# AIIMS Paramedical Physics

## Sample Paper – 8

**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.** The permittivity of free space $\varepsilon_0$ appears in Coulomb's law $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r^2}$. The dimensional formula of $\varepsilon_0$ is

(A) $[\mathrm{M^1L^3T^{-4}A^2}]$

(B) $[\mathrm{M^{-1}L^{-3}T^4A^2}]$

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

(D) $[\mathrm{M^1L^2T^{-3}A^{-1}}]$

**Q2.** A ball is thrown vertically upward from the ground with an initial speed of $20\ \mathrm{m\ s^{-1}}$. Taking $g = 10\ \mathrm{m\ s^{-2}}$, the total time of flight and the maximum height reached are respectively

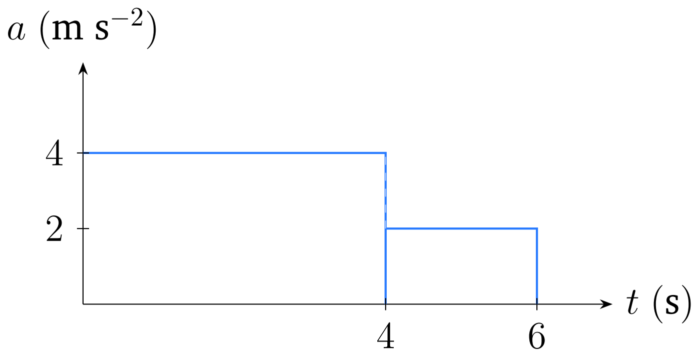
(A) $2$ s and $20$ m

(B) $4$ s and $40$ m

(C) $4$ s and $20$ m

(D) 2 s and 40 m

**Q3.** The acceleration–time graph below describes a particle that starts from rest at $t = 0$. Using the area under the graph, the velocity of the particle at $t = 6$ s is



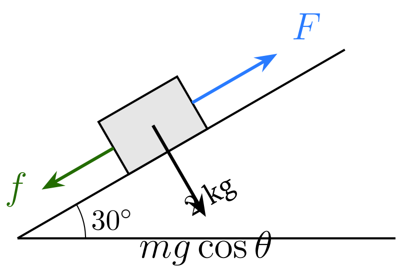

(A) 10 m s$^{-1}$

(B) 12 m s$^{-1}$

(C) 16 m s$^{-1}$

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

**Q4.** A block of mass 2 kg is to be pushed up a rough incline of angle 30° at constant velocity. The coefficient of kinetic friction is $\mu = \frac{1}{2\sqrt{3}}$ and $g = 10$ m s$^{-2}$. The force $F$ applied parallel to the incline (up the slope) is




(A) 15 N

(B) 10 N

(C) 5 N

(D) 20 N

**Q5.** A small bob of mass $0.5$ kg is attached to a string and whirled in a horizontal circle as a conical pendulum, the string making an angle of $60^\circ$ with the vertical. Taking $g = 10$ m s$^{-2}$, the tension in the string is

(A) $5$ N

(B) $2.5$ N

(C) $10$ N

(D) $7.5$ N

**Q6.** A block of mass $1$ kg moving at $6$ m s$^{-1}$ slides across a rough horizontal surface and is acted on by a friction force that does $-16$ J of work before the block reaches a certain point. The speed of the block at that point is

(A) $4$ m s$^{-1}$

(B) $3$ m s$^{-1}$

(C) $1$ m s$^{-1}$

(D) $2$ m s$^{-1}$

**Q7.** A simple machine is used to raise a load of $200$ N through $1$ m when an effort of $50$ N moves through $5$ m. The efficiency of the machine is

(A) $80\%$

(B) $40\%$

(C) $25\%$

(D) $100\%$

**Q8.** A ring and a disc have the same mass $M$ and the same radius $R$. The ratio of the moment of inertia of the ring to that of the disc, both taken about their central axes perpendicular to their planes, is

(A) $1 : 1$

(B) $2 : 1$

(C) $1 : 2$

(D) $4:1$

**Q9.** The acceleration due to gravity at the Earth's surface is $g$. At a depth equal to half the Earth's radius below the surface (assuming uniform density), the value of gravity is

(A) $g$

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

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

(D) $\frac{3g}{4}$

**Q10.** The volume flow rate of a viscous liquid through a capillary tube under a fixed pressure difference is given by Poiseuille's law $Q \propto r^4$. If the radius of the tube is doubled while everything else is kept the same, the flow rate becomes

(A) 2 times

(B) 4 times

(C) 8 times

(D) 16 times

**Q11.** A metal rod is rigidly clamped between two fixed walls so that it cannot expand. When its temperature is raised by $\Delta T = 20$ K, given Young's modulus $Y = 2 \times 10^{11}$ Pa and coefficient of linear expansion $\alpha = 1.2 \times 10^{-5}$ K$^{-1}$, the thermal stress developed in the rod is

(A) $4.8 \times 10^7$ Pa

(B) $2.4 \times 10^7$ Pa

(C) $4.8 \times 10^6$ Pa

(D) $9.6 \times 10^7$ Pa

**Q12.** A Carnot engine operates between a source at 400 K and a sink at 300 K. The efficiency of the engine is

(A) 33%

(B) 25%

(C) 75%

(D) 50%

**Q13.** A particle is subjected simultaneously to two simple harmonic motions of the same frequency along the same line, of amplitudes 3 cm and 4 cm, with a phase difference of $90^\circ$. The amplitude of the resultant motion is

