

**Mathematics****SECTION 1 (Maximum Marks: 12)**

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;  
*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;  
*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;  
*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;  
*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);  
*Negative Marks* : -2 In all other cases.
- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then  
choosing ONLY (A), (B) and (D) will get +4 marks;  
choosing ONLY (A) and (B) will get +2 marks;  
choosing ONLY (A) and (D) will get +2 marks;  
choosing ONLY (B) and (D) will get +2 marks;  
choosing ONLY (A) will get +1 mark;  
choosing ONLY (B) will get +1 mark;  
choosing ONLY (D) will get +1 mark;  
choosing no option (i.e. the question is unanswered) will get 0 marks; and  
choosing any other combination of options will get -2 marks.

Q.1 Let  $S = (0,1) \cup (1,2) \cup (3,4)$  and  $T = \{0,1,2,3\}$ . Then which of the following statements is(are) true?

- (A) There are infinitely many functions from  $S$  to  $T$
- (B) There are infinitely many strictly increasing functions from  $S$  to  $T$
- (C) The number of continuous functions from  $S$  to  $T$  is at most 120
- (D) Every continuous function from  $S$  to  $T$  is differentiable

Q.2

Let  $T_1$  and  $T_2$  be two distinct common tangents to the ellipse  $E : \frac{x^2}{6} + \frac{y^2}{3} = 1$  and the parabola

$P : y^2 = 12x$ . Suppose that the tangent  $T_1$  touches  $P$  and  $E$  at the points  $A_1$  and  $A_2$ ,

respectively and the tangent  $T_2$  touches  $P$  and  $E$  at the points  $A_4$  and  $A_3$ , respectively. Then which of the following statements is(are) true?

- (A) The area of the quadrilateral  $A_1A_2A_3A_4$  is 35 square units
- (B) The area of the quadrilateral  $A_1A_2A_3A_4$  is 36 square units
- (C) The tangents  $T_1$  and  $T_2$  meet the  $x$ -axis at the point  $(-3, 0)$
- (D) The tangents  $T_1$  and  $T_2$  meet the  $x$ -axis at the point  $(-6, 0)$

Q.3

Let  $f : [0, 1] \rightarrow [0, 1]$  be the function defined by  $f(x) = \frac{x^3}{3} - x^2 + \frac{5}{9}x + \frac{17}{36}$ . Consider the square

region  $S = [0, 1] \times [0, 1]$ . Let  $G = \{(x, y) \in S : y > f(x)\}$  be called the green region and

$R = \{(x, y) \in S : y < f(x)\}$  be called the red region. Let  $L_h = \{(x, h) \in S : x \in [0, 1]\}$  be the horizontal line drawn at a height  $h \in [0, 1]$ . Then which of the following statements is(are) true?

- (A) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the green region above the line  $L_h$  equals the area of the green region below the line  $L_h$
- (B) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the red region above the line  $L_h$  equals the area of the red region below the line  $L_h$
- (C) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the green region above the line  $L_h$  equals the area of the red region below the line  $L_h$
- (D) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the red region above the line  $L_h$  equals the area of the green region below the line  $L_h$

**SECTION 2 (Maximum Marks: 12)**

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:  
 Full Marks : +3 If **ONLY** the correct option is chosen;  
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 Negative Marks : -1 In all other cases.

**Q.4** Let  $f : (0,1) \rightarrow \mathbb{R}$  be the function defined as  $f(x) = \sqrt{n}$  if  $x \in \left[ \frac{1}{n+1}, \frac{1}{n} \right]$  where  $n \in \mathbb{N}$ . Let

$g : (0,1) \rightarrow \mathbb{R}$  be a function such that  $\int_{x^2}^x \sqrt{\frac{1-t}{t}} dt < g(x) < 2\sqrt{x}$  for all  $x \in (0,1)$ . Then

$$\lim_{x \rightarrow 0} f(x)g(x)$$

- (A) does **NOT** exist  
 (B) is equal to 1  
 (C) is equal to 2  
 (D) is equal to 3

**Q.5** Let  $Q$  be the cube with the set of vertices  $\{(x_1, x_2, x_3) \in \mathbb{R}^3 : x_1, x_2, x_3 \in \{0, 1\}\}$ . Let  $F$  be the set of all twelve lines containing the diagonals of the six faces of the cube  $Q$ . Let  $S$  be the set of all four lines containing the main diagonals of the cube  $Q$ ; for instance, the line passing through the vertices  $(0,0,0)$  and  $(1,1,1)$  is in  $S$ . For lines  $\ell_1$  and  $\ell_2$ , let  $d(\ell_1, \ell_2)$  denote the shortest distance between them. Then the maximum value of  $d(\ell_1, \ell_2)$ , as  $\ell_1$  varies over  $F$  and  $\ell_2$  varies over  $S$ , is

- (A)  $\frac{1}{\sqrt{6}}$       (B)  $\frac{1}{\sqrt{8}}$       (C)  $\frac{1}{\sqrt{3}}$       (D)  $\frac{1}{\sqrt{12}}$

**Q.6** Let  $X = \left\{ (x, y) \in \mathbb{Z} \times \mathbb{Z} : \frac{x^2}{8} + \frac{y^2}{20} < 1 \text{ and } y^2 < 5x \right\}$ . Three distinct points  $P$ ,  $Q$  and  $R$  are randomly chosen from  $X$ . Then the probability that  $P$ ,  $Q$  and  $R$  form a triangle whose area is a positive integer, is

- (A)  $\frac{71}{220}$       (B)  $\frac{73}{220}$       (C)  $\frac{79}{220}$       (D)  $\frac{83}{220}$

Q.7 Let  $P$  be a point on the parabola  $y^2 = 4ax$ , where  $a > 0$ . The normal to the parabola at  $P$  meets the  $x$ -axis at a point  $Q$ . The area of the triangle  $PFQ$ , where  $F$  is the focus of the parabola, is 120. If the slope  $m$  of the normal and  $a$  are both positive integers, then the pair  $(a, m)$  is

- (A) (2,3)      (B) (1,3)      (C) (2,4)      (D) (3,4)

**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
  - The answer to each question is a **NON-NEGATIVE INTEGER**.
  - For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks* : +4 If **ONLY** the correct integer is entered;  
*Zero Marks* : 0 In all other cases.

Q.8

Let  $\tan^{-1}(x) \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$ , for  $x \in \mathbb{R}$ . Then the number of real solutions of the equation

$$\sqrt{1+\cos(2x)} = \sqrt{2} \tan^{-1}(\tan x) \text{ in the set } \left(-\frac{3\pi}{2}, -\frac{\pi}{2}\right) \cup \left(-\frac{\pi}{2}, \frac{\pi}{2}\right) \cup \left(\frac{\pi}{2}, \frac{3\pi}{2}\right)$$

is equal to

Q.9 Let  $n \geq 2$  be a natural number and  $f : [0, 1] \rightarrow \mathbb{R}$  be the function defined by

$$f(x) = \begin{cases} n(1-2nx) & \text{if } 0 \leq x \leq \frac{1}{2n} \\ 2n(2nx-1) & \text{if } \frac{1}{2n} \leq x \leq \frac{3}{4n} \\ 4n(1-nx) & \text{if } \frac{3}{4n} \leq x \leq \frac{1}{n} \\ \frac{n}{n-1}(nx-1) & \text{if } \frac{1}{n} \leq x \leq 1 \end{cases}$$

If  $n$  is such that the area of the region bounded by the curves  $x=0$ ,  $x=1$ ,  $y=0$  and  $y=f(x)$  is 4, then the maximum value of the function  $f$  is

Q.10

Let  $\overbrace{75\cdots5}^r 7$  denote the  $(r+2)$  digit number where the first and the last digits are 7 and

the remaining  $r$  digits are 5. Consider the sum  $S = 77 + 757 + 7557 + \cdots + \overbrace{75\cdots5}^{98} 7$ . If

$S = \frac{\overbrace{75\cdots5}^{99} 7 + m}{n}$ , where  $m$  and  $n$  are natural numbers less than 3000, then the value of  $m+n$  is

**Q.11** Let  $A = \left\{ \frac{1967 + 1686i \sin \theta}{7 - 3i \cos \theta} : \theta \in \mathbb{R} \right\}$ . If  $A$  contains exactly one positive integer  $n$ , then the value of  $n$  is

**Q.12** Let  $P$  be the plane  $\sqrt{3}x + 2y + 3z = 16$  and let

$$S = \left\{ \alpha \hat{i} + \beta \hat{j} + \gamma \hat{k} : \alpha^2 + \beta^2 + \gamma^2 = 1 \text{ and the distance of } (\alpha, \beta, \gamma) \text{ from the plane } P \text{ is } \frac{7}{2} \right\}.$$

Let  $\vec{u}, \vec{v}$  and  $\vec{w}$  be three distinct vectors in  $S$  such that  $|\vec{u} - \vec{v}| = |\vec{v} - \vec{w}| = |\vec{w} - \vec{u}|$ . Let  $V$  be the volume of the parallelepiped determined by vectors  $\vec{u}, \vec{v}$  and  $\vec{w}$ . Then the value of  $\frac{80}{\sqrt{3}}V$  is

**Q.13** Let  $a$  and  $b$  be two nonzero real numbers. If the coefficient of  $x^5$  in the expansion of

$$\left( ax^2 + \frac{70}{27bx} \right)^4 \text{ is equal to the coefficient of } x^{-5} \text{ in the expansion of } \left( ax - \frac{1}{bx^2} \right)^7, \text{ then}$$

the value of  $2b$  is

**SECTION 4 (Maximum Marks: 12)**

- This section contains **FOUR (04)** Matching List Sets.
  - Each set has **ONE** Multiple Choice Question.
  - Each set has **TWO** lists: **List-I** and **List-II**.
  - **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
  - **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 Let  $\alpha, \beta$  and  $\gamma$  be real numbers. Consider the following system of linear equations

$$x + 2y + z = 7$$

$$x + \alpha z = 11$$

$$2x - 3y + \beta z = \gamma$$

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

**List-II**

(P) If  $\beta = \frac{1}{2}(7\alpha - 3)$  and  $\gamma = 28$ , then the system has

(1) a unique solution

(Q) If  $\beta = \frac{1}{2}(7\alpha - 3)$  and  $\gamma \neq 28$ , then the system has

(2) no solution

(R) If  $\beta \neq \frac{1}{2}(7\alpha - 3)$  where  $\alpha = 1$  and  $\gamma \neq 28$ , then the system has

(3) infinitely many solutions

(S) If  $\beta \neq \frac{1}{2}(7\alpha - 3)$  where  $\alpha = 1$  and  $\gamma = 28$ , then the system has

(4)  $x = 11$ ,  $y = -2$  and  $z = 0$  as a solution

(5)  $x = -15$ ,  $y = 4$  and  $z = 0$  as a solution

The correct option is:

- (A) (P)  $\rightarrow$  (3)    (Q)  $\rightarrow$  (2)    (R)  $\rightarrow$  (1)    (S)  $\rightarrow$  (4)  
 (B) (P)  $\rightarrow$  (3)    (Q)  $\rightarrow$  (2)    (R)  $\rightarrow$  (5)    (S)  $\rightarrow$  (4)  
 (C) (P)  $\rightarrow$  (2)    (Q)  $\rightarrow$  (1)    (R)  $\rightarrow$  (4)    (S)  $\rightarrow$  (5)  
 (D) (P)  $\rightarrow$  (2)    (Q)  $\rightarrow$  (1)    (R)  $\rightarrow$  (1)    (S)  $\rightarrow$  (3)

Q.15 Consider the given data with frequency distribution

$x_i$	3	8	11	10	5	4
$f_i$	5	2	3	2	4	4

Match each entry in **List-I** to the correct entries in **List-II**.

