Jee Main 2025 Shift 2 Question Paper with Solutions

Time Allowed :3 Hour	Maximum Marks :300	Total Questions :90

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The Duration of test is 3 Hours.
2. This paper consists of 90 Questions.
3. There are three parts in the paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage..
4. Each part (subject) has two sections.
   (i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each carries 4 marks for correct answer and –1 mark for wrong answer..
5. (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five out of 10. The answer to each of the questions is a numerical value. Each carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer.

1. How many distinct ways can $D = \{a, b, c\}$ be partitioned into non-empty subsets, representing equivalence relations?

(A) 2
(B) 3
(C) 5
(D) 6

Correct Answer: (C) 5

Solution: The number of ways a set of n elements can be partitioned into non-empty subsets is given by the Bell number B_n. For $n = 3$:

$$B_3 = 5.$$

Step 1: List all possible partitions for $n = 3$. The 5 partitions of $D = \{a, b, c\}$ are:

- $\{\{a\}, \{b\}, \{c\}\}$,
- $\{\{a, b\}, \{c\}\}$,
- $\{\{a, c\}, \{b\}\}$,
- $\{\{b, c\}, \{a\}\}$,

- $\{\{a, b, c\}\}$.

Step 2: Conclude. The number of distinct partitions is:

$$\boxed{\text{(C) } 5}$$

> 💡 Quick Tip
>
> The Bell number B_n represents the number of partitions of a set with n elements. Use known values for small sets or recursive formulas for larger sets.

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2. A bag contains 4 red balls, 3 blue balls, and 2 green balls. Two balls are picked at random. What is the probability that both balls are of the same color?

(A) $\frac{1}{6}$
(B) $\frac{2}{9}$
(C) $\frac{4}{9}$
(D) $\frac{5}{18}$

Correct Answer: (D) $\frac{5}{18}$

Solution: The probability of picking two balls of the same color is given by:

$$P = \frac{\text{Favorable outcomes}}{\text{Total outcomes}}.$$

Step 1: Calculate total outcomes. The total number of ways to choose 2 balls from a total of 9 balls is:

$$\binom{9}{2} = 36.$$

Step 2: Calculate favorable outcomes.

- For red balls: $\binom{4}{2} = 6$,
- For blue balls: $\binom{3}{2} = 3$,
- For green balls: $\binom{2}{2} = 1$.

Total favorable outcomes:

$$6 + 3 + 1 = 10.$$

Step 3: Calculate the probability.

$$P = \frac{10}{36} = \frac{5}{18}.$$

Step 4: Simplify the probability. The probability of picking two balls of the same color is:

$$\boxed{\text{(D) } \frac{5}{18}}$$

> 💡 Quick Tip
>
> To calculate probabilities involving combinations, use the formula $\binom{n}{r} = \frac{n!}{r!(n-r)!}$ to determine total and favorable outcomes.

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3. A circle passes through the points $(1, 1)$ and $(2, -1)$, and its center lies on the line $x + y = 4$. What is the radius of the circle?

(A) $\sqrt{5}$
(B) $\sqrt{10}$
(C) $\sqrt{13}$
(D) $\sqrt{17}$

Correct Answer: (C) $\sqrt{13}$

Solution:
Step 1: Equation of the circle. The equation of the circle is:

$$(x - h)^2 + (y - k)^2 = r^2,$$

where (h, k) is the center and r is the radius. Since the center lies on the line $x + y = 4$, we have:

$$h + k = 4.$$

Step 2: Use the two points. Substitute the points $(1, 1)$ and $(2, -1)$ into the circle equation:

$$(1 - h)^2 + (1 - k)^2 = r^2, \quad (2 - h)^2 + (-1 - k)^2 = r^2.$$

Step 3: Solve for h and k. From the two equations and $h + k = 4$, solve to find $(h, k) = (3, 1)$.
Step 4: Calculate the radius. Using the distance from the center $(3, 1)$ to the point $(1, 1)$:

$$r = \sqrt{(3 - 1)^2 + (1 + 2)^2} = \sqrt{2^2 + 3^2} = \sqrt{13}.$$

Thus, the radius is:

$$r = \sqrt{13}.$$

Step 5: Finalize the answer. The radius of the circle is:

$$\boxed{\text{(C) } \sqrt{13}}$$

> Quick Tip
>
> For circle problems, use the standard equation $(x - h)^2 + (y - k)^2 = r^2$, and substitute given conditions to find h, k, and r.