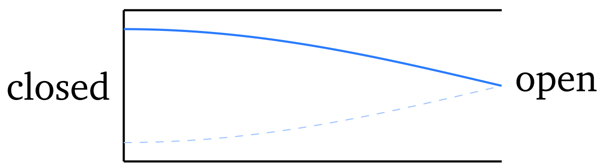
(A) 1 cm

(B) 7 cm

(C) 5 cm

(D) 3.5 cm

**Q14.** A pipe closed at one end has a fundamental frequency of 200 Hz, as represented by the standing-wave pattern shown. The frequency of its first overtone is




fundamental, $\lambda = 4L$

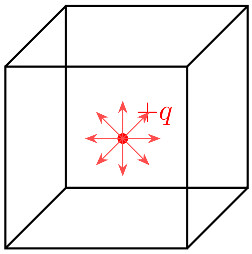
(A) 400 Hz

(B) 800 Hz

(C) 200 Hz

(D) 600 Hz

**Q15.** A point charge of $q = 8.85 \times 10^{-9}$ C is placed at the centre of a closed cubical surface, as shown. Taking $\varepsilon_0 = 8.85 \times 10^{-12}$ $C^2N^{-1}m^{-2}$, the total electric flux passing out through the entire cube is




(A) $1000 \text{ N m}^2\text{C}^{-1}$

(B) $250 \text{ N m}^2\text{C}^{-1}$

(C) $6000 \text{ N m}^2\text{C}^{-1}$

(D) $8.85 \text{ N m}^2\text{C}^{-1}$

**Q16.** A hollow conducting spherical shell of radius $0.2$ m carries a charge of $4 \times 10^{-9}$ C. Taking $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N m}^2\text{C}^{-2}$, the electric potential at a point $0.1$ m from the centre (inside the shell) is

(A) $0$

(B) $180$ V

(C) $360$ V

(D) $90$ V

**Q17.** In the capacitor network shown, the four arms of the bridge have capacitances $C_1 = 2\ \mu\text{F}$, $C_2 = 4\ \mu\text{F}$, $C_3 = 3\ \mu\text{F}$, $C_4 = 6\ \mu\text{F}$, with a bridge capacitor $C_5$ across the middle. Since $\frac{C_1}{C_2} = \frac{C_3}{C_4}$, the bridge is balanced and $C_5$ carries no charge. The equivalent capacitance between the input terminals is

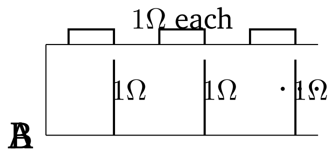
(A) $5\ \mu\text{F}$

(B) $15\ \mu\text{F}$

(C) $\frac{10}{3}\ \mu\text{F}$

(D) $9\ \mu\text{F}$

**Q18.** The infinite resistor ladder network shown is built from identical resistors of $1\ \Omega$, with each "rung" repeating endlessly. The equivalent resistance $R$ between the input terminals A and B satisfies $R = 1 + \dfrac{1 \cdot R}{1+R}$. The value of $R$ is




(A) $1\ \Omega$

(B) $\dfrac{1+\sqrt{5}}{2}\ \Omega$

(C) $2\ \Omega$

(D) $\sqrt{2}\ \Omega$

**Q19.** A cell of emf $E$ and internal resistance $r$ drives a current of $2$ A through an external resistance of $4\ \Omega$, and $1$ A through an external resistance of $9\ \Omega$. The internal resistance $r$ of the cell is

(A) $0.5\ \Omega$

(B) $2\ \Omega$

(C) $1\ \Omega$

(D) $1.5\ \Omega$

**Q20.** In a conductor, the drift velocity of the electrons is $2 \times 10^{-4}$ m s$^{-1}$ when the electric field inside is $4 \times 10^{-2}$ V m$^{-1}$. The mobility of the electrons is

(A) $8 \times 10^{-6}$ m$^2$V$^{-1}$s$^{-1}$

(B) $2 \times 10^{-2}$ m$^2$V$^{-1}$s$^{-1}$

(C) $2 \times 10^{2}$ m$^2$V$^{-1}$s$^{-1}$

(D) $5 \times 10^{-3}$ m$^2$V$^{-1}$s$^{-1}$

**Q21.** A charged particle moving with speed $v$ passes undeviated through a region of crossed uniform electric field $E = 6 \times 10^4$ V m$^{-1}$ and magnetic field $B = 0.2$ T, the fields being mutually perpendicular and both perpendicular to the velocity. The speed $v$ of the particle is

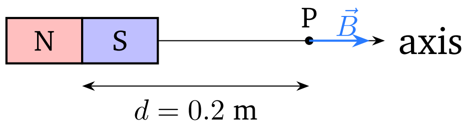
(A) $3 \times 10^5$ m s$^{-1}$

(B) $1.2 \times 10^4$ m s$^{-1}$

(C) $3 \times 10^3$ m s$^{-1}$

(D) $1.2 \times 10^6$ m s$^{-1}$

**Q22.** A short bar magnet of magnetic moment $m = 0.4$ A m$^2$ produces a magnetic field along its axis at a distance $d = 0.2$ m from its centre, as illustrated. Taking $\frac{\mu_0}{4\pi} = 10^{-7}$ T m A$^{-1}$ and using the axial-field formula $B = \frac{\mu_0}{4\pi}\frac{2m}{d^3}$, the field at that point is




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

(B) $1 \times 10^{-5}$ T

(C) $4 \times 10^{-5}$ T

(D) $5 \times 10^{-6}$ T

**Q23.** Eddy currents are induced when a conductor experiences a changing magnetic flux. Which of the following is a direct practical application of eddy currents?