<b>List-I</b>	<b>List-II</b>
(P) The mean of the above data is	(1) 2.5
(Q) The median of the above data is	(2) 5
(R) The mean deviation about the mean of the above data is	(3) 6
(S) The mean deviation about the median of the above data is	(4) 2.7
	(5) 2.4

The correct option is:

- (A) (P) → (3) (Q) → (2) (R) → (4) (S) → (5)  
(B) (P) → (3) (Q) → (2) (R) → (1) (S) → (5)  
(C) (P) → (2) (Q) → (3) (R) → (4) (S) → (1)  
(D) (P) → (3) (Q) → (3) (R) → (5) (S) → (5)

- Q.16** Let  $\ell_1$  and  $\ell_2$  be the lines  $\vec{r}_1 = \lambda(\hat{i} + \hat{j} + \hat{k})$  and  $\vec{r}_2 = (\hat{j} - \hat{k}) + \mu(\hat{i} + \hat{k})$ , respectively. Let  $X$  be the set of all the planes  $H$  that contain the line  $\ell_1$ . For a plane  $H$ , let  $d(H)$  denote the smallest possible distance between the points of  $\ell_2$  and  $H$ . Let  $H_0$  be a plane in  $X$  for which  $d(H_0)$  is the maximum value of  $d(H)$  as  $H$  varies over all planes in  $X$ .

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

- (P) The value of  $d(H_0)$  is
- (Q) The distance of the point  $(0, 1, 2)$  from  $H_0$  is
- (R) The distance of origin from  $H_0$  is
- (S) The distance of origin from the point of intersection of planes  $y = z$ ,  $x = 1$  and  $H_0$  is

**List-II**

- (1)  $\sqrt{3}$
- (2)  $\frac{1}{\sqrt{3}}$
- (3) 0
- (4)  $\sqrt{2}$
- (5)  $\frac{1}{\sqrt{2}}$

The correct option is:

- (A) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (1)
- (B) (P)  $\rightarrow$  (5) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (1)
- (C) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (2)
- (D) (P)  $\rightarrow$  (5) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (4) (S)  $\rightarrow$  (2)

- Q.17** Let  $z$  be a complex number satisfying  $|z|^3 + 2z^2 + 4\bar{z} - 8 = 0$ , where  $\bar{z}$  denotes the complex conjugate of  $z$ . Let the imaginary part of  $z$  be nonzero.

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

- (P)  $|z|^2$  is equal to
- (Q)  $|z - \bar{z}|^2$  is equal to
- (R)  $|z|^2 + |z + \bar{z}|^2$  is equal to
- (S)  $|z + 1|^2$  is equal to

**List-II**

- (1) 12
- (2) 4
- (3) 8
- (4) 10
- (5) 7

The correct option is:

- (A) (P)  $\rightarrow$  (1) (Q)  $\rightarrow$  (3) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (4)
- (B) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (5)
- (C) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (1)
- (D) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (3) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (4)

**END OF THE QUESTION PAPER**

## Physics

### SECTION 1 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
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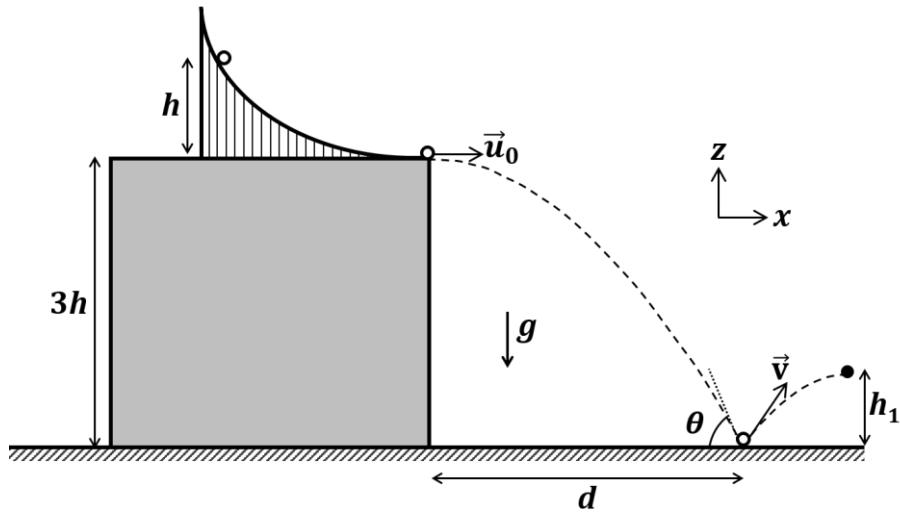
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- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then
  - choosing **ONLY** (A), (B) and (D) will get +4 marks;
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  - choosing **ONLY** (A) and (D) will get +2 marks;
  - choosing **ONLY** (B) and (D) will get +2 marks;
  - choosing **ONLY** (A) will get +1 mark;
  - choosing **ONLY** (B) will get +1 mark;
  - choosing **ONLY** (D) will get +1 mark;
  - choosing no option (i.e. the question is unanswered) will get 0 marks; and
  - choosing any other combination of options will get -2 marks.

- Q.1 A slide with a frictionless curved surface, which becomes horizontal at its lower end, is fixed on the terrace of a building of height  $3h$  from the ground, as shown in the figure. A spherical ball of mass  $m$  is released on the slide from rest at a height  $h$  from the top of the terrace. The ball leaves the slide with a velocity  $\vec{u}_0 = u_0 \hat{x}$  and falls on the ground at a distance  $d$  from the building making an angle  $\theta$  with the horizontal. It bounces off with a velocity  $\vec{v}$  and reaches a maximum height  $h_1$ . The acceleration due to gravity is  $g$  and the coefficient of restitution of the ground is  $1/\sqrt{3}$ . Which of the following statement(s) is(are) correct?



- (A)  $\vec{u}_0 = \sqrt{2gh} \hat{x}$
- (B)  $\vec{v} = \sqrt{2gh} (\hat{x} - \hat{z})$
- (C)  $\theta = 60^\circ$
- (D)  $d/h_1 = 2\sqrt{3}$

- Q.2 A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is  $\delta = 60^\circ$  (see Figure-1). The angle of minimum deviation for red light from the same prism is  $\delta_{\min} = 30^\circ$  (see Figure-2). The refractive index of the prism material for blue light is  $\sqrt{3}$ . Which of the following statement(s) is(are) correct?

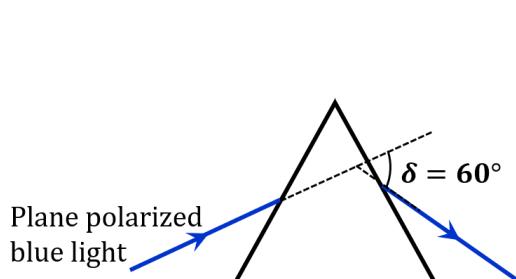


Figure-1

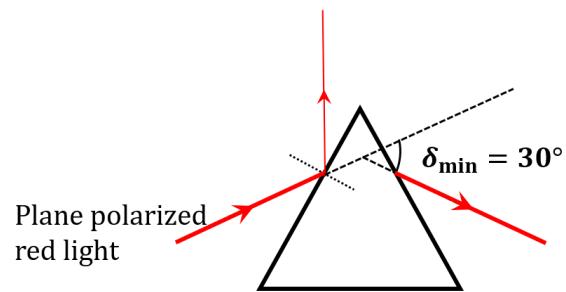
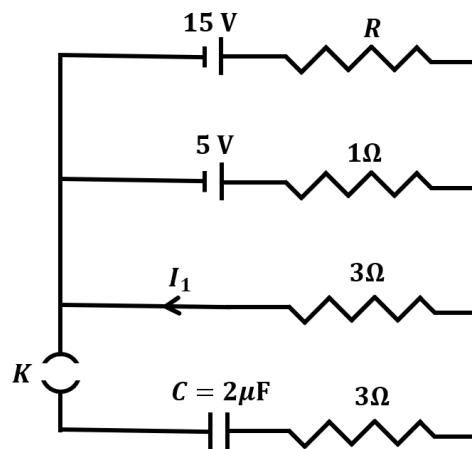


Figure-2

- (A) The blue light is polarized in the plane of incidence.
- (B) The angle of the prism is  $45^\circ$ .
- (C) The refractive index of the material of the prism for red light is  $\sqrt{2}$ .
- (D) The angle of refraction for blue light in air at the exit plane of the prism is  $60^\circ$ .

- Q.3 In a circuit shown in the figure, the capacitor  $C$  is initially uncharged and the key  $K$  is open. In this condition, a current of 1 A flows through the  $1 \Omega$  resistor. The key is closed at time  $t = t_0$ . Which of the following statement(s) is(are) correct?

[Given:  $e^{-1} = 0.36$ ]



- (A) The value of the resistance  $R$  is  $3 \Omega$ .
- (B) For  $t < t_0$ , the value of current  $I_1$  is 2 A.
- (C) At  $t = t_0 + 7.2 \mu s$ , the current in the capacitor is 0.6 A.
- (D) For  $t \rightarrow \infty$ , the charge on the capacitor is  $12 \mu C$ .

**SECTION 2 (Maximum Marks: 12)**

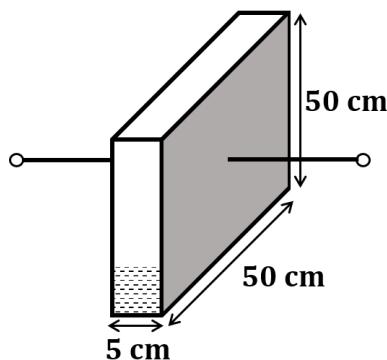
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**Q.4** A bar of mass  $M = 1.00 \text{ kg}$  and length  $L = 0.20 \text{ m}$  is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass  $m = 0.10 \text{ kg}$  is moving on the same horizontal surface with  $5.00 \text{ m s}^{-1}$  speed on a path perpendicular to the bar. It hits the bar at a distance  $L/2$  from the pivoted end and returns back on the same path with speed  $v$ . After this elastic collision, the bar rotates with an angular velocity  $\omega$ . Which of the following statement is correct?