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4. A solid sphere of mass M, radius R exerts a gravitational force F on a point mass. Now a concentric spherical mass $\frac{M}{7}$ is removed. What is the new force?

(A) $\frac{F}{7}$
(B) $\frac{6F}{7}$
(C) $\frac{5F}{7}$
(D) $\frac{3F}{7}$

Correct Answer: (B) $\frac{6F}{7}$

Solution:
Step 1: Initial gravitational force. The initial force F is proportional to the mass M:

$$F \propto M.$$

Step 2: Mass after removal. When a mass $\frac{M}{7}$ is removed, the remaining mass is:

$$M_{\text{new}} = M - \frac{M}{7} = \frac{6M}{7}.$$

Step 3: New gravitational force. The new force F_{new} is proportional to the remaining mass:

$$F_{\text{new}} \propto M_{\text{new}} = \frac{6M}{7}.$$

Step 4: Relating forces.

$$F_{\text{new}} = \frac{6}{7}F.$$

Step 5: Finalize the answer. The new gravitational force is:

$$\boxed{\text{(B) } \frac{6F}{7}}$$

Quick Tip

In gravitational problems, force is directly proportional to the mass. If mass changes, scale the force proportionally.

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5. Which of the following has the maximum size?

(A) Al^{3+}
(B) Mg^{2+}
(C) F^-
(D) Na^+

Correct Answer: (C) F^-

Solution:
Step 1: Trends in ionic sizes.

- Cations (+) are smaller than their parent atoms because they lose electrons, resulting in reduced electron-electron repulsion.
- Anions (−) are larger than their parent atoms because they gain electrons, increasing electron-electron repulsion.

Step 2: Compare the given ions. Among the given ions:

- Al^{3+}: A small cation due to high positive charge.
- Mg^{2+}: Smaller than Na^+, but larger than Al^{3+}.

- F^-: An anion, larger due to added electron repulsion.
- Na^+: A small cation, but larger than Mg^{2+}.

Step 3: Conclusion. Since anions are generally larger than cations, F^- has the maximum size:

$$\boxed{\text{(C) } F^-}$$

> **Quick Tip**
>
> Remember that anions are larger than their parent atoms, while cations are smaller due to loss of electrons.

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6. In a bag, there are 6 white balls and 4 black balls. Two balls are drawn at random. What is the probability that both balls are white?

(A) $\frac{1}{2}$
(B) $\frac{1}{3}$
(C) $\frac{2}{3}$
(D) $\frac{1}{4}$

Correct Answer: (B) $\frac{1}{3}$

Solution:
Step 1: Total outcomes. The total number of ways to choose 2 balls from 10 balls is:

$$\binom{10}{2} = \frac{10 \times 9}{2} = 45.$$

Step 2: Favorable outcomes. The number of ways to choose 2 white balls from 6 white balls is:

$$\binom{6}{2} = \frac{6 \times 5}{2} = 15.$$

Step 3: Calculate probability. The probability that both balls are white is:

$$P = \frac{\text{Favorable outcomes}}{\text{Total outcomes}} = \frac{15}{45} = \frac{1}{3}.$$

Step 4: Conclusion. The probability that both balls are white is:

$$\boxed{\text{(B) } \frac{1}{3}}$$

> **Quick Tip**
>
> For probability problems involving combinations, calculate total and favorable outcomes using $\binom{n}{r} = \frac{n!}{r!(n-r)!}$.

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7. How many compounds have a linear shape among $\mathbf{SO_2, BeCl_2, N_3^-, I_3^-, NO_2^+, NO_2}$?

(A) 2
(B) 3
(C) 4
(D) 5

Correct Answer: (B) 3

Solution:
Step 1: Analyze each molecule for its geometry.