(A) Step-up of voltage in a power transmission line

(B) Storage of charge in a capacitor

(C) Magnetic braking in moving trains

(D) Production of a steady direct current in a cell

**Q24.** A transformer delivers an output power of $440$ W while drawing an input power of $500$ W from the source. The efficiency of the transformer and the power lost (mainly as heat in the windings and core) are respectively

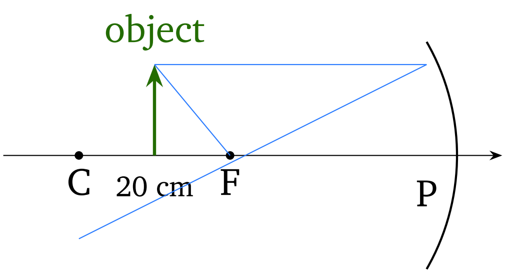
(A) $88\%$ and $440$ W

(B) 60% and 60 W

(C) 90% and 50 W

(D) 88% and 60 W

**Q25.** An object is placed 20 cm in front of a concave mirror of focal length 15 cm, as shown. The image distance and the magnification are respectively




(A) $-60$ cm and $-3$

(B) $-60$ cm and $+3$

(C) $-12$ cm and $-0.6$

(D) $+60$ cm and $-3$

**Q26.** A prism of refracting angle $60^\circ$ produces a minimum deviation of $30^\circ$ for a certain colour of light. The refractive index of the prism material for that light is

(A) 1.33

(B) $\sqrt{2}$

(C) 1.5

(D) $\sqrt{3}$

**Q27.** A thin soap film of refractive index 1.4 appears bright by reflected light of wavelength 560 nm at normal incidence in the lowest-order constructive condition $2\mu t = \frac{\lambda}{2}$. The minimum thickness of the film is

(A) 200 nm

(B) $400$ nm

(C) $100$ nm

(D) $50$ nm

**Q28.** The work function of a metal is $3.0$ eV. When light is incident on it, the most energetic emitted photoelectrons have a maximum kinetic energy of $1.0$ eV. Taking $h = 4.0 \times 10^{-15}$ eV s, the frequency of the incident light is

(A) $7.5 \times 10^{14}$ Hz

(B) $2.5 \times 10^{14}$ Hz

(C) $5.0 \times 10^{14}$ Hz

(D) $1.0 \times 10^{15}$ Hz

**Q29.** In a nuclear reaction the total mass of the reactants exceeds the total mass of the products by a mass defect of $\Delta m = 0.002$ u. Taking $1$ u equivalent to $931.5$ MeV, the energy released (Q-value) in the reaction is approximately

(A) $1.86$ MeV

(B) $0.93$ MeV

(C) $9.3$ MeV

(D) $0.47$ MeV

**Q30.** When silicon is doped with a trivalent impurity such as boron, the resulting extrinsic semiconductor and its majority charge carriers are

(A) n-type, with electrons as majority carriers

(B) p-type, with holes as majority carriers

(C) n-type, with holes as majority carriers

(D) p-type, with electrons as majority carriers

## Detailed Solutions

### Q1.

**Solution**

**Concept — Dimensions from Coulomb's law:** Rearranging $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r^2}$ gives $\varepsilon_0 = \dfrac{q_1 q_2}{4\pi F r^2}$. We substitute the dimensions of charge, force, and distance.

**Step 1 — Write the building blocks:** Charge $q$ = current $\times$ time, so $[q] = [\text{A T}]$. Force $[F] = [\text{M L T}^{-2}]$ and distance $[r] = [\text{L}]$.

**Step 2 — Assemble the formula:**

$$[\varepsilon_0] = \frac{[q]^2}{[F][r]^2} = \frac{[\text{A T}]^2}{[\text{M L T}^{-2}][\text{L}]^2}.$$

**Step 3 — Simplify the powers:**

$$[\varepsilon_0] = \frac{\text{A}^2\text{T}^2}{\text{M L}^3\text{T}^{-2}} = [\text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2].$$

**Why other options are wrong:**

- $[\text{M}^1\text{L}^3\text{T}^{-4}\text{A}^2]$: this is the reciprocal of the correct dimensions.
- $[\text{M}^{-1}\text{L}^{-2}\text{T}^2\text{A}^1]$: wrong powers of length, time, and current.
- $[\text{M}^1\text{L}^2\text{T}^{-3}\text{A}^{-1}]$: these are the dimensions of potential difference, not permittivity.

**Final Answer:** $[\varepsilon_0] = [\text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2] \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q 1

### Q2.

**Solution**

**Concept — Vertical projectile:** For a body thrown up with speed $u$, the time to reach the top is $u/g$, the total time of flight is $2u/g$, and the maximum height is $\dfrac{u^2}{2g}$.

**Step 1 — Time of flight:** With $u = 20$ m s$^{-1}$ and $g = 10$ m s$^{-2}$:

$$T = \frac{2u}{g} = \frac{2 \times 20}{10} = 4 \text{ s}.$$

**Step 2 — Maximum height:**

$$H = \frac{u^2}{2g} = \frac{20^2}{2 \times 10} = \frac{400}{20} = 20 \text{ m}.$$

**Why other options are wrong:**

- $2$ s and $20$ m: uses only the upward time $u/g$, not the full flight.
- $4$ s and $40$ m: doubles the height by forgetting the factor $\frac{1}{2}$.
- $2$ s and $40$ m: both parts wrong.

**Final Answer:** $T = 4$ s, $H = 20$ m $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 2

## Q3.

**Solution**

**Concept — Area under an $a$–$t$ graph:** The change in velocity equals the area between the acceleration curve and the time axis. Starting from rest, the velocity at any time is just that accumulated area.

**Step 1 — First segment ($0$ to $4$ s):** Acceleration is constant at $4$ m s$^{-2}$:

$$\Delta v_1 = 4 \times 4 = 16 \text{ m s}^{-1}.$$

**Step 2 — Second segment ($4$ to $6$ s):** Acceleration is constant at $2$ m s$^{-2}$ over $2$ s:

$$\Delta v_2 = 2 \times 2 = 4 \text{ m s}^{-1}.$$

**Step 3 — Total velocity:** Add the two areas (started from rest):

$$v = \Delta v_1 + \Delta v_2 = 16 + 4 = 20 \text{ m s}^{-1}.$$

**Why other options are wrong:**

- $16$ m s$^{-1}$: counts only the first segment.
- $12$ m s$^{-1}$: misreads the heights of the steps.
- $10$ m s$^{-1}$: averages instead of adding the areas.