- (A)  $\omega = 6.98 \text{ rad s}^{-1}$  and  $v = 4.30 \text{ m s}^{-1}$       (B)  $\omega = 3.75 \text{ rad s}^{-1}$  and  $v = 4.30 \text{ m s}^{-1}$   
 (C)  $\omega = 3.75 \text{ rad s}^{-1}$  and  $v = 10.0 \text{ m s}^{-1}$       (D)  $\omega = 6.80 \text{ rad s}^{-1}$  and  $v = 4.10 \text{ m s}^{-1}$

**Q.5** A container has a base of  $50 \text{ cm} \times 5 \text{ cm}$  and height  $50 \text{ cm}$ , as shown in the figure. It has two parallel electrically conducting walls each of area  $50 \text{ cm} \times 50 \text{ cm}$ . The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of  $250 \text{ cm}^3 \text{ s}^{-1}$ . What is the value of the capacitance of the container after 10 seconds?

[Given: Permittivity of free space  $\epsilon_0 = 9 \times 10^{-12} \text{ C}^2 \text{N}^{-1} \text{m}^{-2}$ , the effects of the non-conducting walls on the capacitance are negligible]



- (A) 27 pF      (B) 63 pF      (C) 81 pF      (D) 135 pF

- Q.6 One mole of an ideal gas expands adiabatically from an initial state  $(T_A, V_0)$  to final state  $(T_f, 5V_0)$ . Another mole of the same gas expands isothermally from a different initial state  $(T_B, V_0)$  to the same final state  $(T_f, 5V_0)$ . The ratio of the specific heats at constant pressure and constant volume of this ideal gas is  $\gamma$ . What is the ratio  $T_A/T_B$ ?

(A)  $5^{\gamma-1}$       (B)  $5^{1-\gamma}$       (C)  $5^\gamma$       (D)  $5^{1+\gamma}$

Q.7 Two satellites P and Q are moving in different circular orbits around the Earth (radius  $R$ ). The heights of P and Q from the Earth surface are  $h_P$  and  $h_Q$ , respectively, where  $h_p = R/3$ . The accelerations of P and Q due to Earth's gravity are  $g_P$  and  $g_Q$ , respectively. If  $g_P/g_Q = 36/25$ , what is the value of  $h_Q$ ?

(A)  $3R/5$       (B)  $R/6$       (C)  $6R/5$       (D)  $5R/6$

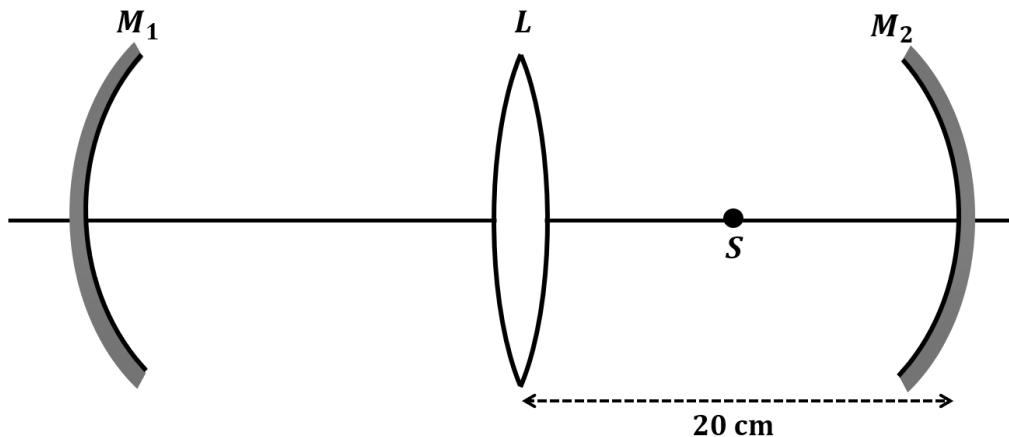
**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
  - The answer to each question is a **NON-NEGATIVE INTEGER**.
  - For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks** : +4 If **ONLY** the correct integer is entered;  
**Zero Marks** : 0 In all other cases.

**Q.8** A Hydrogen-like atom has atomic number  $Z$ . Photons emitted in the electronic transitions from level  $n = 4$  to level  $n = 3$  in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of  $Z$  is \_\_\_\_\_.

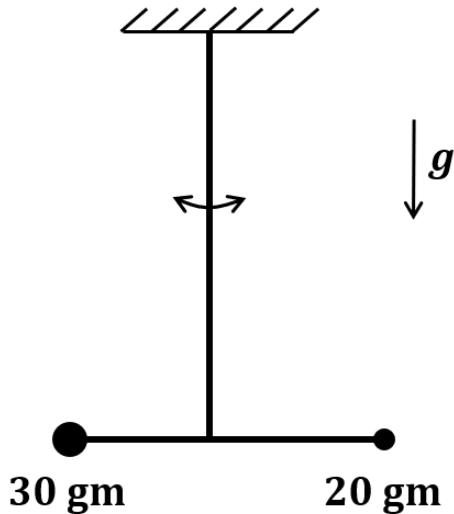
[Given:  $hc = 1240 \text{ eV-nm}$  and  $Rhc = 13.6 \text{ eV}$ , where  $R$  is the Rydberg constant,  $h$  is the Planck's constant and  $c$  is the speed of light in vacuum]

**Q.9** An optical arrangement consists of two concave mirrors  $M_1$  and  $M_2$ , and a convex lens  $L$  with a common principal axis, as shown in the figure. The focal length of  $L$  is 10 cm. The radii of curvature of  $M_1$  and  $M_2$  are 20 cm and 24 cm, respectively. The distance between  $L$  and  $M_2$  is 20 cm. A point object  $S$  is placed at the mid-point between  $L$  and  $M_2$  on the axis. When the distance between  $L$  and  $M_1$  is  $n/7$  cm, one of the images coincides with  $S$ . The value of  $n$  is \_\_\_\_\_.



**Q.10** In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is  $10 \pm 0.1$  cm and the distance of its real image from the lens is  $20 \pm 0.2$  cm. The error in the determination of focal length of the lens is  $n\%$ . The value of  $n$  is \_\_\_\_\_.

- Q.11 A closed container contains a homogeneous mixture of two moles of an ideal monatomic gas ( $\gamma = 5/3$ ) and one mole of an ideal diatomic gas ( $\gamma = 7/5$ ). Here,  $\gamma$  is the ratio of the specific heats at constant pressure and constant volume of an ideal gas. The gas mixture does a work of 66 Joule when heated at constant pressure. The change in its internal energy is \_\_\_\_\_ Joule.
- Q.12 A person of height 1.6 m is walking away from a lamp post of height 4 m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is  $60 \text{ cm s}^{-1}$ , the speed of the tip of the person's shadow on the ground with respect to the person is \_\_\_\_\_  $\text{cm s}^{-1}$ .
- Q.13 Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is  $1.2 \times 10^{-8} \text{ N m rad}^{-1}$ . The angular frequency of the oscillations in  $n \times 10^{-3} \text{ rad s}^{-1}$ . The value of  $n$  is \_\_\_\_\_.



#### SECTION 4 (Maximum Marks: 12)

- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List-I** and **List-II**.
- **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 List-I shows different radioactive decay processes and List-II provides possible emitted particles. Match each entry in List-I with an appropriate entry from List-II, and choose the correct option.

**List-I**

- (P)  $^{238}_{92}U \rightarrow ^{234}_{91}Pa$   
 (Q)  $^{214}_{82}Pb \rightarrow ^{210}_{82}Pb$   
 (R)  $^{210}_{81}Tl \rightarrow ^{206}_{82}Pb$   
 (S)  $^{228}_{91}Pa \rightarrow ^{224}_{88}Ra$

**List-II**

- (1) one  $\alpha$  particle and one  $\beta^+$  particle  
 (2) three  $\beta^-$  particles and one  $\alpha$  particle  
 (3) two  $\beta^-$  particles and one  $\alpha$  particle  
 (4) one  $\alpha$  particle and one  $\beta^-$  particle  
 (5) one  $\alpha$  particle and two  $\beta^+$  particles

- (A) P → 4, Q → 3, R → 2, S → 1  
 (C) P → 5, Q → 3, R → 1, S → 4

- (B) P → 4, Q → 1, R → 2, S → 5  
 (D) P → 5, Q → 1, R → 3, S → 2

Q.15 Match the temperature of a black body given in List-I with an appropriate statement in List-II, and choose the correct option.

[Given: Wien's constant as  $2.9 \times 10^{-3}$  m-K and  $\frac{hc}{e} = 1.24 \times 10^{-6}$  V-m]

**List-I**

- (P) 2000 K  
 (Q) 3000 K  
 (R) 5000 K  
 (S) 10000 K

**List-II**

- (1) The radiation at peak wavelength can lead to emission of photoelectrons from a metal of work function 4 eV.  
 (2) The radiation at peak wavelength is visible to human eye.  
 (3) The radiation at peak emission wavelength will result in the widest central maximum of a single slit diffraction.  
 (4) The power emitted per unit area is 1/16 of that emitted by a blackbody at temperature 6000 K.  
 (5) The radiation at peak emission wavelength can be used to image human bones.

- (A) P → 3, Q → 5, R → 2, S → 3  
 (C) P → 3, Q → 4, R → 2, S → 1

- (B) P → 3, Q → 2, R → 4, S → 1  
 (D) P → 1, Q → 2, R → 5, S → 3

- Q.16** A series LCR circuit is connected to a  $45 \sin(\omega t)$  Volt source. The resonant angular frequency of the circuit is  $10^5 \text{ rad s}^{-1}$  and current amplitude at resonance is  $I_0$ . When the angular frequency of the source is  $\omega = 8 \times 10^4 \text{ rad s}^{-1}$ , the current amplitude in the circuit is  $0.05 I_0$ . If  $L = 50 \text{ mH}$ , match each entry in List-I with an appropriate value from List-II and choose the correct option.

**List-I**

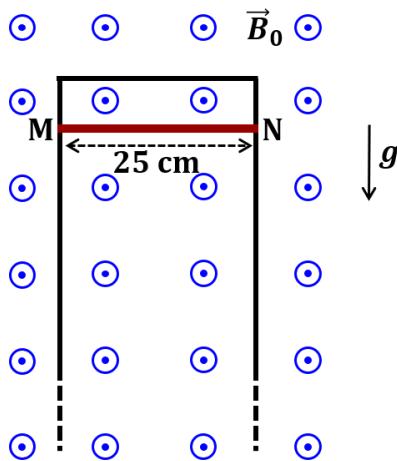
- (P)  $I_0$  in mA
  - (Q) The quality factor of the circuit
  - (R) The bandwidth of the circuit in  $\text{rad s}^{-1}$
  - (S) The peak power dissipated at resonance in Watt
- 
- (A)  $P \rightarrow 2, Q \rightarrow 3, R \rightarrow 5, S \rightarrow 1$
  - (B)  $P \rightarrow 3, Q \rightarrow 1, R \rightarrow 4, S \rightarrow 2$
  - (C)  $P \rightarrow 4, Q \rightarrow 5, R \rightarrow 3, S \rightarrow 1$
  - (D)  $P \rightarrow 4, Q \rightarrow 2, R \rightarrow 1, S \rightarrow 5$

**List-II**

- (1) 44.4
- (2) 18
- (3) 400
- (4) 2250
- (5) 500

- Q.17** A thin conducting rod MN of mass 20 gm, length 25 cm and resistance  $10 \Omega$  is held on frictionless, long, perfectly conducting vertical rails as shown in the figure. There is a uniform magnetic field  $B_0 = 4 \text{ T}$  directed perpendicular to the plane of the rod-rail arrangement. The rod is released from rest at time  $t = 0$  and it moves down along the rails. Assume air drag is negligible. Match each quantity in List-I with an appropriate value from List-II, and choose the correct option.

