AIIMS Paramedical Physics

Sample Paper – 4

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.
- 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. Surface tension is defined as force per unit length. The dimensional formula of surface tension is

(A) $[M\,L\,T^{-2}]$

(B) $[M\,T^{-2}]$

(C) $[M\,L^{-1}\,T^{-2}]$

(D) $[M\,L^{2}\,T^{-2}]$

Q2. A body starts from rest and moves with a uniform acceleration of $4\ \text{m s}^{-2}$. The distance covered by it during the 3^{rd} second of its motion is

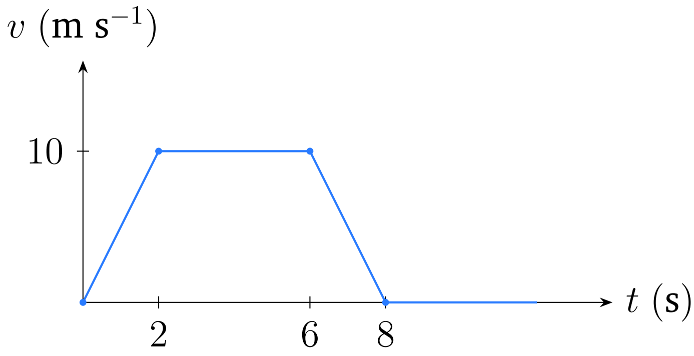
(A) 6 m

(B) 8 m

(C) 10 m

(D) 12 m

Q3. The velocity–time graph of a particle moving along a straight line is shown below. The total displacement of the particle in the 8 s interval is



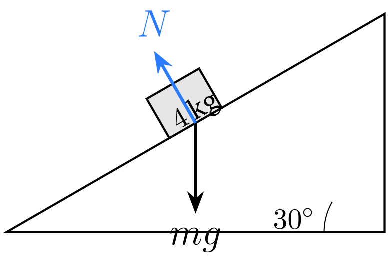
(A) 50 m

(B) 40 m

(C) 60 m

(D) 80 m

Q4. A block of mass 4 kg is placed on a smooth (frictionless) inclined plane making an angle of $30°$ with the horizontal, as shown. Taking $g = 10$ m s^{-2}, the acceleration of the block down the incline and the normal reaction on it are



(A) 10 m s^{-2}, 40 N

(B) 5 m s^{-2}, 40 N

(C) 10 m s^{-2}, $20\sqrt{3}$ N

(D) 5 m s^{-2}, $20\sqrt{3}$ N

Q5. A block of mass 3 kg on a smooth horizontal table is connected by a light inextensible string over a frictionless pulley to a hanging block of mass 2 kg. Taking $g = 10$ m s^{-2}, the tension in the string is

(A) 12 N

(B) 20 N

(C) 10 N

(D) 4 N

Q6. A body of mass 2 kg moving at 6 m s^{-1} collides head-on with a stationary body of mass 4 kg and the two move together after the collision (perfectly inelastic). The kinetic energy lost in the collision is

(A) 12 J

(B) 24 J

(C) 36 J

(D) 48 J

Q7. A horizontal force drags a block of mass 10 kg at a constant velocity of 2 m s^{-1} across a rough floor for which the coefficient of kinetic friction is 0.5. Taking $g = 10$ m s^{-2}, the power delivered by the applied force is

(A) 50 W

(B) 75 W

(C) 100 W

(D) 200 W

Q8. A uniform disc of mass 2 kg and radius 0.5 m can rotate about its central axis. A tangential force of 4 N is applied at its rim. The angular acceleration of the disc is

$$\left(I_{\text{disc}} = \frac{1}{2}MR^2\right)$$

(A) 4 rad s^{-2}

(B) 8 rad s^{-2}

(C) 12 rad s^{-2}

(D) 16 rad s^{-2}

Q9. The gravitational field intensity at a point due to a point mass of 8 kg, at a distance of 2 m from it, is

$$\left(G = 6.67 \times 10^{-11}\ \mathrm{N\ m^2kg^{-2}}\right)$$

(A) $1.33 \times 10^{-10}\ \mathrm{N\ kg^{-1}}$

(B) $2.67 \times 10^{-10}\ \mathrm{N\ kg^{-1}}$

(C) $5.34 \times 10^{-10}\ \mathrm{N\ kg^{-1}}$

(D) $0.67 \times 10^{-10}\ \mathrm{N\ kg^{-1}}$

Q10. A spherical liquid drop of radius 1 mm has a surface tension of $0.075\ \mathrm{N\ m^{-1}}$. The excess pressure inside the drop (over the outside) is

(A) 75 Pa

(B) 150 Pa

(C) 300 Pa

(D) 37.5 Pa

Q11. Two rods of the same length and cross-section but of thermal conductivities K and $3K$ are joined end to end. The free end of the first rod (conductivity K) is kept at $100°$C and the free end of the second rod (conductivity $3K$) at $0°$C. In the steady state, the temperature of the junction is

(A) $25°$C

(B) $75°$C

(C) $50°$C

(D) $20°$C

Q12. A gas is taken through a complete cyclic process and returns to its initial state. During the cycle, the net work done by the gas is 40 J. The net heat absorbed by the gas during the cycle is

(A) 40 J

(B) 0 J

(C) 80 J

(D) 20 J

Q13. A mass m attached to a single spring of force constant k oscillates with period T. When the same mass is attached to two such identical springs joined in parallel, its new period of oscillation is