**Final Answer:** $v = 20$ m s$^{-1}$ $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q 3

## Q4.

### Solution

**Concept — Pushing a block up a rough incline:** At constant velocity the net force is zero. Along the incline the applied force must balance both the gravity component down the slope and the friction (which also acts down the slope when moving up): $F = mg\sin\theta + \mu mg\cos\theta$.

**Step 1 — Gravity component along the incline:** With $m = 2$ kg, $g = 10$ m s$^{-2}$, $\theta = 30°$, $\sin 30° = \frac{1}{2}$:

$$mg\sin\theta = 2 \times 10 \times \tfrac{1}{2} = 10 \text{ N}.$$

**Step 2 — Friction force:** With $\cos 30° = \frac{\sqrt{3}}{2}$ and $\mu = \dfrac{1}{2\sqrt{3}}$:

$$\mu mg\cos\theta = \frac{1}{2\sqrt{3}} \times 2 \times 10 \times \frac{\sqrt{3}}{2} = \frac{20\sqrt{3}}{4\sqrt{3}} = 5 \text{ N}.$$

**Step 3 — Required force:**

$$F = mg\sin\theta + \mu mg\cos\theta = 10 + 5 = 15 \text{ N}.$$

**Why other options are wrong:**

- 10 N: only the gravity component, ignoring friction.
- 5 N: only the friction term.
- 20 N: overcounts by adding an extra normal-force term.

**Final Answer:** $F = 15 \text{ N} \Rightarrow \boxed{\text{A}}$

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

## Q5.

### Solution

**Concept — Conical pendulum:** The string tension has a vertical component balancing gravity: $T\cos\theta = mg$, where $\theta$ is the angle the string makes with the vertical. Hence $T = \dfrac{mg}{\cos\theta}$.

**Step 1 — List the values:** $m = 0.5$ kg, $g = 10$ m s$^{-2}$, $\theta = 60°$, $\cos 60° = \frac{1}{2}$.

**Step 2 — Compute the weight:**

$$mg = 0.5 \times 10 = 5 \text{ N}.$$

**Step 3 — Find the tension:**

$$T = \frac{mg}{\cos\theta} = \frac{5}{\frac{1}{2}} = 10 \text{ N}.$$

**Why other options are wrong:**

- 5 N: equals $mg$, valid only when the string is vertical ($\theta = 0$).
- 2.5 N: multiplies by $\cos\theta$ instead of dividing.
- 7.5 N: not obtained from the balance equation.

**Final Answer:** $T = 10 \text{ N} \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q 5

## Q6.

**Solution**

**Concept — Work–energy theorem:** The net work done on a body equals its change in kinetic energy: $W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$.

**Step 1 — Initial kinetic energy:** With $m = 1$ kg and $v_i = 6 \text{ m s}^{-1}$:

$$KE_i = \tfrac{1}{2} \times 1 \times 6^2 = 18 \text{ J}.$$

**Step 2 — Apply the theorem:** Friction does $W = -16$ J:

$$KE_f = KE_i + W = 18 + (-16) = 2 \text{ J}.$$

**Step 3 — Solve for the final speed:**

$$\tfrac{1}{2} \times 1 \times v_f^2 = 2 \;\Rightarrow\; v_f^2 = 4 \;\Rightarrow\; v_f = 2 \text{ m s}^{-1}.$$

**Why other options are wrong:**

- $4 \text{ m s}^{-1}$: uses $v_f^2 = 16$, subtracting the work as a speed, not energy.
- $3 \text{ m s}^{-1}$: arbitrary, not from the energy balance.
- $1 \text{ m s}^{-1}$: takes $KE_f = 0.5$ J by mis-subtracting.

**Final Answer:** $v_f = 2 \text{ m s}^{-1} \Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q 6

## Q7.

**Solution**

**Concept — Efficiency of a machine:** Efficiency is the ratio of useful work output to work input: $\eta = \dfrac{\text{work output}}{\text{work input}} \times 100\%$.

**Step 1 — Work output (on the load):**

$$W_{out} = \text{load} \times \text{load distance} = 200 \times 1 = 200 \text{ J}.$$

**Step 2 — Work input (by the effort):**

$$W_{in} = \text{effort} \times \text{effort distance} = 50 \times 5 = 250 \text{ J}.$$

**Step 3 — Efficiency:**

$$\eta = \frac{200}{250} \times 100\% = 80\%.$$

**Why other options are wrong:**

- $40\%$: divides load by effort distance incorrectly.
- $25\%$: takes the reciprocal $W_{in}$ over a wrong factor.
- $100\%$: assumes an ideal machine with no friction loss.

**Final Answer:** $\eta = 80\% \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q 7

## Q8.

**Solution**

**Concept — Moment of inertia about the central axis:** For a ring, $I_{ring} = MR^2$; for a disc, $I_{disc} = \frac{1}{2}MR^2$, both about the axis perpendicular to the plane through the centre.

**Step 1 — Write the two values:**

$$I_{ring} = MR^2, \qquad I_{disc} = \tfrac{1}{2}MR^2.$$

**Step 2 — Form the ratio:**

$$\frac{I_{ring}}{I_{disc}} = \frac{MR^2}{\frac{1}{2}MR^2} = 2.$$

So the ratio is $2 : 1$.

**Why other options are wrong:**

- $1:1$: would require equal moments of inertia, but the ring's mass is all at the rim.
- $1:2$: the inverse of the correct ratio.
- $4:1$: comes from squaring the factor of $2$ wrongly.

**Final Answer:** $I_{ring} : I_{disc} = 2:1 \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q 8

## Q9.

### Solution

**Concept — Gravity below the surface:** For a uniform Earth, the gravity at depth $d$ is $g_d = g\left(1 - \frac{d}{R}\right)$, where $R$ is the Earth's radius.