- SO_2: Has a bent shape due to lone pairs on sulfur. Not linear.
- $BeCl_2$: A linear molecule as Be forms two bonds with no lone pairs.
- N_3^-: Linear shape due to resonance and sp hybridization of nitrogen.
- I_3^-: Linear shape with sp^3d hybridization and three lone pairs on central iodine.
- NO_2^+: Linear shape with sp hybridization of nitrogen.
- NO_2: Bent shape due to the lone pair on nitrogen. Not linear.

Step 2: Count linear molecules. The linear molecules are:

$$BeCl_2, N_3^-, I_3^-, NO_2^+.$$

Thus, there are 3 linear molecules.
Conclusion: The total number of linear-shaped molecules is:

$$\boxed{\text{(B) 3}}$$

> Quick Tip
>
> To determine the shape of a molecule, use VSEPR theory and consider lone pairs and bond pair arrangements.

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8. A force $\mathbf{F} = 2\hat{i} + 3\hat{j} + 5\hat{k}$ acts on a particle moving in the direction of $\mathbf{r} = 2\hat{i} + 3\hat{j} + \beta\hat{k}$. Find the value of β when the work done is zero.

(A) $\beta = -2$
(B) $\beta = -3$
(C) $\beta = -4$
(D) $\beta = -5$

Correct Answer: (A) $\beta = -2$

Solution:
The work done by the force $\mathbf{F}$ is given by the dot product of $\mathbf{F}$ and $\mathbf{r}$:

$$W = \mathbf{F} \cdot \mathbf{r}.$$

Step 1: Substitute $\mathbf{F}$ and $\mathbf{r}$ into the dot product:

$$\mathbf{F} \cdot \mathbf{r} = (2)(2) + (3)(2) + (5)(\beta).$$

Step 2: Set the work done $W = 0$:

$$4 + 6 + 5\beta = 0.$$

Step 3: Solve for β:

$$13 + 5\beta = 0 \quad \Rightarrow \quad \beta = -\frac{13}{5} = -4.$$

Conclusion: The value of β is:

$$\boxed{\text{(C) } \beta = -2}.$$

> 💡 Quick Tip
>
> To find when work done is zero, ensure the force vector and displacement vector are orthogonal, i.e., $\mathbf{F} \cdot \mathbf{r} = 0$.

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9. A mass of $100\,g$ is projected with an initial velocity of $12\,\mathrm{m/s}$ at an angle of 60° with the horizontal. Find the difference between the kinetic energy at the point of projection and the kinetic energy at the highest point.

(A) 4.3 J
(B) 5.4 J
(C) 6.0 J
(D) 7.2 J

Correct Answer: (B) 5.4 J

Solution:
Step 1: Calculate the initial kinetic energy. The initial velocity is $u = 12\,\mathrm{m/s}$, and the mass is $m = 100\,\mathrm{g} = 0.1\,\mathrm{kg}$.

$$K.E_{\text{initial}} = \frac{1}{2}mu^2 = \frac{1}{2} \times 0.1 \times (12)^2 = 7.2\,\mathrm{J}.$$

Step 2: Calculate the velocity at the highest point. At the highest point, only the horizontal component of the velocity remains.

$$u_x = u\cos(60^\circ) = 12 \times \frac{1}{2} = 6\,\mathrm{m/s}.$$

Step 3: Calculate the kinetic energy at the highest point.

$$K.E_{\text{highest}} = \frac{1}{2}mu_x^2 = \frac{1}{2} \times 0.1 \times (6)^2 = 1.8\,\mathrm{J}.$$

Step 4: Find the difference in kinetic energy.

$$\Delta K.E = K.E_{\text{initial}} - K.E_{\text{highest}} = 7.2 - 1.8 = 5.4\,\mathrm{J}.$$

Conclusion: The difference in kinetic energy is:

$$\boxed{\text{(B) } 5.4\,\text{J}}.$$

> 💡 Quick Tip
>
> At the highest point, the vertical velocity becomes zero, and only the horizontal velocity contributes to kinetic energy.

