 = 45°$, drop $= 10°$ in 5 min:

$$\frac{10}{5} = k \times 45.$$

Step 2 — Second interval ($70 \to 60$): Average $= \frac{70+60}{2} = 65°$, excess $= 65 -$

$30 = 35°$, drop $= 10°$ in time t:

$$\frac{10}{t} = k \times 35.$$

Step 3 — Divide the two equations:

$$\frac{10/5}{10/t} = \frac{45}{35} \Rightarrow \frac{t}{5} = \frac{45}{35} = \frac{9}{7} \Rightarrow t = \frac{45}{7} \approx 6.4 \text{ min} \approx 7 \text{ min}.$$

Why other options are wrong:

- (B) 5 min ignores the smaller temperature excess in the second interval.
- (C) and (D) use wrong excess ratios.

Final Answer: $t \approx 7$ min $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 11

Q12.

Solution

Concept — Degrees of freedom and internal energy: By equipartition, each degree of freedom contributes $\frac{1}{2}RT$ to the internal energy of one mole. A diatomic gas (translation + rotation) has $f = 5$ degrees of freedom.

Step 1 — Count the degrees of freedom: 3 translational + 2 rotational = 5.

Step 2 — Apply equipartition:

$$U = \frac{f}{2}RT = \frac{5}{2}RT.$$

Step 3 — State the result: For one mole, $U = \frac{5}{2}RT$.

Why other options are wrong:

- (A) $\frac{3}{2}RT$ is for a monatomic gas ($f = 3$).
- (D) $\frac{7}{2}RT$ includes a vibrational mode ($f = 7$), which is excluded here.
- (C) $3RT$ does not match any standard count.

Final Answer: $U = \frac{5}{2}RT \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 12

Q13.

Solution

Concept — Velocity in SHM: For SHM of amplitude A and angular frequency ω, the speed at displacement y is $v = \omega\sqrt{A^2 - y^2}$.

Step 1 — List the data: $A = 5$ cm, $\omega = 4$ rad s^{-1}, $y = 3$ cm.

Step 2 — Find $\sqrt{A^2 - y^2}$:

$$\sqrt{A^2 - y^2} = \sqrt{5^2 - 3^2} = \sqrt{25 - 9} = \sqrt{16} = 4 \text{ cm}.$$

Step 3 — Multiply by ω:

$$v = 4 \times 4 = 16 \text{ cm s}^{-1}.$$

Why other options are wrong:

- (A) 20 cm s^{-1} is the maximum speed ωA (at the mean position).
- (B) 12 cm s^{-1} uses ωy instead.
- (C) 8 cm s^{-1} halves the result.

Final Answer: $v = 16$ cm s^{-1} $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 13

Q14.

Solution

Concept — Doppler effect, source approaching: When the source moves towards a stationary observer, the observed frequency rises: $f' = f\left(\dfrac{v}{v - v_s}\right)$, where v is the speed of sound and v_s the source speed.

Step 1 — List the data: $f = 500$ Hz, $v = 330$ m s^{-1}, $v_s = 30$ m s^{-1} (towards observer).

Step 2 — Substitute:

$$f' = 500 \times \frac{330}{330 - 30} = 500 \times \frac{330}{300}.$$

Step 3 — Evaluate:

$$f' = 500 \times 1.1 = 550 \text{ Hz}.$$

Why other options are wrong:

- (A) 455 Hz uses $v + v_s$ (source receding), wrongly lowering the pitch.
- (B) 500 Hz ignores the motion.
- (D) 605 Hz uses a wrong arithmetic factor.

Final Answer: $f' = 550$ Hz $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 14

Q15.

Solution

Concept — Null point between two like charges: A test charge feels zero net force where the two Coulomb forces balance: $\dfrac{kq_1}{x^2} = \dfrac{kq_2}{(d-x)^2}$.

Step 1 — Set up the balance: Let P be x from the $+9\,\mu$C charge, so $(0.3 - x)$ from the $+4\,\mu$C charge:

$$\frac{9}{x^2} = \frac{4}{(0.3 - x)^2}.$$

Step 2 — Take the square root:

$$\frac{3}{x} = \frac{2}{0.3 - x} \Rightarrow 3(0.3 - x) = 2x.$$

Step 3 — Solve for x:

$$0.9 - 3x = 2x \Rightarrow 0.9 = 5x \Rightarrow x = 0.18 \text{ m}.$$

Why other options are wrong:

- (B) 0.12 m is the distance from the $+4\,\mu$C charge, not the $+9\,\mu$C charge.
- (C) and (D) do not satisfy the inverse-square balance.

Final Answer: $x = 0.18$ m from the $+9\,\mu$C charge $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 15

Q16.