**Step 1 — Substitute the depth:** Here $d = \frac{R}{2}$:

$$g_d = g\left(1 - \frac{R/2}{R}\right).$$

**Step 2 — Simplify:**

$$g_d = g\left(1 - \tfrac{1}{2}\right) = \frac{g}{2}.$$

**Why other options are wrong:**

- $g$: ignores the depth dependence.
- $\frac{g}{4}$: uses an inverse-square law, which applies above the surface, not below.
- $\frac{3g}{4}$: uses $d = R/4$ instead of $R/2$.

**Final Answer:** $g_d = \frac{g}{2} \Rightarrow \boxed{C}$

Answer: (C) Go Back to Q 9

## Q10.

**Solution**

**Concept — Poiseuille's law:** The volume flow rate through a capillary is $Q = \frac{\pi P r^4}{8\eta L}$, so for fixed pressure, length, and viscosity, $Q \propto r^4$.

**Step 1 — Use the proportionality:** Radius doubled ($r \to 2r$):

$$\frac{Q_2}{Q_1} = \left(\frac{2r}{r}\right)^4 = 2^4.$$

**Step 2 — Compute:**

$$\frac{Q_2}{Q_1} = 16.$$

The flow rate becomes 16 times the original.

**Why other options are wrong:**

- 2 times: assumes $Q \propto r$.
- 4 times: assumes $Q \propto r^2$ (cross-sectional area only).
- 8 times: assumes $Q \propto r^3$.

**Final Answer:** $Q_2 = 16\,Q_1 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 10

## Q11.

**Solution**

**Concept — Thermal stress:** A rod that is prevented from expanding develops a thermal stress $\sigma = Y\alpha\,\Delta T$, where $Y$ is Young's modulus, $\alpha$ the coefficient of linear expansion, and $\Delta T$ the temperature rise. The stress is independent of the rod's length.

**Step 1 — List the values:** $Y = 2 \times 10^{11}$ Pa, $\alpha = 1.2 \times 10^{-5}$ K$^{-1}$, $\Delta T = 20$ K.

**Step 2 — Substitute:**

$$\sigma = Y\alpha\,\Delta T = (2 \times 10^{11})(1.2 \times 10^{-5})(20).$$

**Step 3 — Simplify:**

$$\sigma = 2 \times 1.2 \times 20 \times 10^{11-5} = 48 \times 10^6 = 4.8 \times 10^7 \text{ Pa}.$$

**Why other options are wrong:**

- $2.4 \times 10^7$ Pa: uses $\Delta T = 10$ K instead of 20 K.
- $4.8 \times 10^6$ Pa: an error of one power of ten.
- $9.6 \times 10^7$ Pa: doubles the result by an extra factor.

**Final Answer:** $\sigma = 4.8 \times 10^7$ Pa $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q 11

## Q12.

**Solution**

**Concept — Carnot efficiency:** The maximum (Carnot) efficiency of an engine working between a source at $T_1$ and a sink at $T_2$ (in kelvin) is $\eta = 1 - \frac{T_2}{T_1}$.

**Step 1 — List the temperatures:** $T_1 = 400$ K (source), $T_2 = 300$ K (sink).

**Step 2 — Substitute:**

$$\eta = 1 - \frac{300}{400} = 1 - 0.75.$$

**Step 3 — Simplify:**

$$\eta = 0.25 = 25\%.$$

**Why other options are wrong:**

- $33\%$: uses $1 - \frac{300}{450}$ or mixes the temperatures up.
- $75\%$: this is the ratio $T_2/T_1$, not the efficiency.
- $50\%$: arbitrary, not from the Carnot relation.

**Final Answer:** $\eta = 25\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q 12

## Q13.

**Solution**

**Concept — Superposition of two SHMs:** For two SHMs of amplitudes $a_1$ and $a_2$ along the same line with phase difference $\phi$, the resultant amplitude is $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$.

**Step 1 — Substitute the values:** $a_1 = 3$ cm, $a_2 = 4$ cm, $\phi = 90°$, $\cos 90° = 0$:

$$A = \sqrt{3^2 + 4^2 + 2 \times 3 \times 4 \times 0}.$$

**Step 2 — Simplify:**

$$A = \sqrt{9 + 16} = \sqrt{25} = 5 \text{ cm}.$$

**Why other options are wrong:**

- 7 cm: equals $a_1 + a_2$, valid only for $\phi = 0$ (in phase).
- 1 cm: equals $|a_1 - a_2|$, valid only for $\phi = 180°$ (out of phase).
- 3.5 cm: a simple average, not the vector sum.

**Final Answer:** $A = 5$ cm $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q 13

## Q14.

**Solution**

**Concept — Overtones of a closed pipe:** A pipe closed at one end supports only odd harmonics: $f_n = (2n-1)f_1$ for $n = 1, 2, 3, \ldots$ The first overtone is the next allowed mode above the fundamental, namely the third harmonic ($3f_1$).

**Step 1 — Identify the fundamental:** Given $f_1 = 200$ Hz.

**Step 2 — First overtone:** The next odd harmonic is the third:

$$f_{\text{1st overtone}} = 3f_1 = 3 \times 200.$$

**Step 3 — Compute:**

$$f_{\text{1st overtone}} = 600 \text{ Hz}.$$

**Why other options are wrong:**

- 400 Hz: that is $2f_1$, the even harmonic, which a closed pipe does not produce.

- 800 Hz: that is $4f_1$, also an even (forbidden) harmonic.
- 200 Hz: the fundamental itself, not an overtone.

**Final Answer:** First overtone = 600 Hz $\Rightarrow$ D

Answer: (D) Go Back to Q 14

## Q15.

### Solution

**Concept — Gauss's law:** The total electric flux out of any closed surface depends only on the charge enclosed: $\Phi = \frac{q_{enc}}{\varepsilon_0}$. The shape of the surface does not matter.