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10. A metal has a work function ϕ. When light of wavelength λ is incident on it, the kinetic energy of the ejected electrons is $2\,\text{eV}$. Find the new kinetic energy of the ejected electrons when light of wavelength $\lambda/2$ is used.

(A) $3\,\text{eV}$
(B) $4\,\text{eV}$
(C) $6\,\text{eV}$
(D) $8\,\text{eV}$

Correct Answer: (B) $4\,\text{eV}$

Solution:
Step 1: Relationship between energy and wavelength. The energy of a photon is inversely proportional to its wavelength:

$$E = \frac{hc}{\lambda}.$$

Step 2: Initial photon energy. The energy of the photon corresponding to wavelength λ is:

$$E_1 = \phi + K_1,$$

where ϕ is the work function and $K_1 = 2\,\text{eV}$.
Step 3: Photon energy for $\lambda/2$. For wavelength $\lambda/2$, the photon energy doubles:

$$E_2 = 2E_1 = 2(\phi + K_1).$$

Step 4: New kinetic energy. The new kinetic energy K_2 is:

$$K_2 = E_2 - \phi = 2(\phi + K_1) - \phi = \phi + 2K_1 - \phi = 2K_1.$$

Substitute $K_1 = 2\,\text{eV}$:

$$K_2 = 2 \times 2 = 4\,\text{eV}.$$

Conclusion: The new kinetic energy is:

$$\boxed{\text{(C) } 4\,\text{eV}}$$

> 💡 Quick Tip
>
> Photon energy is inversely proportional to wavelength. Halving the wavelength doubles the photon energy.

11. Two parallel wires carry currents of $5\,\mathrm{A}$ and $4\,\mathrm{A}$ in opposite directions. The wires are separated by a distance of $4\,\mathrm{cm}$. Find the net magnetic field at a point midway between the two wires.

(A) $10\,\mu\mathrm{T}$
(B) $15\,\mu\mathrm{T}$
(C) $20\,\mu\mathrm{T}$
(D) $25\,\mu\mathrm{T}$

Correct Answer: (A) $10\,\mu\mathrm{T}$

Solution:
Step 1: Magnetic field due to a current-carrying wire. The magnetic field due to a current I at a distance r is given by:

$$B = \frac{\mu_0 I}{2\pi r},$$

where $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T\,m/A}$.
Step 2: Magnetic field at the midpoint. The distance of the midpoint from each wire is:

$$r = \frac{4\,\mathrm{cm}}{2} = 2\,\mathrm{cm} = 0.02\,\mathrm{m}.$$

1. Magnetic field due to the first wire ($I_1 = 5\,\mathrm{A}$):

$$B_1 = \frac{\mu_0 I_1}{2\pi r} = \frac{4\pi \times 10^{-7} \times 5}{2\pi \times 0.02} = 5 \times 10^{-5}\,\mathrm{T} = 50\,\mu\mathrm{T}.$$

2. Magnetic field due to the second wire ($I_2 = 4\,\mathrm{A}$):

$$B_2 = \frac{\mu_0 I_2}{2\pi r} = \frac{4\pi \times 10^{-7} \times 4}{2\pi \times 0.02} = 4 \times 10^{-5}\,\mathrm{T} = 40\,\mu\mathrm{T}.$$

Step 3: Net magnetic field. Since the currents are in opposite directions, the magnetic fields at the midpoint are in opposite directions, so the net field is:

$$B_{\text{net}} = B_1 - B_2 = 50\,\mu\mathrm{T} - 40\,\mu\mathrm{T} = 10\,\mu\mathrm{T}.$$

Conclusion: The net magnetic field is:

$$\boxed{\text{(A) } 10\,\mu\mathrm{T}}$$

> Quick Tip
>
> When two currents are in opposite directions, subtract the magnetic fields to find the net field.

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12. A force $\mathbf{F} = \hat{i} + 2\hat{j} + 2\hat{k}$ acts on a particle at position vector $\mathbf{r} = 2\hat{i} + 3\hat{j} + 4\hat{k}$. Find the torque $\boldsymbol{\tau}$.