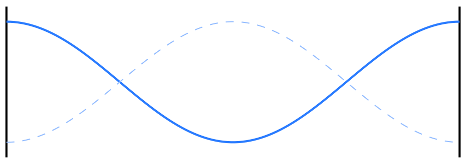
(A) $2T$

(B) $\sqrt{2}\,T$

(C) T

(D) $\dfrac{T}{\sqrt{2}}$

Q14. An open organ pipe of length 0.5 m is vibrating in the standing-wave pattern shown below. Taking the speed of sound in air as 340 m s^{-1}, the frequency of this mode is



open–open, second harmonic

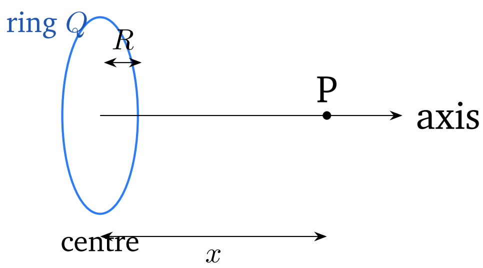
(A) 340 Hz

(B) 680 Hz

(C) 170 Hz

(D) 1020 Hz

Q15. A thin ring of radius R carries a uniformly distributed charge Q. The electric field is evaluated at a point P on the axis at distance x from the centre, as shown. The axial field is maximum when



(A) $x = 0$

(B) $x = R$

(C) $x = \dfrac{R}{\sqrt{2}}$

(D) $x \to \infty$

Q16. A charge of 2×10^{-6} C is moved from a point at potential 20 V to another point at potential 50 V. The work done by the external agent (against the field) is

(A) 1.4×10^{-4} J

(B) 1.0×10^{-4} J

(C) 4.0×10^{-5} J

(D) 6.0×10^{-5} J

Q17. A capacitor charged to a potential difference V stores energy U. If the potential difference across the same capacitor is doubled to $2V$, the energy now stored becomes

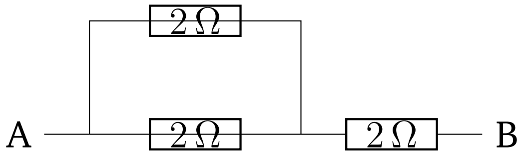
(A) $4U$

(B) $2U$

(C) U

(D) $\dfrac{U}{2}$

Q18. In the resistor network shown, each resistor has resistance 2 Ω. The equivalent resistance between terminals A and B is



(A) 6 Ω

(B) 4 Ω

(C) 3 Ω

(D) 2 Ω

Q19. Two identical cells, each of emf 1.5 V and internal resistance 0.5 Ω, are connected in series across an external resistance of 2 Ω. The current drawn from the combination is

(A) 0.5 A

(B) 1.0 A

(C) 1.5 A

(D) 2.0 A

Q20. A galvanometer of resistance 50 Ω gives a full-scale deflection for a current of 1 mA. To convert it into an ammeter that reads up to 1 A, the value of the shunt resistance required is approximately

(A) 0.5 Ω

(B) 5 Ω

(C) 50 Ω

(D) 0.05 Ω

Q21. In a velocity selector, charged particles pass undeflected through mutually perpendicular electric and magnetic fields of magnitudes $E = 3 \times 10^4$ V m^{-1} and $B = 0.2$ T. The speed of the particles that pass straight through is

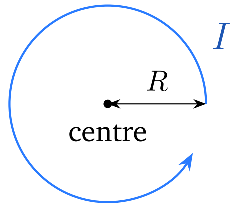
(A) 1.5×10^5 m s^{-1}

(B) 6×10^3 m s^{-1}

(C) 3×10^5 m s^{-1}

(D) 1.5×10^4 m s^{-1}

Q22. A circular loop of radius 0.1 m carries a current of 5 A, as shown. Taking $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}, the magnetic field at the centre of the loop is



(A) $2\pi \times 10^{-5}$ T

(B) $\frac{\pi}{2} \times 10^{-5}$ T

(C) $\pi \times 10^{-5}$ T

(D) $\pi \times 10^{-6}$ T

Q23. The north pole of a bar magnet is pushed towards a closed circular conducting loop, so that the magnetic flux through the loop increases. According to Lenz's law, the induced current in the loop, as seen from the side of the approaching magnet, flows so as to

(A) flow clockwise, attracting the magnet

(B) flow anticlockwise, attracting the magnet

(C) flow clockwise, opposing nothing

(D) flow anticlockwise, repelling the approaching magnet

Q24. A capacitor of 5 μF is connected to an AC source of rms voltage 220 V and angular frequency 1000 rad s^{-1}. The rms current in the circuit is

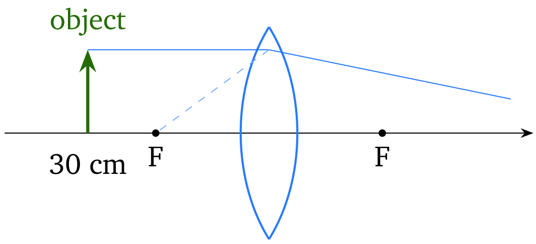
(A) 0.55 A

(B) 1.1 A

(C) 2.2 A

(D) 0.22 A

Q25. An object is placed 30 cm in front of a concave (diverging) lens of focal length 15 cm, as shown. The image distance from the lens is



(A) -15 cm

(B) $+10$ cm

(C) -10 cm

(D) -30 cm

Q26. A thin prism of refracting angle 6° is made of glass of refractive index 1.5. The angle of deviation produced by the prism (for small angles) is