[Given: The acceleration due to gravity  $g = 10 \text{ m s}^{-2}$  and  $e^{-1} = 0.4$ ]

**List-I**

- (P) At  $t = 0.2 \text{ s}$ , the magnitude of the induced emf in Volt
  - (Q) At  $t = 0.2 \text{ s}$ , the magnitude of the magnetic force in Newton
  - (R) At  $t = 0.2 \text{ s}$ , the power dissipated as heat in Watt
  - (S) The magnitude of terminal velocity of the rod in  $\text{m s}^{-1}$
- 
- (A)  $P \rightarrow 5, Q \rightarrow 2, R \rightarrow 3, S \rightarrow 1$
  - (B)  $P \rightarrow 3, Q \rightarrow 1, R \rightarrow 4, S \rightarrow 5$
  - (C)  $P \rightarrow 4, Q \rightarrow 3, R \rightarrow 1, S \rightarrow 2$
  - (D)  $P \rightarrow 3, Q \rightarrow 4, R \rightarrow 2, S \rightarrow 5$

**List-II**

- (1) 0.07
- (2) 0.14
- (3) 1.20
- (4) 0.12
- (5) 2.00

**END OF THE QUESTION PAPER**

**Chemistry****SECTION 1 (Maximum Marks: 12)**

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;

*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;

*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;

*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);

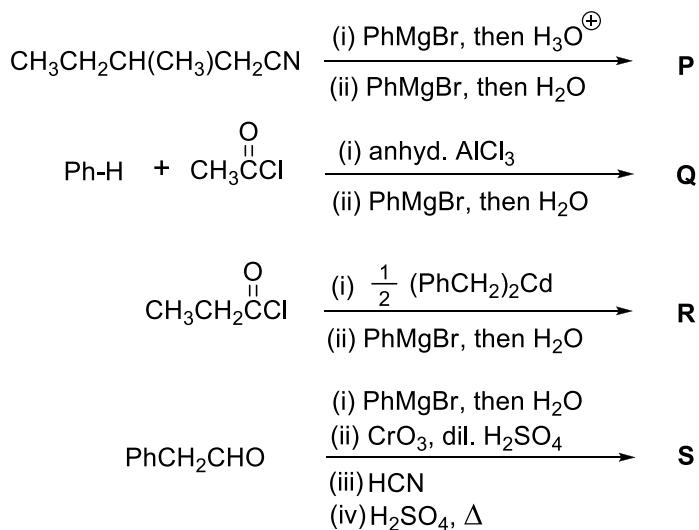
*Negative Marks* : -2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then
  - choosing ONLY (A), (B) and (D) will get +4 marks;
  - choosing ONLY (A) and (B) will get +2 marks;
  - choosing ONLY (A) and (D) will get +2 marks;
  - choosing ONLY (B) and (D) will get +2 marks;
  - choosing ONLY (A) will get +1 mark;
  - choosing ONLY (B) will get +1 mark;
  - choosing ONLY (D) will get +1 mark;
  - choosing no option (i.e. the question is unanswered) will get 0 marks; and
  - choosing any other combination of options will get -2 marks.

Q.1 The correct statement(s) related to processes involved in the extraction of metals is(are)

- (A) Roasting of Malachite produces Cuprite.
- (B) Calcination of Calamine produces Zincite.
- (C) Copper pyrites is heated with silica in a reverberatory furnace to remove iron.
- (D) Impure silver is treated with aqueous KCN in the presence of oxygen followed by reduction with zinc metal.

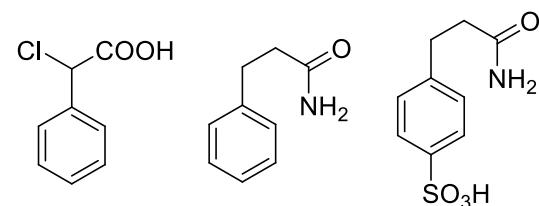
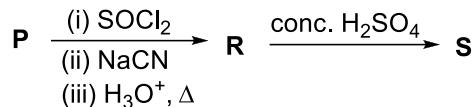
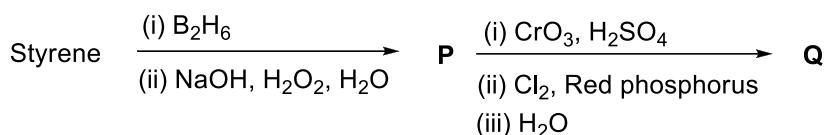
Q.2 In the following reactions, **P**, **Q**, **R**, and **S** are the major products.



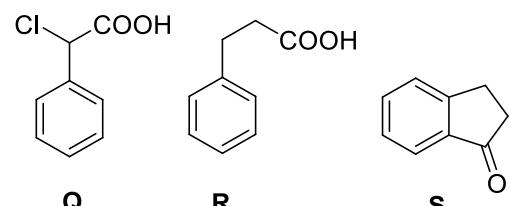
The correct statement(s) about **P**, **Q**, **R**, and **S** is(are)

- (A) Both **P** and **Q** have asymmetric carbon(s).
- (B) Both **Q** and **R** have asymmetric carbon(s).
- (C) Both **P** and **R** have asymmetric carbon(s).
- (D) **P** has asymmetric carbon(s), **S** does **not** have any asymmetric carbon.

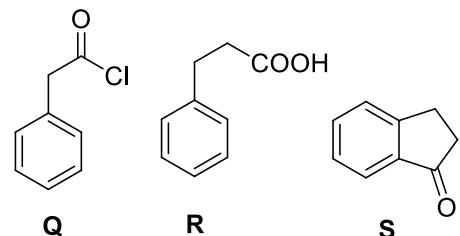
Q.3 Consider the following reaction scheme and choose the correct option(s) for the major products **Q**, **R** and **S**.



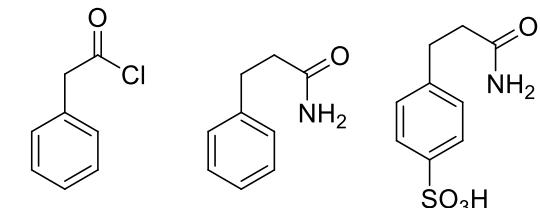
(A)      **Q**            **R**            **S**



(B)      **Q**            **R**            **S**



(C)      **Q**            **R**            **S**

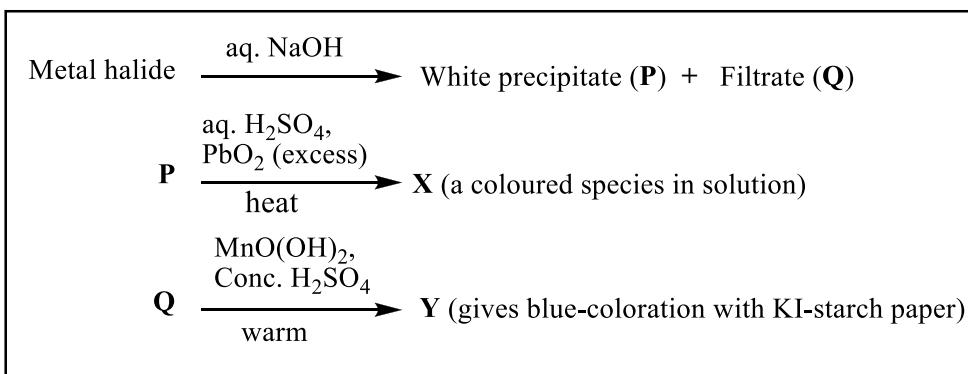


(D)      **Q**            **R**            **S**

**SECTION 2 (Maximum Marks: 12)**

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
  - Full Marks** : +3 If **ONLY** the correct option is chosen;
  - Zero Marks** : 0 If none of the options is chosen (i.e. the question is unanswered);
  - Negative Marks** : -1 In all other cases.

Q.4 In the scheme given below, **X** and **Y**, respectively, are



- (A)  $\text{CrO}_4^{2-}$  and  $\text{Br}_2$   
 (B)  $\text{MnO}_4^{2-}$  and  $\text{Cl}_2$   
 (C)  $\text{MnO}_4^-$  and  $\text{Cl}_2$   
 (D)  $\text{MnSO}_4$  and  $\text{HOCl}$

Q.5 Plotting  $1/\Lambda_m$  against  $c\Lambda_m$  for aqueous solutions of a monobasic weak acid (HX) resulted in a straight line with y-axis intercept of P and slope of S. The ratio P/S is

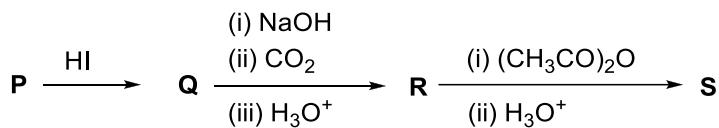
[ $\Lambda_m$  = molar conductivity  
 $\Lambda_m^0$  = limiting molar conductivity  
 $c$  = molar concentration  
 $K_a$  = dissociation constant of HX]

- (A)  $K_a \Lambda_m^0$   
 (B)  $K_a \Lambda_m^0/2$   
 (C)  $2 K_a \Lambda_m^0$   
 (D)  $1 / (K_a \Lambda_m^0)$

Q.6 On decreasing the *pH* from 7 to 2, the solubility of a sparingly soluble salt (MX) of a weak acid (HX) increased from  $10^{-4}$  mol L<sup>-1</sup> to  $10^{-3}$  mol L<sup>-1</sup>. The *pK<sub>a</sub>* of HX is

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

Q.7 In the given reaction scheme, **P** is a phenyl alkyl ether, **Q** is an aromatic compound; **R** and **S** are the major products.



The correct statement about **S** is

- (A) It primarily inhibits noradrenaline degrading enzymes.
- (B) It inhibits the synthesis of prostaglandin.
- (C) It is a narcotic drug.
- (D) It is *ortho*-acetylbenzoic acid.

**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +4 If **ONLY** the correct integer is entered;  
*Zero Marks* : 0 In all other cases.