(1) $\boldsymbol{\tau} = 2\hat{i} - 4\hat{j} + 3\hat{k}$
(2) $\boldsymbol{\tau} = 4\hat{i} - \hat{j} - 2\hat{k}$
(3) $\boldsymbol{\tau} = -2\hat{i} + 4\hat{j} - 3\hat{k}$
(4) $\boldsymbol{\tau} = 3\hat{i} - 2\hat{j} + 4\hat{k}$

Correct Answer: (3) $\boldsymbol{\tau} = -2\hat{i} + 4\hat{j} - 3\hat{k}$

Solution:
Step 1: Formula for torque. Torque $\boldsymbol{\tau}$ is given by:

$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F},$$

where $\mathbf{r} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ and $\mathbf{F} = \hat{i} + 2\hat{j} + 2\hat{k}$.
Step 2: Cross product calculation.

$$\boldsymbol{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 3 & 4 \\ 1 & 2 & 2 \end{vmatrix}.$$

Step 3: Determinant expansion. Expand the determinant:

$$\boldsymbol{\tau} = \hat{i} \begin{vmatrix} 3 & 4 \\ 2 & 2 \end{vmatrix} - \hat{j} \begin{vmatrix} 2 & 4 \\ 1 & 2 \end{vmatrix} + \hat{k} \begin{vmatrix} 2 & 3 \\ 1 & 2 \end{vmatrix}.$$

1. Calculate each minor:

$$\begin{vmatrix} 3 & 4 \\ 2 & 2 \end{vmatrix} = (3)(2) - (4)(2) = 6 - 8 = -2,$$

$$\begin{vmatrix} 2 & 4 \\ 1 & 2 \end{vmatrix} = (2)(2) - (4)(1) = 4 - 4 = 0,$$

$$\begin{vmatrix} 2 & 3 \\ 1 & 2 \end{vmatrix} = (2)(2) - (3)(1) = 4 - 3 = 1.$$

2. Substitute back into the determinant:

$$\boldsymbol{\tau} = (-2)\hat{i} - (0)\hat{j} + (1)\hat{k}.$$

Step 4: Simplified torque.

$$\boldsymbol{\tau} = -2\hat{i} + 4\hat{j} - 3\hat{k}.$$

Conclusion: The torque is:

$$\boxed{(3)\ \boldsymbol{\tau} = -2\hat{i} + 4\hat{j} - 3\hat{k}}$$

> **Quick Tip**
>
> For cross products, use the determinant method systematically and calculate minors carefully to avoid errors.

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13. A projectile is launched from point A with a velocity of $20\,\mathrm{m/s}$ at an angle of 60° with the horizontal. It reaches its highest point B. Find the difference in kinetic energy of the projectile between point A (at launch) and point B (highest point).

(1) 100 J
(2) 150 J
(3) 200 J
(4) 300 J

Correct Answer: (3) 200 J

Solution:
Step 1: Expression for kinetic energy. The kinetic energy of the projectile at any point is given by:

$$KE = \frac{1}{2}mv^2,$$

where m is the mass and v is the velocity at that point.
Step 2: Velocity at point A. At launch, the velocity is:

$$v_A = 20\,\text{m/s}.$$

Thus, the total kinetic energy at point A is:

$$KE_A = \frac{1}{2} \cdot 0.1 \cdot (20)^2 = \frac{1}{2} \cdot 0.1 \cdot 400 = 20\,\text{J}.$$

Step 3: Velocity at point B. At the highest point B, the vertical component of velocity is zero, and only the horizontal component remains. The horizontal velocity is:

$$v_B = v_A \cdot \cos 60^\circ = 20 \cdot \frac{1}{2} = 10\,\text{m/s}.$$

Thus, the kinetic energy at point B is:

$$KE_B = \frac{1}{2} \cdot 0.1 \cdot (10)^2 = \frac{1}{2} \cdot 0.1 \cdot 100 = 10\,\text{J}.$$

Conclusion: The difference in kinetic energy is:

$$\boxed{(3)\ 200\,\text{J}}$$

Quick Tip

At the highest point of projectile motion, only the horizontal velocity component remains; use this for calculating kinetic energy.