(A) 6°

(B) 4.5°

(C) 1.5°

(D) 3°

Q27. In a single-slit diffraction experiment, light of wavelength 600 nm falls on a slit of width 0.2 mm. The angular position of the first minimum (measured from the central maximum) is

(A) 3×10^{-3} rad

(B) 6×10^{-3} rad

(C) 1.5×10^{-3} rad

(D) 3×10^{-4} rad

Q28. Light of energy 5 eV per photon is incident on a metal of work function 2 eV. The maximum kinetic energy of the emitted photoelectrons is

(A) 2 eV

(B) 3 eV

(C) 5 eV

(D) 7 eV

Q29. The energy of the electron in the ground state ($n = 1$) of a hydrogen atom is -13.6 eV. The energy required to ionise a hydrogen atom from its ground state is

(A) 3.4 eV

(B) 27.2 eV

(C) 13.6 eV

(D) 6.8 eV

Q30. A pure (intrinsic) silicon crystal is doped with a small amount of a pentavalent impurity such as phosphorus. The resulting extrinsic semiconductor is

(A) p-type, with holes as the majority carriers

(B) intrinsic, with equal electrons and holes

(C) p-type, with electrons as the majority carriers

(D) n-type, with electrons as the majority carriers

Detailed Solutions

Q1.

Solution

Concept — Dimensions of surface tension: Surface tension S is force per unit length, $S = \frac{\text{Force}}{\text{Length}}$. We obtain its dimensions by dividing the dimensions of force by those of length.

Step 1 — Dimensions of force: Force = mass × acceleration, so

$$[\text{Force}] = [\text{M}\,\text{L}\,\text{T}^{-2}].$$

Step 2 — Divide by length:

$$[S] = \frac{[\text{M}\,\text{L}\,\text{T}^{-2}]}{[\text{L}]} = [\text{M}\,\text{L}^0\,\text{T}^{-2}] = [\text{M}\,\text{T}^{-2}].$$

Step 3 — Interpret: Surface tension has the same dimensions as surface energy per unit area, $\text{J m}^{-2} = [\text{M}\,\text{T}^{-2}]$, confirming the result.

Why other options are wrong:

- $[\text{M}\,\text{L}\,\text{T}^{-2}]$: that is the dimension of force itself, not of force per length.
- $[\text{M}\,\text{L}^{-1}\,\text{T}^{-2}]$: that is the dimension of pressure (force per area).
- $[\text{M}\,\text{L}^2\,\text{T}^{-2}]$: that is the dimension of energy.

Final Answer: $[S] = [\text{M}\,\text{T}^{-2}] \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 1

Q2.

Solution

Concept — Distance in the n^{th} second: For uniformly accelerated motion starting from rest, the distance covered during the n^{th} second is

$$s_n = u + \frac{a}{2}(2n - 1),$$

where u is the initial velocity and a the acceleration.

Step 1 — List the values: $u = 0$, $a = 4\ \text{m s}^{-2}$, $n = 3$.

Step 2 — Substitute:

$$s_3 = 0 + \frac{4}{2}(2 \times 3 - 1) = 2 \times (6 - 1).$$

Step 3 — Simplify:

$$s_3 = 2 \times 5 = 10 \text{ m}.$$

Why other options are wrong:

- 6 m: uses $(2n - 1)$ with $n = 2$, the 2^{nd} second.
- 8 m: comes from $\frac{1}{2}at^2$ ideas mixed up, not the n^{th}-second formula.
- 12 m: uses $2n$ instead of $(2n - 1)$.

Final Answer: $s_3 = 10 \text{ m} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 2

Q3.

Solution

Concept — Displacement from a v–t graph: The displacement equals the area between the velocity line and the time axis. Since the velocity is positive throughout, we add the areas of each segment.

Step 1 — Read the graph: The velocity rises linearly from 0 to 10 m s^{-1} during 0 to 2 s, stays constant at 10 m s^{-1} from 2 to 6 s, then falls linearly back to 0 from 6 to 8 s.

Step 2 — Area of the rising triangle (0 to 2 s):

$$A_1 = \tfrac{1}{2} \times 2 \times 10 = 10 \text{ m}.$$

Step 3 — Area of the rectangle (2 to 6 s):

$$A_2 = 4 \times 10 = 40 \text{ m}.$$

Step 4 — Area of the falling triangle (6 to 8 s):

$$A_3 = \tfrac{1}{2} \times 2 \times 10 = 10 \text{ m}.$$

Step 5 — Add the areas:

$$s = A_1 + A_2 + A_3 = 10 + 40 + 10 = 60 \text{ m}.$$

Why other options are wrong:

- 50 m: omits one of the triangular areas.
- 40 m: counts only the rectangle.
- 80 m: treats both end portions as full rectangles rather than triangles.

Final Answer: Total displacement = 60 m $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) **Go Back to Q 3**

Q4.

Solution

Concept — Block on a smooth incline: On a frictionless incline of angle θ, the component of gravity along the incline gives the acceleration $a = g \sin\theta$, while the normal reaction balances the perpendicular component, $N = mg\cos\theta$.