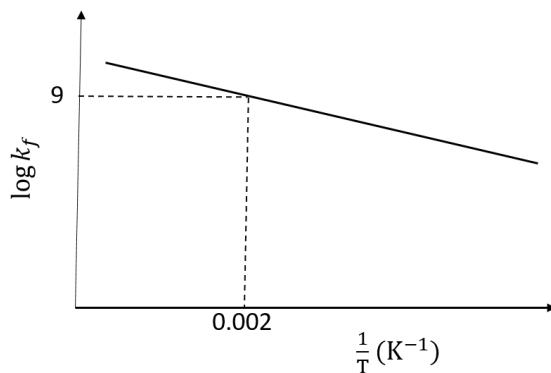
Q.8 The stoichiometric reaction of 516 g of dimethyldichlorosilane with water results in a tetrameric cyclic product **X** in 75% yield. The weight (in g) of **X** obtained is \_\_\_\_.

[Use, molar mass (g mol<sup>-1</sup>): H = 1, C = 12, O = 16, Si = 28, Cl = 35.5]

Q.9 A gas has a compressibility factor of 0.5 and a molar volume of 0.4 dm<sup>3</sup> mol<sup>-1</sup> at a temperature of 800 K and pressure **x** atm. If it shows ideal gas behaviour at the same temperature and pressure, the molar volume will be **y** dm<sup>3</sup> mol<sup>-1</sup>. The value of **x/y** is \_\_\_\_.

[Use: Gas constant, R = 8 × 10<sup>-2</sup> L atm K<sup>-1</sup> mol<sup>-1</sup>]

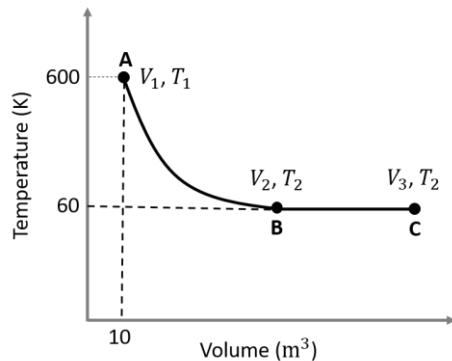
- Q.10 The plot of  $\log k_f$  versus  $1/T$  for a reversible reaction  $A(g) \rightleftharpoons P(g)$  is shown.



Pre-exponential factors for the forward and backward reactions are  $10^{15} \text{ s}^{-1}$  and  $10^{11} \text{ s}^{-1}$ , respectively. If the value of  $\log K$  for the reaction at 500 K is 6, the value of  $|\log k_b|$  at 250 K is \_\_\_\_.

[ $K$  = equilibrium constant of the reaction  
 $k_f$  = rate constant of forward reaction  
 $k_b$  = rate constant of backward reaction]

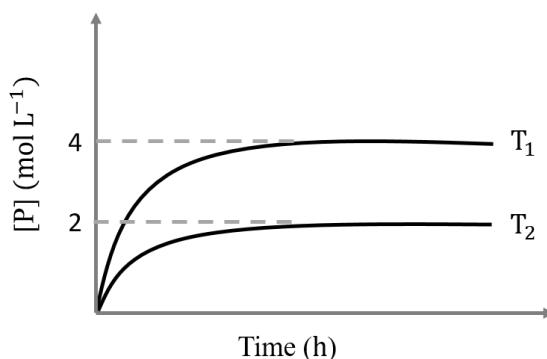
- Q.11 One mole of an ideal monoatomic gas undergoes two reversible processes (A  $\rightarrow$  B and B  $\rightarrow$  C) as shown in the given figure:



A  $\rightarrow$  B is an adiabatic process. If the total heat absorbed in the entire process (A  $\rightarrow$  B and B  $\rightarrow$  C) is  $RT_2 \ln 10$ , the value of  $2 \log V_3$  is \_\_\_\_.

[Use, molar heat capacity of the gas at constant pressure,  $C_{p,m} = \frac{5}{2} R$ ]

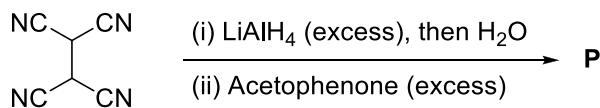
- Q.12 In a one-litre flask, 6 moles of A undergoes the reaction  $A(g) \rightleftharpoons P(g)$ . The progress of product formation at two temperatures (in Kelvin),  $T_1$  and  $T_2$ , is shown in the figure:



If  $T_1 = 2T_2$  and  $(\Delta G_2^\Theta - \Delta G_1^\Theta) = RT_2 \ln x$ , then the value of  $x$  is \_\_\_\_.

[ $\Delta G_1^\Theta$  and  $\Delta G_2^\Theta$  are standard Gibb's free energy change for the reaction at temperatures  $T_1$  and  $T_2$ , respectively.]

- Q.13 The total number of  $sp^2$  hybridised carbon atoms in the major product **P** (a non-heterocyclic compound) of the following reaction is \_\_\_\_.



**SECTION 4 (Maximum Marks: 12)**

- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List-I** and **List-II**.
- **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 Match the reactions (in the given stoichiometry of the reactants) in List-I with one of their products given in List-II and choose the correct option.

**List-I**

- (P)  $\text{P}_2\text{O}_3 + 3\text{H}_2\text{O} \rightarrow$   
(Q)  $\text{P}_4 + 3\text{NaOH} + 3\text{H}_2\text{O} \rightarrow$   
(R)  $\text{PCl}_5 + \text{CH}_3\text{COOH} \rightarrow$   
(S)  $\text{H}_3\text{PO}_2 + 2\text{H}_2\text{O} + 4\text{AgNO}_3 \rightarrow$

**List-II**

- (1)  $\text{P}(\text{O})(\text{OCH}_3)\text{Cl}_2$   
(2)  $\text{H}_3\text{PO}_3$   
(3)  $\text{PH}_3$   
(4)  $\text{POCl}_3$   
(5)  $\text{H}_3\text{PO}_4$

- (A) P → 2; Q → 3; R → 1; S → 5  
(B) P → 3; Q → 5; R → 4; S → 2  
(C) P → 5; Q → 2; R → 1; S → 3  
(D) P → 2; Q → 3; R → 4; S → 5

**Q.15** Match the electronic configurations in List-I with appropriate metal complex ions in List-II and choose the correct option.

[Atomic Number: Fe = 26, Mn = 25, Co = 27]

**List-I**

- (P)  $t_{2g}^6 e_g^0$
- (Q)  $t_{2g}^3 e_g^2$
- (R)  $e^2 t_2^3$
- (S)  $t_{2g}^4 e_g^2$

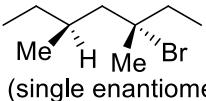
**List-II**

- (1)  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
- (2)  $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$
- (3)  $[\text{Co}(\text{NH}_3)_6]^{3+}$
- (4)  $[\text{FeCl}_4]^-$
- (5)  $[\text{CoCl}_4]^{2-}$

- (A) P → 1; Q → 4; R → 2; S → 3
- (B) P → 1; Q → 2; R → 4; S → 5
- (C) P → 3; Q → 2; R → 5; S → 1
- (D) P → 3; Q → 2; R → 4; S → 1

**Q.16** Match the reactions in List-I with the features of their products in List-II and choose the correct option.

**List-I**

- (P) (-)-1-Bromo-2-ethylpentane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}2 \text{ reaction}]{\text{aq. NaOH}}$
- (Q) (-)-2-Bromopentane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}2 \text{ reaction}]{\text{aq. NaOH}}$
- (R) (-)-3-Bromo-3-methylhexane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}1 \text{ reaction}]{\text{aq. NaOH}}$
- (S)   $\xrightarrow[\text{S}_{\text{N}}1 \text{ reaction}]{\text{aq. NaOH}}$

**List-II**

- (1) Inversion of configuration
- (2) Retention of configuration
- (3) Mixture of enantiomers
- (4) Mixture of structural isomers
- (5) Mixture of diastereomers

- (A) P → 1; Q → 2; R → 5; S → 3
- (B) P → 2; Q → 1; R → 3; S → 5
- (C) P → 1; Q → 2; R → 5; S → 4
- (D) P → 2; Q → 4; R → 3; S → 5

**Q.17** The major products obtained from the reactions in List-II are the reactants for the named reactions mentioned in List-I. Match List-I with List-II and choose the correct option.

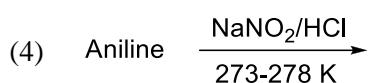
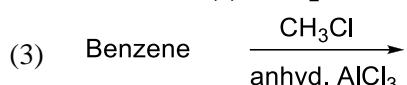
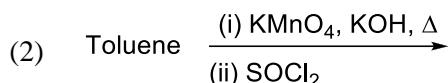
**List-I**

(P) Etard reaction

(Q) Gattermann reaction

(R) Gattermann-Koch reaction

(S) Rosenmund reduction

**List-II**

- (A) P → 2; Q → 4; R → 1; S → 3  
 (B) P → 1; Q → 3; R → 5; S → 2  
 (C) P → 3; Q → 2; R → 1; S → 4  
 (D) P → 3; Q → 4; R → 5; S → 2

**END OF THE QUESTION PAPER**

1. Why are open-ended questions so important?
  - They require a person to pause, think, and reflect.
  - Answers include personal feelings, opinions, or ideas about a subject.
  - The control of the conversation switches from the person asking the question to the person being asked the question. It begins an exchange between the caseworker and the family. If the control of the conversation stays with the caseworker, you are asking closed-ended questions.
2. Open-ended questions begin in very specific ways. Open-ended questions begin with the following words: why, how, what, describe, tell me about..., or what do you think about...
3. Use open-ended questions as follow ups for other questions. These follow ups can be asked after open or closed-ended questions.
  - Ask "why" and "how" to follow up and gain a more thorough answer after asking a closed-ended question.
  - When the participant has finished talking, ask an open-ended question that refers to what they just said, or is related to what they just said. This keeps the conversation flowing in an open and engaging way.
4. Wording is very important when asking open-ended questions, especially if you are looking for a certain type of answer.
  - Gauge the family's comfort level when asking questions. Be careful when asking questions that are very personal or require too much personal information early in the conversation.
  - A person who is uncomfortable answering open-ended questions either doesn't understand where you are going with it or doesn't want to answer. Explain why you are asking the question, re-phrase the question or save the question for another time.
  - Open-ended questions can result in long answers. If you would like to keep them brief or relevant, be specific when asking the question.

## Examples of Open-Ended Questions

Use open-ended questions as follow ups for other questions; can be asked after open or closed-ended questions.

1. How did you get involved in...?
2. What kind of challenges are you facing?
3. What's the most important priority to you? Why?
4. What could make this no longer a priority?
5. What other issues are important to you?
6. What would you like to see improved?
7. Who else is involved in this decision?
8. What do you see as the next steps?
9. How do you measure that?
10. What is your timeline for implementing this action?
11. What is it that you'd like to see accomplished?
12. What are your expectations?
13. How do you see this happening?
14. With whom have you had success in the past?
15. With whom have you had difficulties in the past?
16. Can you help me understand that a little better?
17. What concerns do you have?
18. What's changed since we last talked?
19. What other items should we discuss?
20. How did you reach this decision?