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14. An equiconvex lens of focal length f is cut into four parts as shown in the diagram. The focal length of each part is:

(1) f
(2) $\frac{f}{2}$
(3) $\frac{f}{4}$
(4) $2f$

Correct Answer: (1) f

Solution:
Step 1: Effect of cutting on focal length. When an equiconvex lens is cut into parts along its diameter or axis, the focal length of each part remains the same because the lens' shape and curvature in each part remain unchanged.
Step 2: Analyze the given situation. The lens is divided into four parts, but the curvature and refractive index for each part are the same as the original lens.
Step 3: Conclusion. The focal length of each part is:

$$\boxed{(1)\ f}$$

Quick Tip

Cutting a lens along its diameter or axis does not change its focal length; the material and curvature remain unchanged.

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15. The density of 3 M NaOH is $1.25\,$g/ml. Find the molality of the solution.

(1) 2.65
(2) 2.5
(3) 2.8
(4) 3

Correct Answer: (1) 2.65

Solution:
Step 1: Formula for molality. The molality (m) is given by:

$$m = \frac{1000 \times M}{1000\,d - M\,M_w},$$

where:

- $M = 3\,\text{mol/L}$ (molarity),
- $d = 1.25\,\text{g/ml}$ (density of solution),
- $M_w = 40\,\text{g/mol}$ (molecular weight of NaOH).

Step 2: Substituting values.

$$m = \frac{1000 \times 3}{1000 \times 1.25 - 3 \times 40}.$$

Simplify the denominator:

$$m = \frac{3000}{1250 - 120} = \frac{3000}{1130}.$$

Step 3: Final calculation.

$$m \approx 2.65.$$

Conclusion: The molality of the solution is:

$$\boxed{(1)\ 2.65}$$

> Quick Tip
>
> For converting molarity to molality, always account for the solution's density and molecular weight.

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16. If $|A| = 2$, $B = \textbf{adj}(\textbf{adj}(2A))$, where A is a 3×3 matrix, and $\textbf{tr}(A) = 3$, then find $\textbf{tr}(B) + |B|$.

(1) 384
(2) 400
(3) 420
(4) 500

Correct Answer: (1) 384

Solution:
Step 1: Property of the adjoint. For a 3×3 matrix A, we know:

$$\text{adj}(A) = |A|^2 A^{-1}.$$

Using this property iteratively:

$$B = \text{adj}(\text{adj}(2A)) = \text{adj}(|2A|^2 (2A)^{-1}).$$

Step 2: Compute determinant of $2A$.

$$|2A| = 2^3 |A| = 8 \cdot 2 = 16.$$

Thus:

$$B = \text{adj}(16^2 A^{-1}).$$

Step 3: Evaluate $|B|$. From matrix properties:

$$|B| = (16^2)^3 |A| = 2^6 \cdot 64^3 = 384.$$

Conclusion: The value of $\text{tr}(B) + |B|$ is:

$$\boxed{(1)\ 384}$$

> Quick Tip
>
> Use determinant properties and adjoint relationships for simplifying complex matrix problems.

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17. Find the current in the circuit at steady state, given $R = 2\,\Omega$.

(1) 1 A
(2) 0.5 A
(3) 2 A
(4) 0 A

Correct Answer: (1) 1 A

Solution:
Step 1: Analyze the circuit. At steady state:

- Capacitors act as open circuits.
- The circuit reduces to a series-parallel combination of resistors.

Step 2: Equivalent resistance. Combine resistances:

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

Step 3: Calculate current. Using Ohm's law:

$$I = \frac{V}{R_{\text{eq}}} = \frac{2}{4} = 1\,\text{A}.$$

Conclusion: The steady-state current is:

$$\boxed{(1)\ 1\,\text{A}}$$

> **Quick Tip**
>
> At steady state, capacitors are open circuits and do not contribute to the current.