**Step 1 — List the values:** $q = 8.85 \times 10^{-9}$ C, $\varepsilon_0 = 8.85 \times 10^{-12}$ C$^2$N$^{-1}$m$^{-2}$.

**Step 2 — Apply Gauss's law:**

$$\Phi = \frac{q}{\varepsilon_0} = \frac{8.85 \times 10^{-9}}{8.85 \times 10^{-12}}.$$

**Step 3 — Simplify:**

$$\Phi = 10^{-9-(-12)} = 10^3 = 1000 \text{ N m}^2\text{C}^{-1}.$$

**Why other options are wrong:**

- 250 N m$^2$C$^{-1}$: divides the total flux among the six faces, but the question asks for the whole cube.
- 6000 N m$^2$C$^{-1}$: multiplies by six unnecessarily.
- 8.85 N m$^2$C$^{-1}$: keeps only the mantissa, ignoring the powers of ten.

**Final Answer:** $\Phi = 1000$ N m$^2$C$^{-1}$ $\Rightarrow$ A

Answer: (A) Go Back to Q 15

## Q16.

**Solution**

**Concept — Potential inside a charged shell:** Inside a charged conducting shell the field is zero, so the potential is constant everywhere inside and equals the surface value $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$, where $R$ is the shell radius.

**Step 1 — Recognise the constant interior potential:** Any interior point ($0.1$ m here) has the same potential as the surface ($R = 0.2$ m).

**Step 2 — Compute the surface potential:**

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = 9\times10^9 \times \frac{4\times10^{-9}}{0.2}.$$

**Step 3 — Simplify:**

$$V = \frac{9\times4}{0.2} = \frac{36}{0.2} = 180\ \text{V}.$$

**Why other options are wrong:**

- $0$: the field is zero inside, but the potential is not zero.
- $360$ V: uses $r = 0.1$ m in the formula, but inside the shell the potential stays at the surface value.
- $90$ V: halves the correct value.

**Final Answer:** $V = 180\ \text{V} \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q 16

## Q17.

**Solution**

**Concept — Balanced capacitor bridge:** When $\frac{C_1}{C_2} = \frac{C_3}{C_4}$, the bridge capacitor $C_5$ has no charge and is removed. The network reduces to two series branches ($C_1$ with $C_2$) and ($C_3$ with $C_4$) in parallel.

**Step 1 — Series branch 1 ($C_1, C_2$):**

$$C_a = \frac{C_1C_2}{C_1+C_2} = \frac{2\times4}{2+4} = \frac{8}{6} = \frac{4}{3}\ \mu\text{F}.$$

**Step 2 — Series branch 2 ($C_3, C_4$):**

$$C_b = \frac{C_3C_4}{C_3 + C_4} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2\ \mu\text{F}.$$

**Step 3 — Parallel combination:**

$$C_{eq} = C_a + C_b = \frac{4}{3} + 2 = \frac{4 + 6}{3} = \frac{10}{3}\ \mu\text{F}.$$

**Why other options are wrong:**

- $5\ \mu$F: adds the series branches as if in parallel without reducing them.
- $15\ \mu$F: sums all four capacitances directly.
- $9\ \mu$F: treats both branches as parallel sums.

**Final Answer:** $C_{eq} = \frac{10}{3}\ \mu\text{F} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 17

## Q18.

**Solution**

**Concept — Infinite ladder self-similarity:** Because the ladder is infinite, removing one section leaves an identical network of resistance $R$. This gives the self-consistent equation $R = 1 + \frac{1 \cdot R}{1 + R}$, where the first $1\ \Omega$ is the series resistor and the parallel term is the $1\ \Omega$ rung in parallel with the rest.

**Step 1 — Clear the fraction:** Multiply through by $(1 + R)$:

$$R(1 + R) = (1 + R) + R.$$

**Step 2 — Expand and collect:**

$$R + R^2 = 1 + R + R \ \Rightarrow\ R^2 - R - 1 = 0.$$

**Step 3 — Solve the quadratic:** Taking the positive root,

$$R = \frac{1 + \sqrt{1 + 4}}{2} = \frac{1 + \sqrt{5}}{2} \approx 1.62\ \Omega.$$

**Why other options are wrong:**

- $1\ \Omega$: only the first series resistor, ignoring the rest of the ladder.
- $2\ \Omega$: a rounded guess; the exact root is the golden-ratio value.
- $\sqrt{2}\ \Omega$: comes from $R^2 = 2$, a different (incorrect) equation.

**Final Answer:** $R = \dfrac{1+\sqrt{5}}{2}\ \Omega \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q 18

## Q19.

### Solution

**Concept — Cell with internal resistance:** For a cell of emf $E$ and internal resistance $r$ driving current $I$ through external resistance $R$, $E = I(R + r)$. Two different loads give two equations to solve for $E$ and $r$.

**Step 1 — Write both equations:**

$$E = 2(4 + r), \qquad E = 1(9 + r).$$

**Step 2 — Equate the two expressions for $E$:**

$$2(4 + r) = 1(9 + r) \;\Rightarrow\; 8 + 2r = 9 + r.$$

**Step 3 — Solve for $r$:**

$$2r - r = 9 - 8 \;\Rightarrow\; r = 1\ \Omega.$$

**Why other options are wrong:**

- $0.5\ \Omega$: comes from a sign slip in the subtraction.
- $2\ \Omega$: doubles the correct value.
- $1.5\ \Omega$: results from mismatching the currents and resistances.

**Final Answer:** $r = 1\ \Omega \Rightarrow \boxed{\text{C}}$

**Answer: (C)** Go Back to Q 19

## Q20.

**Solution**

**Concept — Mobility:** The mobility $\mu$ of charge carriers is the drift velocity per unit electric field: $\mu = \frac{v_d}{E}$.