Step 1 — Acceleration down the incline:

$$a = g \sin 30^\circ = 10 \times \tfrac{1}{2} = 5 \text{ m s}^{-2}.$$

Step 2 — Normal reaction:

$$N = mg\cos 30^\circ = 4 \times 10 \times \frac{\sqrt{3}}{2}.$$

Step 3 — Simplify N:

$$N = 40 \times \frac{\sqrt{3}}{2} = 20\sqrt{3} \text{ N} \approx 34.6 \text{ N}.$$

Why other options are wrong:

- $10 \text{ m s}^{-2},\ 40$ N: uses $a = g$ and $N = mg$, ignoring the incline angle.
- $5 \text{ m s}^{-2},\ 40$ N: correct acceleration but takes $N = mg$ instead of $mg\cos\theta$.
- $10 \text{ m s}^{-2},\ 20\sqrt{3}$ N: correct normal force but wrong acceleration.

Final Answer: $a = 5 \text{ m s}^{-2}$, $N = 20\sqrt{3}$ N $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) **Go Back to Q 4**

Q5.

Solution

Concept — Connected masses over a pulley: For a block of mass M on a smooth table connected to a hanging mass m, the common acceleration is $a = \dfrac{mg}{M+m}$ and the string tension is $T = \dfrac{Mmg}{M+m}$.

Step 1 — Identify the masses: Table block $M = 3$ kg, hanging block $m = 2$ kg, $g = 10$ m s^{-2}.

Step 2 — Find the acceleration:

$$a = \frac{mg}{M+m} = \frac{2\times 10}{3+2} = \frac{20}{5} = 4 \text{ m s}^{-2}.$$

Step 3 — Find the tension (from the table block, $T = Ma$):

$$T = Ma = 3 \times 4 = 12 \text{ N}.$$

Why other options are wrong:

- 20 N: equals mg, the weight of the hanging block, valid only if it were in equilibrium.
- 10 N: half of mg, not from the correct two-body analysis.
- 4 N: this is the acceleration value, not the tension.

Final Answer: $T = 12 \text{ N} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 5

Q6.

Solution

Concept — Perfectly inelastic collision: Momentum is conserved and the bodies move together afterwards. Kinetic energy is lost; the loss equals the initial KE minus the final KE.

Step 1 — Common velocity from momentum conservation:

$$v = \frac{m_1 u_1}{m_1 + m_2} = \frac{2\times 6}{2+4} = \frac{12}{6} = 2 \text{ m s}^{-1}.$$

Step 2 — Initial kinetic energy:

$$KE_i = \frac{1}{2} \times 2 \times 6^2 = \frac{1}{2} \times 2 \times 36 = 36 \text{ J}.$$

Step 3 — Final kinetic energy:

$$KE_f = \frac{1}{2} \times (2 + 4) \times 2^2 = \frac{1}{2} \times 6 \times 4 = 12 \text{ J}.$$

Step 4 — Energy lost:

$$\Delta KE = KE_i - KE_f = 36 - 12 = 24 \text{ J}.$$

Why other options are wrong:

- 12 J: that is the final kinetic energy, not the loss.
- 36 J: that is the initial kinetic energy, before any loss.
- 48 J: adds the energies instead of subtracting.

Final Answer: $\Delta KE = 24 \text{ J} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 6

Q7.

Solution

Concept — Power against friction at constant velocity: At constant velocity the applied force just balances kinetic friction, $F = \mu_k mg$. The power delivered is $P = F v$.

Step 1 — Friction force:

$$f = \mu_k mg = 0.5 \times 10 \times 10 = 50 \text{ N}.$$

Step 2 — Applied force: At constant velocity, $F = f = 50$ N.

Step 3 — Power:

$$P = F v = 50 \times 2 = 100 \text{ W}.$$

Why other options are wrong:

- 50 W: uses the force value as power, omitting the speed.

- 75 W: arbitrary, not from $P = Fv$.
- 200 W: uses $\mu_k = 1$ or doubles the speed wrongly.

Final Answer: $P = 100$ W $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 7

Q8.

Solution

Concept — Torque and angular acceleration: A tangential force F at the rim produces a torque $\tau = FR$. With moment of inertia I, the angular acceleration is $\alpha = \frac{\tau}{I}$.

Step 1 — Moment of inertia of the disc:

$$I = \tfrac{1}{2}MR^2 = \tfrac{1}{2} \times 2 \times (0.5)^2 = \tfrac{1}{2} \times 2 \times 0.25 = 0.25 \text{ kg m}^2.$$

Step 2 — Torque about the axis:

$$\tau = FR = 4 \times 0.5 = 2 \text{ N m}.$$

Step 3 — Angular acceleration:

$$\alpha = \frac{\tau}{I} = \frac{2}{0.25} = 8 \text{ rad s}^{-2}.$$

Why other options are wrong:

- 4 rad s^{-2}: uses $I = MR^2$ (ring) instead of $\frac{1}{2}MR^2$ (disc).
- 12 rad s^{-2}: arithmetic slip.
- 16 rad s^{-2}: uses $\tau = FR$ with $R = 1$ or doubles the torque.

Final Answer: $\alpha = 8$ rad s^{-2} $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q 8

Q9.

Solution

Concept — Gravitational field of a point mass: The gravitational field intensity (force per unit mass) at distance r from a point mass M is $g = \frac{GM}{r^2}$.

Step 1 — List the values: $M = 8$ kg, $r = 2$ m, $G = 6.67 \times 10^{-11}$ N m^{2}kg^{-2}.