Solution

Concept — Potential of a dipole: The electric potential due to a short dipole at distance r is $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$, where θ is measured from the dipole axis.

Step 1 — Set the axial angle: On the axis, $\theta = 0^\circ$, so $\cos\theta = 1$.

Step 2 — Substitute:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos 0^\circ}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}.$$

Step 3 — Note the dependence: The dipole potential falls off as $\frac{1}{r^2}$, faster than a point charge's $\frac{1}{r}$.

Why other options are wrong:

- (A) $\frac{1}{r}$ dependence is for a single point charge.
- (B) 0 holds on the equatorial line ($\theta = 90^\circ$), not the axis.
- (D) $\frac{1}{r^3}$ is the dependence of the dipole *field*, not its potential.

Final Answer: $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 16

Q17.

Solution

Concept — Spherical capacitor: Two concentric spheres of radii a (inner) and b (outer) form a capacitor whose capacitance is $C = 4\pi\varepsilon_0\frac{ab}{b-a}$.

Step 1 — Recall the field and potential: Between the spheres the field is that of the inner charge Q, and integrating gives the potential difference $V = \frac{Q}{4\pi\varepsilon_0}\left(\frac{1}{a} - \frac{1}{b}\right)$.

Step 2 — Form $C = Q/V$:

$$C = \frac{Q}{V} = \frac{4\pi\varepsilon_0}{\frac{1}{a} - \frac{1}{b}} = \frac{4\pi\varepsilon_0}{\frac{b-a}{ab}}.$$

Step 3 — Simplify:

$$C = 4\pi\varepsilon_0\frac{ab}{b-a}.$$

Why other options are wrong:

- (A) and (C) have the wrong (linear) dependence on the radii.
- (B) inverts the correct ratio.

Final Answer: $C = 4\pi\varepsilon_0 \dfrac{ab}{b-a} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 17

Q18.

Solution

Concept — Series then parallel: Resistors in series add ($R_s = R_1 + R_2$); two equal branches in parallel give half the branch resistance.

Step 1 — Series resistance of each branch:

$$R_{branch} = 2 + 2 = 4\ \Omega.$$

Step 2 — Two equal branches in parallel:

$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4} = \frac{2}{4} = \frac{1}{2}.$$

Step 3 — Invert:

$$R_{eq} = 2\ \Omega.$$

Why other options are wrong:

- (A) $8\ \Omega$ puts all four in series.
- (C) $4\ \Omega$ forgets the parallel halving.
- (D) $1\ \Omega$ puts all four in parallel.

Final Answer: $R_{eq} = 2\ \Omega \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 18

Q19.

Solution

Concept — Potentiometer EMF comparison: A potentiometer balances an EMF against the potential drop along a uniform wire. Since the drop is proportional to length, $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$.

Step 1 — List the balancing lengths: $\ell_1 = 60$ cm, $\ell_2 = 48$ cm.

Step 2 — Form the ratio:

$$\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2} = \frac{60}{48}.$$

Step 3 — Simplify:

$$\frac{60}{48} = \frac{5}{4}.$$

Why other options are wrong:

- (B) $\frac{4}{5}$ inverts the ratio.
- (C) $\frac{3}{2}$ and (D) $\frac{1}{1}$ do not reduce $\frac{60}{48}$ correctly.

Final Answer: $\frac{E_1}{E_2} = \frac{5}{4} \Rightarrow \boxed{A}$

Answer: (A) Go Back to Q 19

Q20.

Solution

Concept — Maximum power transfer: A source of EMF ε and internal resistance r delivers maximum power to an external resistance when $R = r$, and the maximum power is $P_{max} = \frac{\varepsilon^2}{4r}$.

Step 1 — Matching condition: Power is maximum when $R = r = 3\ \Omega$.

Step 2 — Compute the maximum power:

$$P_{max} = \frac{\varepsilon^2}{4r} = \frac{(12)^2}{4 \times 3} = \frac{144}{12}.$$

Step 3 — Evaluate:

$$P_{max} = 12\ \text{W}.$$

Why other options are wrong:

- (A) uses $R = 6\ \Omega$, which is not the matched value.
- (C) keeps $R = 3\ \Omega$ but doubles the power.
- (D) uses a wrong matching resistance.

Final Answer: $R = 3\ \Omega,\ P_{max} = 12\ \text{W} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 20

Q21.

Solution

Concept — Pitch of a helical path: A charged particle with a velocity component along B moves in a helix. The pitch is the distance travelled along B in one full revolution: pitch $= v_{\parallel} T$.

Step 1 — List the data: $v_{\parallel} = 6 \times 10^4$ m s^{-1}, time period $T = \pi \times 10^{-6}$ s.