**Mathematics****SECTION 1 (Maximum Marks: 12)**

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;  
*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;  
*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;  
*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;  
*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);  
*Negative Marks* : -2 In all other cases.
- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then  
choosing ONLY (A), (B) and (D) will get +4 marks;  
choosing ONLY (A) and (B) will get +2 marks;  
choosing ONLY (A) and (D) will get +2 marks;  
choosing ONLY (B) and (D) will get +2 marks;  
choosing ONLY (A) will get +1 mark;  
choosing ONLY (B) will get +1 mark;  
choosing ONLY (D) will get +1 mark;  
choosing no option (i.e. the question is unanswered) will get 0 marks; and  
choosing any other combination of options will get -2 marks.

Q.1 Let  $S = (0,1) \cup (1,2) \cup (3,4)$  and  $T = \{0,1,2,3\}$ . Then which of the following statements is(are) true?

- (A) There are infinitely many functions from  $S$  to  $T$
- (B) There are infinitely many strictly increasing functions from  $S$  to  $T$
- (C) The number of continuous functions from  $S$  to  $T$  is at most 120
- (D) Every continuous function from  $S$  to  $T$  is differentiable

Q.2

Let  $T_1$  and  $T_2$  be two distinct common tangents to the ellipse  $E : \frac{x^2}{6} + \frac{y^2}{3} = 1$  and the parabola

$P : y^2 = 12x$ . Suppose that the tangent  $T_1$  touches  $P$  and  $E$  at the points  $A_1$  and  $A_2$ ,

respectively and the tangent  $T_2$  touches  $P$  and  $E$  at the points  $A_4$  and  $A_3$ , respectively. Then which of the following statements is(are) true?

- (A) The area of the quadrilateral  $A_1A_2A_3A_4$  is 35 square units
- (B) The area of the quadrilateral  $A_1A_2A_3A_4$  is 36 square units
- (C) The tangents  $T_1$  and  $T_2$  meet the  $x$ -axis at the point  $(-3, 0)$
- (D) The tangents  $T_1$  and  $T_2$  meet the  $x$ -axis at the point  $(-6, 0)$

Q.3

Let  $f : [0, 1] \rightarrow [0, 1]$  be the function defined by  $f(x) = \frac{x^3}{3} - x^2 + \frac{5}{9}x + \frac{17}{36}$ . Consider the square

region  $S = [0, 1] \times [0, 1]$ . Let  $G = \{(x, y) \in S : y > f(x)\}$  be called the green region and

$R = \{(x, y) \in S : y < f(x)\}$  be called the red region. Let  $L_h = \{(x, h) \in S : x \in [0, 1]\}$  be the horizontal line drawn at a height  $h \in [0, 1]$ . Then which of the following statements is(are) true?

- (A) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the green region above the line  $L_h$  equals the area of the green region below the line  $L_h$
- (B) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the red region above the line  $L_h$  equals the area of the red region below the line  $L_h$
- (C) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the green region above the line  $L_h$  equals the area of the red region below the line  $L_h$
- (D) There exists an  $h \in \left[\frac{1}{4}, \frac{2}{3}\right]$  such that the area of the red region above the line  $L_h$  equals the area of the green region below the line  $L_h$

**SECTION 2 (Maximum Marks: 12)**

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:  
 Full Marks : +3 If **ONLY** the correct option is chosen;  
 Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);  
 Negative Marks : -1 In all other cases.

**Q.4** Let  $f : (0,1) \rightarrow \mathbb{R}$  be the function defined as  $f(x) = \sqrt{n}$  if  $x \in \left[ \frac{1}{n+1}, \frac{1}{n} \right]$  where  $n \in \mathbb{N}$ . Let

$g : (0,1) \rightarrow \mathbb{R}$  be a function such that  $\int_{x^2}^x \sqrt{\frac{1-t}{t}} dt < g(x) < 2\sqrt{x}$  for all  $x \in (0,1)$ . Then

$$\lim_{x \rightarrow 0} f(x)g(x)$$

- (A) does **NOT** exist  
 (B) is equal to 1  
 (C) is equal to 2  
 (D) is equal to 3

**Q.5** Let  $Q$  be the cube with the set of vertices  $\{(x_1, x_2, x_3) \in \mathbb{R}^3 : x_1, x_2, x_3 \in \{0, 1\}\}$ . Let  $F$  be the set of all twelve lines containing the diagonals of the six faces of the cube  $Q$ . Let  $S$  be the set of all four lines containing the main diagonals of the cube  $Q$ ; for instance, the line passing through the vertices  $(0,0,0)$  and  $(1,1,1)$  is in  $S$ . For lines  $\ell_1$  and  $\ell_2$ , let  $d(\ell_1, \ell_2)$  denote the shortest distance between them. Then the maximum value of  $d(\ell_1, \ell_2)$ , as  $\ell_1$  varies over  $F$  and  $\ell_2$  varies over  $S$ , is

- (A)  $\frac{1}{\sqrt{6}}$       (B)  $\frac{1}{\sqrt{8}}$       (C)  $\frac{1}{\sqrt{3}}$       (D)  $\frac{1}{\sqrt{12}}$

**Q.6** Let  $X = \left\{ (x, y) \in \mathbb{Z} \times \mathbb{Z} : \frac{x^2}{8} + \frac{y^2}{20} < 1 \text{ and } y^2 < 5x \right\}$ . Three distinct points  $P$ ,  $Q$  and  $R$  are randomly chosen from  $X$ . Then the probability that  $P$ ,  $Q$  and  $R$  form a triangle whose area is a positive integer, is

- (A)  $\frac{71}{220}$       (B)  $\frac{73}{220}$       (C)  $\frac{79}{220}$       (D)  $\frac{83}{220}$

Q.7 Let  $P$  be a point on the parabola  $y^2 = 4ax$ , where  $a > 0$ . The normal to the parabola at  $P$  meets the  $x$ -axis at a point  $Q$ . The area of the triangle  $PFQ$ , where  $F$  is the focus of the parabola, is 120. If the slope  $m$  of the normal and  $a$  are both positive integers, then the pair  $(a, m)$  is

- (A) (2,3)      (B) (1,3)      (C) (2,4)      (D) (3,4)

**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
  - The answer to each question is a **NON-NEGATIVE INTEGER**.
  - For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks* : +4 If **ONLY** the correct integer is entered;  
*Zero Marks* : 0 In all other cases.

Q.8

Let  $\tan^{-1}(x) \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$ , for  $x \in \mathbb{R}$ . Then the number of real solutions of the equation

$$\sqrt{1+\cos(2x)} = \sqrt{2} \tan^{-1}(\tan x) \text{ in the set } \left(-\frac{3\pi}{2}, -\frac{\pi}{2}\right) \cup \left(-\frac{\pi}{2}, \frac{\pi}{2}\right) \cup \left(\frac{\pi}{2}, \frac{3\pi}{2}\right)$$

is equal to

Q.9 Let  $n \geq 2$  be a natural number and  $f : [0, 1] \rightarrow \mathbb{R}$  be the function defined by

$$f(x) = \begin{cases} n(1-2nx) & \text{if } 0 \leq x \leq \frac{1}{2n} \\ 2n(2nx-1) & \text{if } \frac{1}{2n} \leq x \leq \frac{3}{4n} \\ 4n(1-nx) & \text{if } \frac{3}{4n} \leq x \leq \frac{1}{n} \\ \frac{n}{n-1}(nx-1) & \text{if } \frac{1}{n} \leq x \leq 1 \end{cases}$$

If  $n$  is such that the area of the region bounded by the curves  $x=0$ ,  $x=1$ ,  $y=0$  and  $y=f(x)$  is 4, then the maximum value of the function  $f$  is

Q.10

Let  $\overbrace{75\cdots5}^r 7$  denote the  $(r+2)$  digit number where the first and the last digits are 7 and

the remaining  $r$  digits are 5. Consider the sum  $S = 77 + 757 + 7557 + \cdots + \overbrace{75\cdots5}^{98} 7$ . If

$S = \frac{\overbrace{75\cdots5}^{99} 7 + m}{n}$ , where  $m$  and  $n$  are natural numbers less than 3000, then the value of  $m+n$  is

Q.11 Let  $A = \left\{ \frac{1967 + 1686i \sin \theta}{7 - 3i \cos \theta} : \theta \in \mathbb{R} \right\}$ . If  $A$  contains exactly one positive integer  $n$ , then the value of  $n$  is

Q.12 Let  $P$  be the plane  $\sqrt{3}x + 2y + 3z = 16$  and let

$$S = \left\{ \alpha \hat{i} + \beta \hat{j} + \gamma \hat{k} : \alpha^2 + \beta^2 + \gamma^2 = 1 \text{ and the distance of } (\alpha, \beta, \gamma) \text{ from the plane } P \text{ is } \frac{7}{2} \right\}.$$

Let  $\vec{u}, \vec{v}$  and  $\vec{w}$  be three distinct vectors in  $S$  such that  $|\vec{u} - \vec{v}| = |\vec{v} - \vec{w}| = |\vec{w} - \vec{u}|$ . Let  $V$  be the volume of the parallelepiped determined by vectors  $\vec{u}, \vec{v}$  and  $\vec{w}$ . Then the value of  $\frac{80}{\sqrt{3}}V$  is

Q.13 Let  $a$  and  $b$  be two nonzero real numbers. If the coefficient of  $x^5$  in the expansion of

$$\left( ax^2 + \frac{70}{27bx} \right)^4 \text{ is equal to the coefficient of } x^{-5} \text{ in the expansion of } \left( ax - \frac{1}{bx^2} \right)^7, \text{ then}$$

the value of  $2b$  is

**SECTION 4 (Maximum Marks: 12)**

- This section contains **FOUR (04)** Matching List Sets.
  - Each set has **ONE** Multiple Choice Question.
  - Each set has **TWO** lists: **List-I** and **List-II**.
  - **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
  - **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 Let  $\alpha, \beta$  and  $\gamma$  be real numbers. Consider the following system of linear equations

$$x + 2y + z = 7$$

$$x + \alpha z = 11$$

$$2x - 3y + \beta z = \gamma$$

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

**List-II**

(P) If  $\beta = \frac{1}{2}(7\alpha - 3)$  and  $\gamma = 28$ , then the system has

(1) a unique solution

(Q) If  $\beta = \frac{1}{2}(7\alpha - 3)$  and  $\gamma \neq 28$ , then the system has

(2) no solution

(R) If  $\beta \neq \frac{1}{2}(7\alpha - 3)$  where  $\alpha = 1$  and  $\gamma \neq 28$ , then the system has

(3) infinitely many solutions

(S) If  $\beta \neq \frac{1}{2}(7\alpha - 3)$  where  $\alpha = 1$  and  $\gamma = 28$ , then the system has

(4)  $x = 11$ ,  $y = -2$  and  $z = 0$  as a solution

(5)  $x = -15$ ,  $y = 4$  and  $z = 0$  as a solution

The correct option is:

- (A) (P)  $\rightarrow$  (3)    (Q)  $\rightarrow$  (2)    (R)  $\rightarrow$  (1)    (S)  $\rightarrow$  (4)  
 (B) (P)  $\rightarrow$  (3)    (Q)  $\rightarrow$  (2)    (R)  $\rightarrow$  (5)    (S)  $\rightarrow$  (4)  
 (C) (P)  $\rightarrow$  (2)    (Q)  $\rightarrow$  (1)    (R)  $\rightarrow$  (4)    (S)  $\rightarrow$  (5)  
 (D) (P)  $\rightarrow$  (2)    (Q)  $\rightarrow$  (1)    (R)  $\rightarrow$  (1)    (S)  $\rightarrow$  (3)

Q.15 Consider the given data with frequency distribution

$x_i$	3	8	11	10	5	4
$f_i$	5	2	3	2	4	4

Match each entry in **List-I** to the correct entries in **List-II**.