Step 2 — Substitute:

$$g = \frac{GM}{r^2} = \frac{(6.67 \times 10^{-11}) \times 8}{2^2} = \frac{6.67 \times 10^{-11} \times 8}{4}.$$

Step 3 — Simplify:

$$g = 6.67 \times 10^{-11} \times \frac{8}{4} = 6.67 \times 10^{-11} \times 2 = 1.33 \times 10^{-10} \text{ N kg}^{-1}.$$

Why other options are wrong:

- 2.67×10^{-10} N kg^{-1}: forgets to square r (uses r instead of r^2).
- 5.34×10^{-10} N kg^{-1}: omits the division by r^2 entirely.
- 0.67×10^{-10} N kg^{-1}: uses $r^2 = 8$ wrongly.

Final Answer: $g = 1.33 \times 10^{-10}$ N kg^{-1} $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 9

Q10.

Solution

Concept — Excess pressure in a liquid drop: A spherical liquid drop has a single surface, so the excess pressure inside it is $\Delta P = \frac{2S}{R}$, where S is the surface tension and R the radius.

Step 1 — List the values: $S = 0.075$ N m^{-1}, $R = 1$ mm $= 1 \times 10^{-3}$ m.

Step 2 — Substitute:

$$\Delta P = \frac{2S}{R} = \frac{2 \times 0.075}{1 \times 10^{-3}} = \frac{0.15}{10^{-3}}.$$

Step 3 — Simplify:

$$\Delta P = 0.15 \times 10^3 = 150 \text{ Pa}.$$

Why other options are wrong:

- 75 Pa: uses $\frac{S}{R}$, omitting the factor 2.
- 300 Pa: uses $\frac{4S}{R}$, the formula for a soap bubble (two surfaces).
- 37.5 Pa: uses $\frac{S}{2R}$, an extra factor of $\frac{1}{2}$.

Final Answer: $\Delta P = 150$ Pa $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 10

Q11.

Solution

Concept — Junction temperature of rods in series: In steady state the same heat current flows through both rods. With equal length and area, equating the heat currents gives $K_1(\theta_1 - \theta) = K_2(\theta - \theta_2)$, where θ is the junction temperature.

Step 1 — Set up the equation: Rod 1 has conductivity K with hot end $\theta_1 = 100°\text{C}$; rod 2 has conductivity $3K$ with cold end $\theta_2 = 0°\text{C}$:

$$K(100 - \theta) = 3K(\theta - 0).$$

Step 2 — Cancel K and expand:

$$100 - \theta = 3\theta.$$

Step 3 — Solve for θ:

$$100 = 4\theta \;\Rightarrow\; \theta = \frac{100}{4} = 25°\text{C}.$$

Why other options are wrong:

- $50°\text{C}$: assumes equal conductivities, ignoring the factor 3.
- $75°\text{C}$: puts the higher conductivity on the wrong side.
- $20°\text{C}$: arithmetic slip using a factor of 5 instead of 4.

Final Answer: $\theta = 25°\text{C} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 11

Q12.

Solution

Concept — First law over a cycle: For a cyclic process the system returns to its initial state, so the change in internal energy over the complete cycle is zero, $\Delta U = 0$. The first law $\Delta U = Q - W$ then gives $Q = W$.

Step 1 — Apply $\Delta U = 0$:

$$\Delta U = Q - W = 0.$$

Step 2 — Relate heat and work:

$$Q = W.$$

Step 3 — Substitute the given work: The net work done by the gas is $W = 40$ J, so

$$Q = 40 \text{ J}.$$

Why other options are wrong:

- 0 J: confuses $\Delta U = 0$ with $Q = 0$; internal energy returns to its value but heat is still exchanged.
- 80 J: doubles the work for no reason.
- 20 J: halves the work; the first law gives $Q = W$ exactly.

Final Answer: Net heat absorbed $= 40$ J $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 12

Q13.

Solution

Concept — Springs in parallel: Two identical springs of constant k connected in parallel act as a single spring of constant $k_{\text{eff}} = k + k = 2k$. The period of a spring-mass system is $T = 2\pi\sqrt{\frac{m}{k}}$, so $T \propto \frac{1}{\sqrt{k}}$.

Step 1 — Effective spring constant:

$$k_{\text{eff}} = k + k = 2k.$$

Step 2 — Set up the ratio of periods:

$$\frac{T'}{T} = \sqrt{\frac{k}{k_{\text{eff}}}} = \sqrt{\frac{k}{2k}} = \frac{1}{\sqrt{2}}.$$

Step 3 — Solve for the new period:

$$T' = \frac{T}{\sqrt{2}}.$$

Why other options are wrong:

- $2T$: would result if the spring constant became one-quarter, not double.
- $\sqrt{2}\,T$: corresponds to springs in series ($k_{\text{eff}} = k/2$), which softens the system.
- T: ignores the change in stiffness.

Final Answer: $T' = \dfrac{T}{\sqrt{2}} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 13

Q14.

Solution

Concept — Harmonics of an open organ pipe: An open pipe (open at both ends) supports all harmonics, with frequencies $f_n = \frac{nv}{2L}$, where $n = 1, 2, 3, \ldots$ The figure shows the second harmonic, so $n = 2$.

Step 1 — Identify the mode: The standing-wave pattern shows the second harmonic, so $n = 2$.

Step 2 — Apply the formula:

$$f_2 = \frac{nv}{2L} = \frac{2 \times 340}{2 \times 0.5}.$$

Step 3 — Simplify:

$$f_2 = \frac{680}{1} = 680 \text{ Hz}.$$

Why other options are wrong:

- 340 Hz: the fundamental ($n = 1$), not the second harmonic.
- 170 Hz: uses a closed-pipe fundamental $\frac{v}{4L}$.
- 1020 Hz: the third harmonic ($n = 3$).