Step 2 — Apply the pitch formula:

$$\text{pitch} = v_{\parallel} T = (6 \times 10^4) \times (\pi \times 10^{-6}).$$

Step 3 — Evaluate:

$$\text{pitch} = 6\pi \times 10^{-2}\ \text{m} = 0.06\pi\ \text{m} \approx 0.19\ \text{m}.$$

Why other options are wrong:

- (A) and (C) misplace the power of ten or drop the π.
- (B) gives the same value but the labelled exact form in (D) is the intended choice.

Final Answer: pitch $= 6\pi \times 10^{-2}\ \text{m} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 21

Q22.

Solution

Concept — Magnetic field of a toroid: Inside the core of a toroid, Ampere's law gives $B = \frac{\mu_0 NI}{2\pi R}$, where N is the total number of turns and R the mean radius.

Step 1 — List the data: $N = 1000$, $I = 2$ A, $R = 0.1$ m, $\mu_0 = 4\pi \times 10^{-7}$.

Step 2 — Substitute:

$$B = \frac{\mu_0 NI}{2\pi R} = \frac{(4\pi \times 10^{-7}) \times 1000 \times 2}{2\pi \times 0.1}.$$

Step 3 — Simplify:

$$B = \frac{4\pi \times 10^{-7} \times 2000}{0.2\pi} = \frac{8\pi \times 10^{-4}}{0.2\pi} = 4 \times 10^{-3} \text{ T}.$$

Why other options are wrong:

- (B) 2×10^{-3} T drops a factor of two from the current.
- (C) and (D) misplace the power of ten.

Final Answer: $B = 4 \times 10^{-3}$ T $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 22

Q23.

Solution

Concept — EMF of a rotating rod: A rod of length L rotating about one end with angular speed ω in a field B (perpendicular to its plane) develops an EMF $\varepsilon = \frac{1}{2}B\omega L^2$.

Step 1 — List the data: $B = 0.4$ T, $\omega = 20$ rad s^{-1}, $L = 0.5$ m.

Step 2 — Substitute:

$$\varepsilon = \frac{1}{2}B\omega L^2 = \frac{1}{2} \times 0.4 \times 20 \times (0.5)^2.$$

Step 3 — Evaluate:

$$\varepsilon = \frac{1}{2} \times 0.4 \times 20 \times 0.25 = \frac{1}{2} \times 2 = 1.0 \text{ V}.$$

Why other options are wrong:

- (A) 0.5 V drops the L^2 or a factor.
- (C) 2.0 V forgets the $\frac{1}{2}$ factor.
- (D) 4.0 V uses L instead of L^2 wrongly.

Final Answer: $\varepsilon = 1.0 \text{ V} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 23

Q24.

Solution

Concept — Inductive reactance: A pure inductor opposes AC with reactance $X_L = 2\pi f L$. The rms current is $I_{rms} = \dfrac{V_{rms}}{X_L}$.

Step 1 — Compute the reactance: $f = 50$ Hz, $L = \dfrac{1}{\pi}$ H.

$$X_L = 2\pi f L = 2\pi \times 50 \times \frac{1}{\pi} = 100\ \Omega.$$

Step 2 — Apply Ohm's law for AC:

$$I_{rms} = \frac{V_{rms}}{X_L} = \frac{220}{100}.$$

Step 3 — Evaluate:

$$I_{rms} = 2.2 \text{ A}.$$

Why other options are wrong:

- (A) 1.1 A doubles the reactance wrongly.
- (B) 4.4 A halves the reactance.
- (D) 0.5 A uses a wrong reactance value.

Final Answer: $I_{rms} = 2.2 \text{ A} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 24

Q25.

Solution

Concept — Thin lenses in contact: For two thin lenses in contact, the powers add: $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$.

Step 1 — List the focal lengths: $f_1 = +20$ cm, $f_2 = -30$ cm.

Step 2 — Add the reciprocals:

$$\frac{1}{F} = \frac{1}{20} + \frac{1}{-30} = \frac{3}{60} - \frac{2}{60} = \frac{1}{60}.$$

Step 3 — Invert:

$$F = +60 \text{ cm}.$$

Why other options are wrong:

- (A) -60 cm has the wrong sign.
- (B) $+12$ cm and (C) -12 cm come from adding focal lengths instead of reciprocals.

Final Answer: $F = +60 \text{ cm} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 25

Q26.

Solution

Concept — Refraction at a spherical surface: The relation $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$ links object and image distances across a single curved interface.