<b>List-I</b>	<b>List-II</b>
(P) The mean of the above data is	(1) 2.5
(Q) The median of the above data is	(2) 5
(R) The mean deviation about the mean of the above data is	(3) 6
(S) The mean deviation about the median of the above data is	(4) 2.7
	(5) 2.4

The correct option is:

(A) (P) → (3) (Q) → (2) (R) → (4) (S) → (5)

(B) (P) → (3) (Q) → (2) (R) → (1) (S) → (5)

(C) (P) → (2) (Q) → (3) (R) → (4) (S) → (1)

(D) (P) → (3) (Q) → (3) (R) → (5) (S) → (5)

- Q.16** Let  $\ell_1$  and  $\ell_2$  be the lines  $\vec{r}_1 = \lambda(\hat{i} + \hat{j} + \hat{k})$  and  $\vec{r}_2 = (\hat{j} - \hat{k}) + \mu(\hat{i} + \hat{k})$ , respectively. Let  $X$  be the set of all the planes  $H$  that contain the line  $\ell_1$ . For a plane  $H$ , let  $d(H)$  denote the smallest possible distance between the points of  $\ell_2$  and  $H$ . Let  $H_0$  be a plane in  $X$  for which  $d(H_0)$  is the maximum value of  $d(H)$  as  $H$  varies over all planes in  $X$ .

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

- (P) The value of  $d(H_0)$  is
- (Q) The distance of the point  $(0, 1, 2)$  from  $H_0$  is
- (R) The distance of origin from  $H_0$  is
- (S) The distance of origin from the point of intersection of planes  $y = z$ ,  $x = 1$  and  $H_0$  is

**List-II**

- (1)  $\sqrt{3}$
- (2)  $\frac{1}{\sqrt{3}}$
- (3) 0
- (4)  $\sqrt{2}$
- (5)  $\frac{1}{\sqrt{2}}$

The correct option is:

- (A) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (1)
- (B) (P)  $\rightarrow$  (5) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (1)
- (C) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (2)
- (D) (P)  $\rightarrow$  (5) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (4) (S)  $\rightarrow$  (2)

- Q.17** Let  $z$  be a complex number satisfying  $|z|^3 + 2z^2 + 4\bar{z} - 8 = 0$ , where  $\bar{z}$  denotes the complex conjugate of  $z$ . Let the imaginary part of  $z$  be nonzero.

Match each entry in **List-I** to the correct entries in **List-II**.

**List-I**

- (P)  $|z|^2$  is equal to
- (Q)  $|z - \bar{z}|^2$  is equal to
- (R)  $|z|^2 + |z + \bar{z}|^2$  is equal to
- (S)  $|z + 1|^2$  is equal to

**List-II**

- (1) 12
- (2) 4
- (3) 8
- (4) 10
- (5) 7

The correct option is:

- (A) (P)  $\rightarrow$  (1) (Q)  $\rightarrow$  (3) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (4)
- (B) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (1) (R)  $\rightarrow$  (3) (S)  $\rightarrow$  (5)
- (C) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (4) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (1)
- (D) (P)  $\rightarrow$  (2) (Q)  $\rightarrow$  (3) (R)  $\rightarrow$  (5) (S)  $\rightarrow$  (4)

**END OF THE QUESTION PAPER**

## Physics

### SECTION 1 (Maximum Marks: 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;

*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;

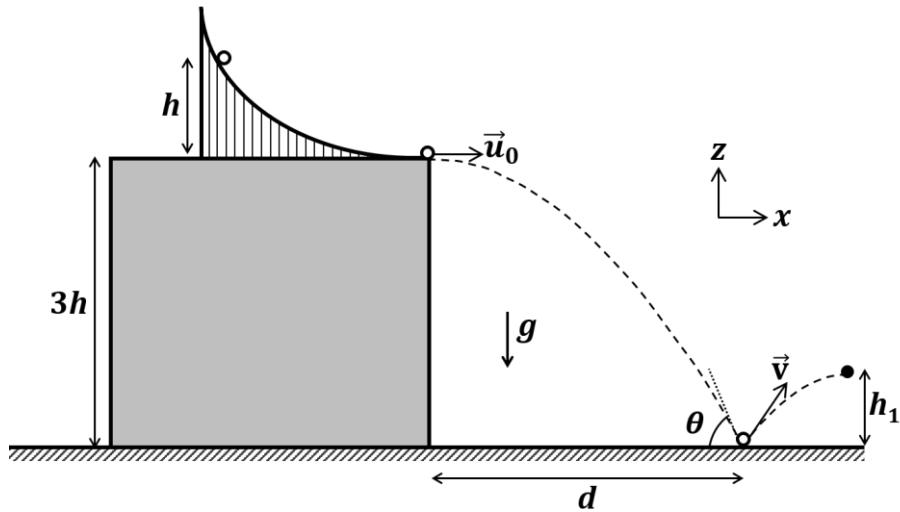
*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;

*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);

*Negative Marks* : -2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then
  - choosing **ONLY** (A), (B) and (D) will get +4 marks;
  - choosing **ONLY** (A) and (B) will get +2 marks;
  - choosing **ONLY** (A) and (D) will get +2 marks;
  - choosing **ONLY** (B) and (D) will get +2 marks;
  - choosing **ONLY** (A) will get +1 mark;
  - choosing **ONLY** (B) will get +1 mark;
  - choosing **ONLY** (D) will get +1 mark;
  - choosing no option (i.e. the question is unanswered) will get 0 marks; and
  - choosing any other combination of options will get -2 marks.

- Q.1 A slide with a frictionless curved surface, which becomes horizontal at its lower end, is fixed on the terrace of a building of height  $3h$  from the ground, as shown in the figure. A spherical ball of mass  $m$  is released on the slide from rest at a height  $h$  from the top of the terrace. The ball leaves the slide with a velocity  $\vec{u}_0 = u_0 \hat{x}$  and falls on the ground at a distance  $d$  from the building making an angle  $\theta$  with the horizontal. It bounces off with a velocity  $\vec{v}$  and reaches a maximum height  $h_1$ . The acceleration due to gravity is  $g$  and the coefficient of restitution of the ground is  $1/\sqrt{3}$ . Which of the following statement(s) is(are) correct?



- (A)  $\vec{u}_0 = \sqrt{2gh} \hat{x}$
- (B)  $\vec{v} = \sqrt{2gh} (\hat{x} - \hat{z})$
- (C)  $\theta = 60^\circ$
- (D)  $d/h_1 = 2\sqrt{3}$

- Q.2 A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is  $\delta = 60^\circ$  (see Figure-1). The angle of minimum deviation for red light from the same prism is  $\delta_{\min} = 30^\circ$  (see Figure-2). The refractive index of the prism material for blue light is  $\sqrt{3}$ . Which of the following statement(s) is(are) correct?

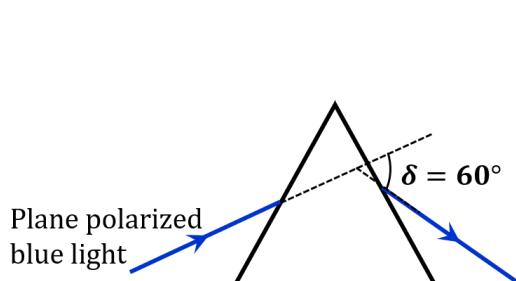


Figure-1

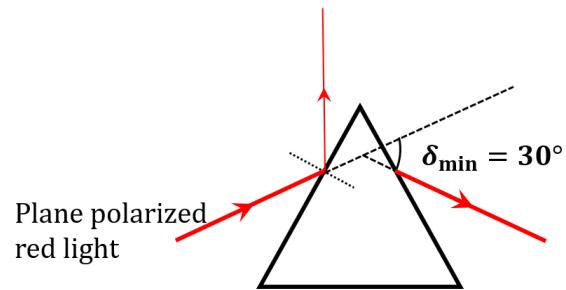
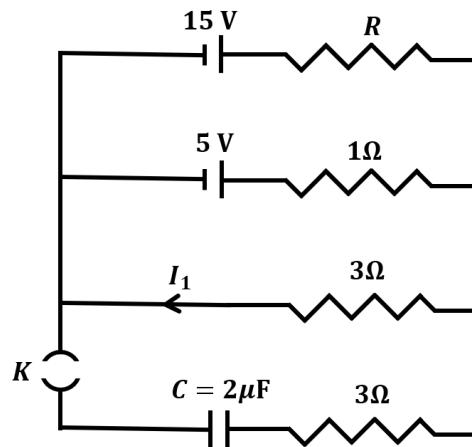


Figure-2

- (A) The blue light is polarized in the plane of incidence.
- (B) The angle of the prism is  $45^\circ$ .
- (C) The refractive index of the material of the prism for red light is  $\sqrt{2}$ .
- (D) The angle of refraction for blue light in air at the exit plane of the prism is  $60^\circ$ .

- Q.3 In a circuit shown in the figure, the capacitor  $C$  is initially uncharged and the key  $K$  is open. In this condition, a current of 1 A flows through the  $1 \Omega$  resistor. The key is closed at time  $t = t_0$ . Which of the following statement(s) is(are) correct?

[Given:  $e^{-1} = 0.36$ ]



- (A) The value of the resistance  $R$  is  $3 \Omega$ .
- (B) For  $t < t_0$ , the value of current  $I_1$  is 2 A.
- (C) At  $t = t_0 + 7.2 \mu s$ , the current in the capacitor is 0.6 A.
- (D) For  $t \rightarrow \infty$ , the charge on the capacitor is  $12 \mu C$ .

**SECTION 2 (Maximum Marks: 12)**

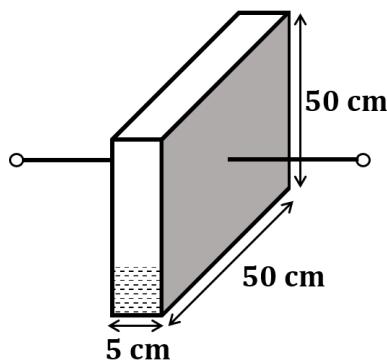
- This section contains **FOUR (04)** questions.
  - Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
  - For each question, choose the option corresponding to the correct answer.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks* : +3 If **ONLY** the correct option is chosen;  
*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);  
*Negative Marks* : -1 In all other cases.