Final Answer: $f_2 = 680\text{ Hz} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 14

Q15.

Solution

Concept — Axial field of a charged ring: The electric field on the axis of a uniformly charged ring at distance x from the centre is

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Qx}{(R^2+x^2)^{3/2}}.$$

It is zero at the centre, rises to a maximum, then falls off. The maximum is found by setting $\frac{dE}{dx} = 0$.

Step 1 — Differentiate and set to zero: Differentiating $E \propto x(R^2+x^2)^{-3/2}$ and equating to zero gives

$$(R^2+x^2)^{-3/2} - 3x^2(R^2+x^2)^{-5/2} = 0.$$

Step 2 — Simplify: Multiply through by $(R^2+x^2)^{5/2}$:

$$(R^2+x^2) - 3x^2 = 0 \;\Rightarrow\; R^2 - 2x^2 = 0.$$

Step 3 — Solve for x:

$$x^2 = \frac{R^2}{2} \;\Rightarrow\; x = \frac{R}{\sqrt{2}}.$$

Why other options are wrong:

- $x = 0$: at the centre the axial field is zero, not maximum.
- $x = R$: a common guess, but the derivative condition gives $R/\sqrt{2}$.
- $x \to \infty$: the field tends to zero far away.

Final Answer: Field is maximum at $x = \frac{R}{\sqrt{2}} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 15

Q16.

Solution

Concept — Work between equipotentials: The work done by an external agent in moving a charge q from potential V_1 to V_2 (slowly, no change in kinetic energy) equals the change in potential energy, $W = q(V_2 - V_1)$.

Step 1 — List the values: $q = 2 \times 10^{-6}$ C, $V_1 = 20$ V, $V_2 = 50$ V.

Step 2 — Potential difference:

$$V_2 - V_1 = 50 - 20 = 30 \text{ V}.$$

Step 3 — Compute the work:

$$W = q(V_2 - V_1) = (2 \times 10^{-6}) \times 30 = 60 \times 10^{-6} = 6.0 \times 10^{-5} \text{ J}.$$

Why other options are wrong:

- 1.4×10^{-4} J: uses the sum of the potentials (70 V) instead of the difference.
- 1.0×10^{-4} J: uses $V = 50$ V alone, ignoring the starting potential.
- 4.0×10^{-5} J: uses $V = 20$ V alone.

Final Answer: $W = 6.0 \times 10^{-5}$ J $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 16

Q17.

Solution

Concept — Energy stored in a capacitor: The energy stored in a capacitor at potential difference V is $U = \frac{1}{2}CV^2$, so for a fixed capacitor $U \propto V^2$.

Step 1 — Use the proportionality: The voltage is doubled, $V \to 2V$:

$$\frac{U'}{U} = \left(\frac{2V}{V}\right)^2 = 4.$$

Step 2 — Compute the new energy:

$$U' = 4U.$$

Why other options are wrong:

- $2U$: assumes $U \propto V$ instead of V^2.
- U: ignores the change in voltage.
- $\frac{U}{2}$: corresponds to reducing, not increasing, the voltage.

Final Answer: $U' = 4U \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 17

Q18.

Solution

Concept — Series and parallel combination: Two equal resistors in parallel give half their value; a resistor in series adds directly.

Step 1 — Combine the two $2\ \Omega$ resistors in parallel: The top and bottom $2\ \Omega$ resistors between the same two nodes are in parallel:

$$R_p = \frac{2 \times 2}{2 + 2} = \frac{4}{4} = 1\ \Omega.$$

Step 2 — Add the series $2\ \Omega$ resistor: This parallel pair is in series with the remaining $2\ \Omega$ resistor leading to B:

$$R_{AB} = R_p + 2 = 1 + 2 = 3\ \Omega.$$

Why other options are wrong:

- $6\ \Omega$: adds all three in series, ignoring the parallel pair.
- $4\ \Omega$: treats the parallel pair as $2\ \Omega$ instead of $1\ \Omega$.
- $2\ \Omega$: stops at the parallel combination plus error, dropping the series resistor.

Final Answer: $R_{AB} = 3\ \Omega \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 18

Q19.

Solution

Concept — Cells in series: For n identical cells in series, the total emf adds and the internal resistances add. The current is $I = \frac{n\mathcal{E}}{R + nr}$.

Step 1 — Total emf: Two cells in series:

$$\mathcal{E}_{\text{total}} = 2 \times 1.5 = 3 \text{ V}.$$

Step 2 — Total internal resistance:

$$r_{\text{total}} = 2 \times 0.5 = 1 \ \Omega.$$

Step 3 — Apply Ohm's law for the full circuit:

$$I = \frac{\mathcal{E}_{\text{total}}}{R + r_{\text{total}}} = \frac{3}{2+1} = \frac{3}{3} = 1.0 \text{ A}.$$

Why other options are wrong:

- 0.5 A: uses one cell's emf (1.5 V) over the total resistance.
- 1.5 A: ignores the internal resistance entirely.
- 2.0 A: doubles the current by mishandling the resistances.

Final Answer: $I = 1.0 \text{ A} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 19

Q20.

Solution

Concept — Shunt for an ammeter: A small shunt resistance S is placed in parallel with the galvanometer so that most of the current bypasses it. The shunt is $S = \frac{I_g G}{I - I_g}$, where I_g is the full-scale galvanometer current, G its resistance, and I the maximum current to be read.