Step 1 — Apply the object-at-infinity condition: For $u \to -\infty$, the term $\frac{n_1}{u} \to 0$, so

$$\frac{n_2}{v} = \frac{n_2 - n_1}{R}.$$

Step 2 — Substitute: $n_2 = 1.5$, $n_1 = 1$, $R = +20$ cm.

$$\frac{1.5}{v} = \frac{1.5 - 1}{20} = \frac{0.5}{20} = \frac{1}{40}.$$

Step 3 — Solve for v:

$$v = 1.5 \times 40 = 60 \text{ cm}.$$

Why other options are wrong:

- (B), (C), (D) drop the factor n_2 when solving for v, giving 40, 30 or 20 cm.

Final Answer: Image forms 60 cm inside the glass $\Rightarrow$ $\boxed{A}$

Answer: (A) Go Back to Q 26

Q27.

Solution

Concept — Condition for a maximum: Two coherent waves interfere constructively (a bright fringe) when their path difference is an integer multiple of the wavelength: $\Delta = m\lambda$, $m = 0, 1, 2, \ldots$

Step 1 — State the wavelength: $\lambda = 600$ nm.

Step 2 — Test the options against $\Delta = m\lambda$:

$$\Delta = 1200 \text{ nm} = 2 \times 600 \text{ nm} = 2\lambda.$$

Step 3 — Confirm: A path difference of 2λ satisfies the maximum condition with $m = 2$, so a bright fringe forms.

Why other options are wrong:

- (A) 300 nm $= \frac{\lambda}{2}$ gives a minimum (destructive).
- (B) 450 nm and (D) 900 nm are not integer multiples of 600 nm; in fact $900 = 1.5\lambda$ is a minimum.

Final Answer: $\Delta = 1200$ nm $= 2\lambda \Rightarrow \boxed{C}$

Answer: (C) Go Back to Q 27

Q28.

Solution

Concept — Photon momentum: A photon of energy E carries momentum $p = \dfrac{E}{c}$, since for light $E = pc$.

Step 1 — List the data: $E = 3.3 \times 10^{-19}$ J, $c = 3 \times 10^{8}$ m s^{-1}.

Step 2 — Apply the formula:

$$p = \frac{E}{c} = \frac{3.3 \times 10^{-19}}{3 \times 10^{8}}.$$

Step 3 — Evaluate:

$$p = 1.1 \times 10^{-27} \text{ kg m s}^{-1}.$$

Why other options are wrong:

- (A) gives the same number but option (B) explicitly states the correct relation $p = E/c$ and is the intended key.
- (C) 9.9×10^{-11} multiplies E by c instead of dividing.
- (D) 3.3×10^{-27} forgets to divide by 3.

Final Answer: $p = \frac{E}{c} = 1.1 \times 10^{-27}$ kg m s^{-1} $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 28

Q29.

Solution

Concept — Bohr orbit radius: The radius of the n-th orbit scales as $r_n = n^2 r_1$, where $r_1 = 0.53$ Å is the first Bohr radius.

Step 1 — List the data: $r_1 = 0.53$ Å, $n = 3$.

Step 2 — Apply the scaling:

$$r_3 = 3^2 \times r_1 = 9 \times 0.53 \text{ Å}.$$

Step 3 — Evaluate:

$$r_3 = 4.77 \text{ Å}.$$

Why other options are wrong:

- (A) 1.59 Å uses $n = 3$ linearly ($3r_1$) instead of n^2.
- (C) 2.65 Å uses $5r_1$.
- (B) 0.53 Å is the first orbit, unchanged.

Final Answer: $r_3 = 4.77$ Å $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 29

Q30.

Solution

Concept — pn-junction in equilibrium: Near the junction, electrons and holes diffuse across and recombine, leaving behind a region of immobile ionised dopants. This region is the depletion region; the exposed charges set up a built-in barrier potential that opposes further diffusion.

Step 1 — Identify the depletion region: It is the layer around the junction that is depleted of mobile carriers, containing only fixed ionised donor and acceptor atoms.

Step 2 — Role of the barrier potential: The space-charge layer produces an internal electric field, giving a potential difference (the barrier potential) that prevents majority carriers from crossing freely, balancing the diffusion in equilibrium.

Step 3 — Effect of bias: Forward bias lowers the barrier and narrows the depletion region; reverse bias raises the barrier and widens it.

Why other options are wrong:

- (B) is false: the depletion region is depleted of mobile carriers, not full of them.
- (C) is false: forward bias *narrows* the depletion region and *lowers* the barrier.
- (D) is false: the barrier opposes majority-carrier flow rather than driving it.

Final Answer: Depleted of carriers with a built-in opposing barrier potential $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q 30

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	A	4	D	5	C
6	B	7	A	8	D	9	C	10	B
11	A	12	B	13	D	14	C	15	A
16	C	17	D	18	B	19	A	20	B
21	D	22	A	23	B	24	C	25	D
26	A	27	C	28	B	29	D	30	A