**Step 1 — List the values:** $v_d = 2 \times 10^{-4}$ m s$^{-1}$, $E = 4 \times 10^{-2}$ V m$^{-1}$.

**Step 2 — Substitute:**

$$\mu = \frac{v_d}{E} = \frac{2 \times 10^{-4}}{4 \times 10^{-2}}.$$

**Step 3 — Simplify:**

$$\mu = \frac{2}{4} \times 10^{-4-(-2)} = 0.5 \times 10^{-2} = 5 \times 10^{-3} \text{ m}^2\text{V}^{-1}\text{s}^{-1}.$$

**Why other options are wrong:**

- $8 \times 10^{-6}$: multiplies $v_d$ and $E$ instead of dividing.
- $2 \times 10^{-2}$: keeps the wrong power of ten.
- $2 \times 10^{2}$: inverts the ratio (divides $E$ by $v_d$).

**Final Answer:** $\mu = 5 \times 10^{-3}$ m$^2$V$^{-1}$s$^{-1}$ $\Rightarrow$ D

Answer: (D) Go Back to Q 20

## Q21.

**Solution**

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

**Step 1 — List the values:** $E = 6 \times 10^{4}$ V m$^{-1}$, $B = 0.2$ T.

**Step 2 — Substitute:**

$$v = \frac{E}{B} = \frac{6 \times 10^{4}}{0.2}.$$

**Step 3 — Simplify:**

$$v = \frac{6 \times 10^{4}}{0.2} = 3 \times 10^{5} \text{ m s}^{-1}.$$

**Why other options are wrong:**

- $1.2 \times 10^{4}$ m s$^{-1}$: multiplies $E$ and $B$ instead of dividing.

- $3 \times 10^3$ m s$^{-1}$: an error of two powers of ten.
- $1.2 \times 10^6$ m s$^{-1}$: misplaces the decimal of $B$.

**Final Answer:** $v = 3 \times 10^5$ m s$^{-1}$ $\Rightarrow$ $\boxed{\text{A}}$

**Answer: (A)** **Go Back to Q 21**

## Q22.

### Solution

**Concept — Axial field of a bar magnet:** On the axis of a short bar magnet at distance $d$, the magnetic field is $B = \frac{\mu_0}{4\pi}\frac{2m}{d^3}$, where $m$ is the magnetic moment.

**Step 1 — List the values:** $\frac{\mu_0}{4\pi} = 10^{-7}$ T m A$^{-1}$, $m = 0.4$ A m$^2$, $d = 0.2$ m.

**Step 2 — Compute $d^3$:**

$$d^3 = (0.2)^3 = 0.008 = 8 \times 10^{-3} \text{ m}^3.$$

**Step 3 — Substitute:**

$$B = 10^{-7} \times \frac{2 \times 0.4}{8 \times 10^{-3}} = 10^{-7} \times \frac{0.8}{8 \times 10^{-3}}.$$

**Step 4 — Simplify:**

$$B = 10^{-7} \times 100 = 1 \times 10^{-5} \text{ T}.$$

**Why other options are wrong:**

- $2 \times 10^{-5}$ T: forgets to take $d^3$ and uses $d^2$ instead.
- $4 \times 10^{-5}$ T: drops the factor of 2 wrongly and mis-cubes $d$.
- $5 \times 10^{-6}$ T: halves the correct value.

**Final Answer:** $B = 1 \times 10^{-5}$ T $\Rightarrow$ $\boxed{\text{B}}$

**Answer: (B)** **Go Back to Q 22**

## Q23.

**Solution**

**Concept — Eddy currents:** A changing magnetic flux induces circulating (eddy) currents in a bulk conductor. By Lenz's law these currents oppose the motion that produces them, dissipating energy as heat. This opposition is exploited as a braking mechanism.

**Step 1 — Identify the eddy-current application:** In electromagnetic (magnetic) braking, a metal disc or rail moving through a magnetic field has eddy currents induced in it; the resulting retarding force slows the train smoothly.

**Step 2 — Match the option:** "Magnetic braking in moving trains" is the direct eddy-current application.

**Why other options are wrong:**

- Step-up of voltage in a transmission line: that is mutual induction in a transformer, not eddy currents (which are an unwanted loss there).
- Storage of charge in a capacitor: an electrostatic effect, no induced currents.
- Production of a steady direct current in a cell: a chemical effect, unrelated to changing flux.

**Final Answer:** Magnetic braking in moving trains $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 23

## Q24.

**Solution**

**Concept — Transformer efficiency:** Efficiency is the ratio of output power to input power, $\eta = \frac{P_{out}}{P_{in}} \times 100\%$, and the power lost is $P_{in} - P_{out}$.

**Step 1 — Compute the efficiency:**

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{440}{500} \times 100\% = 88\%.$$

**Step 2 — Compute the power lost:**

$$P_{loss} = P_{in} - P_{out} = 500 - 440 = 60 \text{ W}.$$

**Why other options are wrong:**

- $88\%$ and $440$ W: the efficiency is right but $440$ W is the output, not the loss.
- $60\%$ and $60$ W: wrong efficiency; $440/500 = 0.88$, not $0.60$.
- $90\%$ and $50$ W: rounds the figures incorrectly.

**Final Answer:** $\eta = 88\%$, loss $= 60$ W $\Rightarrow \boxed{\text{D}}$

**Answer: (D)** Go Back to Q 24

## Q25.

### Solution

**Concept — Mirror formula:** For a concave mirror, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ with the sign convention $u < 0$, $f < 0$. The magnification is $m = -\frac{v}{u}$.

**Step 1 — Assign signs:** $u = -20$ cm, $f = -15$ cm.

**Step 2 — Apply the mirror formula:**

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{-15} - \frac{1}{-20} = -\frac{1}{15} + \frac{1}{20}.$$

**Step 3 — Combine the fractions:**

$$\frac{1}{v} = \frac{-4+3}{60} = \frac{-1}{60} \quad \Rightarrow \quad v = -60 \text{ cm}.$$

**Step 4 — Magnification:**

$$m = -\frac{v}{u} = -\frac{-60}{-20} = -3.$$

The image is real, inverted, and three times the size of the object.