Step 1 — List the values: $G = 50 \ \Omega$, $I_g = 1 \text{ mA} = 1 \times 10^{-3}$ A, $I = 1$ A.

Step 2 — Compute the remaining current:

$$I - I_g = 1 - 0.001 = 0.999 \text{ A}.$$

Step 3 — Apply the shunt formula:

$$S = \frac{I_g G}{I - I_g} = \frac{(1 \times 10^{-3}) \times 50}{0.999} = \frac{0.05}{0.999} \approx 0.05\ \Omega.$$

Why other options are wrong:

- $0.5\ \Omega$: misplaces a power of ten in I_g.
- $5\ \Omega$: uses $I_g = 0.1$ A instead of 1 mA.
- $50\ \Omega$: equals the galvanometer resistance; a shunt must be far smaller.

Final Answer: $S \approx 0.05\ \Omega \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 20

Q21.

Solution

Concept — Velocity selector: A particle passes undeflected through crossed electric and magnetic fields when the electric force balances the magnetic force, $qE = qvB$, giving $v = \frac{E}{B}$ independent of charge and mass.

Step 1 — Set the forces equal:

$$qE = qvB \;\Rightarrow\; v = \frac{E}{B}.$$

Step 2 — Substitute the values:

$$v = \frac{3 \times 10^4}{0.2}.$$

Step 3 — Simplify:

$$v = \frac{3 \times 10^4}{0.2} = 15 \times 10^4 = 1.5 \times 10^5 \text{ m s}^{-1}.$$

Why other options are wrong:

- 6×10^3 m s^{-1}: multiplies E by B instead of dividing.
- 3×10^5 m s^{-1}: uses $B = 0.1$ T instead of 0.2 T.
- 1.5×10^4 m s^{-1}: misplaces a power of ten.

Final Answer: $v = 1.5 \times 10^5$ m s^{-1} $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 21

Q22.

Solution

Concept — Field at the centre of a current loop: A circular loop of radius R carrying current I produces a magnetic field at its centre of magnitude $B = \frac{\mu_0 I}{2R}$.

Step 1 — List the values: $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}, $I = 5$ A, $R = 0.1$ m.

Step 2 — Substitute:

$$B = \frac{\mu_0 I}{2R} = \frac{(4\pi \times 10^{-7}) \times 5}{2 \times 0.1}.$$

Step 3 — Simplify the numerator and denominator:

$$B = \frac{20\pi \times 10^{-7}}{0.2} = 100\pi \times 10^{-7} = \pi \times 10^{-5}\ \text{T} \approx 3.14 \times 10^{-5}\ \text{T}.$$

Why other options are wrong:

- $2\pi \times 10^{-5}$ T: uses $B = \frac{\mu_0 I}{R}$, omitting the factor 2 in the denominator.
- $\frac{\pi}{2} \times 10^{-5}$ T: uses $B = \frac{\mu_0 I}{4R}$, an extra factor of 2.
- $\pi \times 10^{-6}$ T: misplaces a power of ten.

Final Answer: $B = \pi \times 10^{-5}\ \text{T} \approx 3.14 \times 10^{-5}\ \text{T} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 22

Q23.

Solution

Concept — Lenz's law: The induced current always opposes the change that produces it. When the north pole approaches, the flux through the loop increases, so the induced current must create a magnetic north pole on the near face to oppose (repel) the approaching magnet.

Step 1 — Identify the change: A north pole moving towards the loop increases the magnetic flux directed into the loop (from the side of the magnet).

Step 2 — Apply Lenz's law: To oppose the increase, the loop's near face must become a north pole, repelling the magnet.

Step 3 — Find the current direction: Viewed from the magnet's side, a near-face north pole corresponds to an anticlockwise induced current (the field points out of the loop towards the magnet, repelling it).

Why other options are wrong:

- flow clockwise, attracting the magnet: attraction would aid the motion, violating energy conservation.
- flow anticlockwise, attracting the magnet: anticlockwise gives a north pole, which repels, not attracts.
- flow clockwise, opposing nothing: an induced current must always oppose the change.

Final Answer: Anticlockwise current, repelling the magnet $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 23

Q24.

Solution

Concept — Capacitive reactance and current: In a purely capacitive AC circuit the reactance is $X_C = \dfrac{1}{\omega C}$, and the rms current is $I_{rms} = \dfrac{V_{rms}}{X_C} = V_{rms}\,\omega C$.

Step 1 — Capacitive reactance:

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times (5 \times 10^{-6})} = \frac{1}{5 \times 10^{-3}} = 200\ \Omega.$$

Step 2 — RMS current:

$$I_{rms} = \frac{V_{rms}}{X_C} = \frac{220}{200}.$$

Step 3 — Simplify:

$$I_{rms} = 1.1\ \text{A}.$$

Why other options are wrong:

- 0.55 A: uses $X_C = 400\ \Omega$ (a factor-of-two slip).
- 2.2 A: uses $X_C = 100\ \Omega$.
- 0.22 A: misplaces a power of ten in C.

Final Answer: $I_{rms} = 1.1\ \text{A} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 24

Q25.

Solution

Concept — Concave (diverging) lens: For a diverging lens the focal length is negative. Using the lens formula $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ with the sign convention (u negative for a real object, f negative for a concave lens) gives a virtual, upright image on the same side as the object.

Step 1 — Assign signs: $u = -30$ cm, $f = -15$ cm.

Step 2 — Apply the lens formula:

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{-15} + \frac{1}{-30}.$$

Step 3 — Combine the fractions:

$$\frac{1}{v} = -\frac{2}{30} - \frac{1}{30} = -\frac{3}{30} = -\frac{1}{10}.$$

Step 4 — Solve for v:

$$v = -10 \text{ cm}.$$

The negative sign means the image is virtual and on the same side as the object, as expected for a concave lens.

Why other options are wrong:

- -15 cm: equals the focal length; a concave lens never forms an image beyond its focus.
- $+10$ cm: wrong sign; a concave lens cannot form a real image of a real object.
- -30 cm: equals the object distance, which is not the image position here.

Final Answer: $v = -10$ cm (virtual image) $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 25

Q26.

Solution

Concept — Deviation by a thin prism: For a thin prism of small refracting angle A and refractive index μ, the angle of deviation is $\delta = (\mu - 1)A$.

Step 1 — List the values: $A = 6^\circ$, $\mu = 1.5$.

Step 2 — Substitute:

$$\delta = (\mu - 1)A = (1.5 - 1) \times 6^\circ.$$

Step 3 — Simplify:

$$\delta = 0.5 \times 6^\circ = 3^\circ.$$

Why other options are wrong:

- 6°: uses $\delta = A$, ignoring the $(\mu - 1)$ factor.
- 4.5°: uses μA instead of $(\mu - 1)A$.
- 1.5°: multiplies by 0.25, an arithmetic slip.

Final Answer: $\delta = 3^\circ \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 26

Q27.

Solution

Concept — First minimum in single-slit diffraction: The condition for the first minimum is $a \sin\theta = \lambda$. For small angles, $\sin\theta \approx \theta$, so $\theta = \frac{\lambda}{a}$.

Step 1 — List the values: $\lambda = 600$ nm $= 600 \times 10^{-9}$ m $= 6 \times 10^{-7}$ m, $a = 0.2$ mm $= 2 \times 10^{-4}$ m.

Step 2 — Apply the formula:

$$\theta = \frac{\lambda}{a} = \frac{6 \times 10^{-7}}{2 \times 10^{-4}}.$$

Step 3 — Simplify:

$$\theta = 3 \times 10^{-3} \text{ rad}.$$

Why other options are wrong:

- 6×10^{-3} rad: uses $2\lambda/a$ (the second minimum) or doubles wrongly.
- 1.5×10^{-3} rad: halves the correct value.
- 3×10^{-4} rad: misplaces a power of ten.

Final Answer: $\theta = 3 \times 10^{-3}$ rad $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q 27

Q28.

Solution

Concept — Einstein's photoelectric equation: The maximum kinetic energy of an emitted photoelectron is $KE_{\text{max}} = E_{\text{photon}} - \phi$, where ϕ is the work function of the metal.

Step 1 — List the values: $E_{\text{photon}} = 5$ eV, $\phi = 2$ eV.

Step 2 — Substitute:

$$KE_{\text{max}} = E_{\text{photon}} - \phi = 5 - 2.$$

Step 3 — Simplify:

$$KE_{\text{max}} = 3 \text{ eV}.$$

Why other options are wrong:

- 2 eV: that is the work function, the energy needed just to release an electron.
- 5 eV: that is the photon energy, before subtracting the work function.
- 7 eV: adds the work function instead of subtracting it.

Final Answer: $KE_{\text{max}} = 3$ eV $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q 28

Q29.

Solution

Concept — Ionisation energy of hydrogen: Ionisation means removing the electron completely, taking it from the ground state ($E_1 = -13.6$ eV) to free ($E_\infty = 0$). The energy required is $E_{\text{ion}} = E_\infty - E_1$.

Step 1 — Ground-state energy: $E_1 = -13.6$ eV.

Step 2 — Energy required to reach $E_\infty = 0$:

$$E_{\text{ion}} = 0 - (-13.6) = 13.6 \text{ eV}.$$

Step 3 — Interpret: A photon (or collision) supplying 13.6 eV just frees the ground-state electron of hydrogen.

Why other options are wrong:

- 3.4 eV: the magnitude of the $n = 2$ energy, the ionisation energy from the first excited state.
- 27.2 eV: double the ground-state energy magnitude, not the ionisation energy.
- 6.8 eV: half the ground-state magnitude, an arbitrary value.

Final Answer: $E_{\text{ion}} = 13.6$ eV $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 29

Q30.

Solution

Concept — Doping with a pentavalent impurity: A pentavalent atom (such as phosphorus) has five valence electrons. Four form covalent bonds with neighbouring silicon atoms; the fifth is loosely bound and easily donated to the conduction band, making electrons the majority carriers. This produces an n-type semiconductor.

Step 1 — Count the valence electrons: Phosphorus is pentavalent (five valence electrons); silicon is tetravalent (four).

Step 2 — Identify the surplus carrier: Four electrons bond with silicon; the fifth becomes a free electron, a negative charge carrier.

Step 3 — Classify the semiconductor: With extra free electrons as the majority carriers, the doped crystal is n-type (the impurity is a donor).

Why other options are wrong:

- p-type, holes as majority carriers: results from trivalent (acceptor) doping, not pentavalent.
- intrinsic, equal electrons and holes: doping destroys the intrinsic equality by adding carriers.
- p-type, electrons as majority carriers: contradictory; p-type has holes as the majority carriers.

Final Answer: n-type, electrons are the majority carriers $\Rightarrow \boxed{D}$

Answer: (D) **Go Back to Q 30**

Answer Key

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