**Why other options are wrong:**

- $-60$ cm and $+3$: correct distance but wrong sign of $m$; a real image here is inverted ($m < 0$).
- $-12$ cm and $-0.6$: uses $u = -30$ cm instead of $-20$ cm.
- $+60$ cm and $-3$: a positive $v$ would mean a virtual image, which is not the case here.

**Final Answer:** $v = -60$ cm, $m = -3 \Rightarrow \boxed{\text{A}}$

**Answer: (A)** Go Back to Q 25

## Q26.

**Solution**

**Concept — Prism formula at minimum deviation:** The refractive index is $\mu = \dfrac{\sin\left(\dfrac{A+D_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$, where $A$ is the prism angle and $D_m$ the minimum deviation.

**Step 1 — List the values:** $A = 60^\circ$, $D_m = 30^\circ$.

**Step 2 — Evaluate the half-angles:**

$$\frac{A+D_m}{2} = \frac{60^\circ + 30^\circ}{2} = 45^\circ, \qquad \frac{A}{2} = 30^\circ.$$

**Step 3 — Substitute:**

$$\mu = \frac{\sin 45^\circ}{\sin 30^\circ} = \frac{\frac{1}{\sqrt{2}}}{\frac{1}{2}} = \frac{2}{\sqrt{2}} = \sqrt{2}.$$

**Why other options are wrong:**

- $1.33$: the value for water, not this prism.
- $1.5$: a typical glass value but not what these angles give.
- $\sqrt{3}$: would arise from $\sin 60^\circ / \sin 30^\circ$, the wrong half-angles.

**Final Answer:** $\mu = \sqrt{2} \approx 1.414 \Rightarrow \boxed{\text{B}}$

**Answer: (B)** Go Back to Q 26

## Q27.

**Solution**

**Concept — Thin-film interference (reflected light):** For constructive interference in reflection from a thin film, including the half-wave phase change on reflection, the lowest-order condition is $2\mu t = \dfrac{\lambda}{2}$, giving the minimum thickness $t = \dfrac{\lambda}{4\mu}$.

**Step 1 — List the values:** $\lambda = 560$ nm, $\mu = 1.4$.

**Step 2 — Substitute:**

$$t = \frac{\lambda}{4\mu} = \frac{560}{4 \times 1.4} = \frac{560}{5.6}.$$

**Step 3 — Simplify:**

$$t = 100 \text{ nm}.$$

**Why other options are wrong:**

- 200 nm: uses $t = \frac{\lambda}{2\mu}$, omitting the half-wave shift.
- 400 nm: uses $t = \frac{\lambda}{\mu}$ without the interference factor.
- 50 nm: divides by an extra factor of two.

**Final Answer:** $t = 100 \text{ nm} \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q 27

## Q28.

Solution

**Concept — Einstein's photoelectric equation:** The photon energy splits into the work function and the maximum kinetic energy of the ejected electron: $h\nu = \phi + K_{max}$. So $\nu = \frac{\phi + K_{max}}{h}$.

**Step 1 — Total photon energy:**

$$E = \phi + K_{max} = 3.0 + 1.0 = 4.0 \text{ eV}.$$

**Step 2 — Solve for the frequency:** With $h = 4.0 \times 10^{-15}$ eV s,

$$\nu = \frac{E}{h} = \frac{4.0}{4.0 \times 10^{-15}}.$$

**Step 3 — Simplify:**

$$\nu = 1.0 \times 10^{15} \text{ Hz}.$$

**Why other options are wrong:**

- $7.5 \times 10^{14}$ Hz: uses only $\phi = 3.0$ eV, ignoring $K_{max}$.
- $2.5 \times 10^{14}$ Hz: uses only $K_{max} = 1.0$ eV.
- $5.0 \times 10^{14}$ Hz: an arithmetic slip in dividing by $h$.

**Final Answer:** $\nu = 1.0 \times 10^{15} \text{ Hz} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q 28

## Q29.

**Solution**

**Concept — Q-value from mass defect:** The energy released equals the mass defect converted via $E = \Delta m\, c^2$. Using the convenient conversion $1$ u $\equiv 931.5$ MeV, $Q = \Delta m\,(\text{in u}) \times 931.5$ MeV.

**Step 1 — List the values:** $\Delta m = 0.002$ u.

**Step 2 — Substitute:**

$$Q = 0.002 \times 931.5 \text{ MeV}.$$

**Step 3 — Simplify:**

$$Q = 1.863 \approx 1.86 \text{ MeV}.$$

**Why other options are wrong:**

- $0.93$ MeV: uses $\Delta m = 0.001$ u (half the given defect).
- $9.3$ MeV: uses $\Delta m = 0.01$ u, off by a power of ten.
- $0.47$ MeV: a quarter of the correct value.

**Final Answer:** $Q \approx 1.86$ MeV $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q 29

## Q30.

**Solution**

**Concept — Doping of semiconductors:** A trivalent dopant (such as boron) has one fewer valence electron than silicon, creating an electron vacancy called a hole. This produces a p-type semiconductor in which holes are the majority carriers and electrons the minority carriers.

**Step 1 — Identify the dopant type:** Boron has $3$ valence electrons, one short of silicon's $4$, so it accepts an electron and leaves a hole.

**Step 2 — Classify the semiconductor:** Acceptor (trivalent) doping gives a p-type material whose majority carriers are holes.

**Why other options are wrong:**

- n-type with electrons: that results from a pentavalent (donor) dopant such as phosphorus, not boron.
- n-type with holes: inconsistent; n-type majority carriers are electrons.

- p-type with electrons: inconsistent; p-type majority carriers are holes, not electrons.

**Final Answer:** p-type, holes as majority carriers $\Rightarrow \boxed{B}$

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

## Answer Key

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