**Q.4** A bar of mass  $M = 1.00 \text{ kg}$  and length  $L = 0.20 \text{ m}$  is lying on a horizontal frictionless surface. One end of the bar is pivoted at a point about which it is free to rotate. A small mass  $m = 0.10 \text{ kg}$  is moving on the same horizontal surface with  $5.00 \text{ m s}^{-1}$  speed on a path perpendicular to the bar. It hits the bar at a distance  $L/2$  from the pivoted end and returns back on the same path with speed  $v$ . After this elastic collision, the bar rotates with an angular velocity  $\omega$ . Which of the following statement is correct?

- (A)  $\omega = 6.98 \text{ rad s}^{-1}$  and  $v = 4.30 \text{ m s}^{-1}$       (B)  $\omega = 3.75 \text{ rad s}^{-1}$  and  $v = 4.30 \text{ m s}^{-1}$   
 (C)  $\omega = 3.75 \text{ rad s}^{-1}$  and  $v = 10.0 \text{ m s}^{-1}$       (D)  $\omega = 6.80 \text{ rad s}^{-1}$  and  $v = 4.10 \text{ m s}^{-1}$

**Q.5** A container has a base of  $50 \text{ cm} \times 5 \text{ cm}$  and height  $50 \text{ cm}$ , as shown in the figure. It has two parallel electrically conducting walls each of area  $50 \text{ cm} \times 50 \text{ cm}$ . The remaining walls of the container are thin and non-conducting. The container is being filled with a liquid of dielectric constant 3 at a uniform rate of  $250 \text{ cm}^3 \text{ s}^{-1}$ . What is the value of the capacitance of the container after 10 seconds?

[Given: Permittivity of free space  $\epsilon_0 = 9 \times 10^{-12} \text{ C}^2 \text{N}^{-1} \text{m}^{-2}$ , the effects of the non-conducting walls on the capacitance are negligible]



- (A) 27 pF      (B) 63 pF      (C) 81 pF      (D) 135 pF

- Q.6 One mole of an ideal gas expands adiabatically from an initial state  $(T_A, V_0)$  to final state  $(T_f, 5V_0)$ . Another mole of the same gas expands isothermally from a different initial state  $(T_B, V_0)$  to the same final state  $(T_f, 5V_0)$ . The ratio of the specific heats at constant pressure and constant volume of this ideal gas is  $\gamma$ . What is the ratio  $T_A/T_B$ ?

(A)  $5^{\gamma-1}$       (B)  $5^{1-\gamma}$       (C)  $5^\gamma$       (D)  $5^{1+\gamma}$

Q.7 Two satellites P and Q are moving in different circular orbits around the Earth (radius  $R$ ). The heights of P and Q from the Earth surface are  $h_P$  and  $h_Q$ , respectively, where  $h_p = R/3$ . The accelerations of P and Q due to Earth's gravity are  $g_P$  and  $g_Q$ , respectively. If  $g_P/g_Q = 36/25$ , what is the value of  $h_Q$ ?

(A)  $3R/5$       (B)  $R/6$       (C)  $6R/5$       (D)  $5R/6$

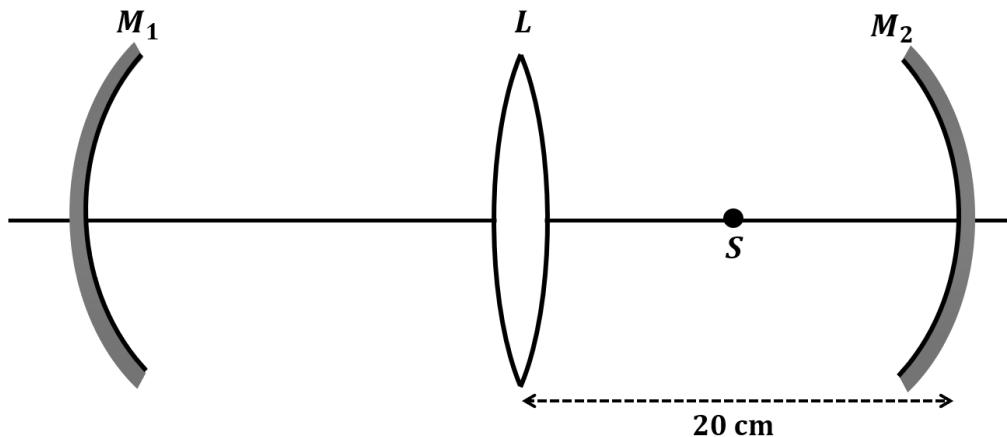
**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
  - The answer to each question is a **NON-NEGATIVE INTEGER**.
  - For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks** : +4 If **ONLY** the correct integer is entered;  
**Zero Marks** : 0 In all other cases.

**Q.8** A Hydrogen-like atom has atomic number  $Z$ . Photons emitted in the electronic transitions from level  $n = 4$  to level  $n = 3$  in these atoms are used to perform photoelectric effect experiment on a target metal. The maximum kinetic energy of the photoelectrons generated is 1.95 eV. If the photoelectric threshold wavelength for the target metal is 310 nm, the value of  $Z$  is \_\_\_\_\_.

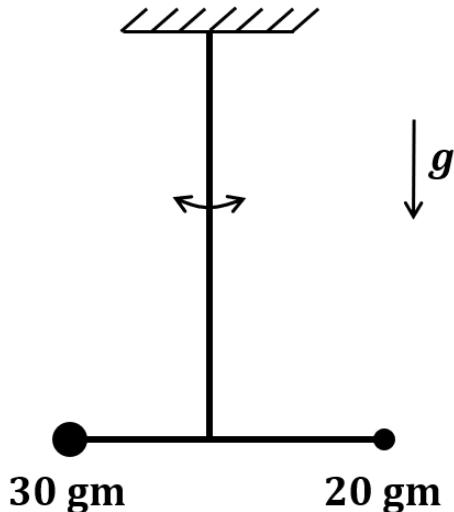
[Given:  $hc = 1240 \text{ eV-nm}$  and  $Rhc = 13.6 \text{ eV}$ , where  $R$  is the Rydberg constant,  $h$  is the Planck's constant and  $c$  is the speed of light in vacuum]

**Q.9** An optical arrangement consists of two concave mirrors  $M_1$  and  $M_2$ , and a convex lens  $L$  with a common principal axis, as shown in the figure. The focal length of  $L$  is 10 cm. The radii of curvature of  $M_1$  and  $M_2$  are 20 cm and 24 cm, respectively. The distance between  $L$  and  $M_2$  is 20 cm. A point object  $S$  is placed at the mid-point between  $L$  and  $M_2$  on the axis. When the distance between  $L$  and  $M_1$  is  $n/7$  cm, one of the images coincides with  $S$ . The value of  $n$  is \_\_\_\_\_.



**Q.10** In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is  $10 \pm 0.1$  cm and the distance of its real image from the lens is  $20 \pm 0.2$  cm. The error in the determination of focal length of the lens is  $n\%$ . The value of  $n$  is \_\_\_\_\_.

- Q.11 A closed container contains a homogeneous mixture of two moles of an ideal monatomic gas ( $\gamma = 5/3$ ) and one mole of an ideal diatomic gas ( $\gamma = 7/5$ ). Here,  $\gamma$  is the ratio of the specific heats at constant pressure and constant volume of an ideal gas. The gas mixture does a work of 66 Joule when heated at constant pressure. The change in its internal energy is \_\_\_\_\_ Joule.
- Q.12 A person of height 1.6 m is walking away from a lamp post of height 4 m along a straight path on the flat ground. The lamp post and the person are always perpendicular to the ground. If the speed of the person is  $60 \text{ cm s}^{-1}$ , the speed of the tip of the person's shadow on the ground with respect to the person is \_\_\_\_\_  $\text{cm s}^{-1}$ .
- Q.13 Two point-like objects of masses 20 gm and 30 gm are fixed at the two ends of a rigid massless rod of length 10 cm. This system is suspended vertically from a rigid ceiling using a thin wire attached to its center of mass, as shown in the figure. The resulting torsional pendulum undergoes small oscillations. The torsional constant of the wire is  $1.2 \times 10^{-8} \text{ N m rad}^{-1}$ . The angular frequency of the oscillations in  $n \times 10^{-3} \text{ rad s}^{-1}$ . The value of  $n$  is \_\_\_\_\_.



#### SECTION 4 (Maximum Marks: 12)

- This section contains **FOUR (04)** Matching List Sets.
- Each set has **ONE** Multiple Choice Question.
- Each set has **TWO** lists: **List-I** and **List-II**.
- **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
- **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 List-I shows different radioactive decay processes and List-II provides possible emitted particles. Match each entry in List-I with an appropriate entry from List-II, and choose the correct option.

**List-I**

- (P)  $^{238}_{92}U \rightarrow ^{234}_{91}Pa$   
 (Q)  $^{214}_{82}Pb \rightarrow ^{210}_{82}Pb$   
 (R)  $^{210}_{81}Tl \rightarrow ^{206}_{82}Pb$   
 (S)  $^{228}_{91}Pa \rightarrow ^{224}_{88}Ra$

**List-II**

- (1) one  $\alpha$  particle and one  $\beta^+$  particle  
 (2) three  $\beta^-$  particles and one  $\alpha$  particle  
 (3) two  $\beta^-$  particles and one  $\alpha$  particle  
 (4) one  $\alpha$  particle and one  $\beta^-$  particle  
 (5) one  $\alpha$  particle and two  $\beta^+$  particles

- (A) P → 4, Q → 3, R → 2, S → 1  
 (C) P → 5, Q → 3, R → 1, S → 4

- (B) P → 4, Q → 1, R → 2, S → 5  
 (D) P → 5, Q → 1, R → 3, S → 2

Q.15 Match the temperature of a black body given in List-I with an appropriate statement in List-II, and choose the correct option.

[Given: Wien's constant as  $2.9 \times 10^{-3}$  m-K and  $\frac{hc}{e} = 1.24 \times 10^{-6}$  V-m]

**List-I**

- (P) 2000 K  
 (Q) 3000 K  
 (R) 5000 K  
 (S) 10000 K

**List-II**

- (1) The radiation at peak wavelength can lead to emission of photoelectrons from a metal of work function 4 eV.  
 (2) The radiation at peak wavelength is visible to human eye.  
 (3) The radiation at peak emission wavelength will result in the widest central maximum of a single slit diffraction.  
 (4) The power emitted per unit area is 1/16 of that emitted by a blackbody at temperature 6000 K.  
 (5) The radiation at peak emission wavelength can be used to image human bones.

- (A) P → 3, Q → 5, R → 2, S → 3  
 (C) P → 3, Q → 4, R → 2, S → 1

- (B) P → 3, Q → 2, R → 4, S → 1  
 (D) P → 1, Q → 2, R → 5, S → 3

- Q.16** A series LCR circuit is connected to a  $45 \sin(\omega t)$  Volt source. The resonant angular frequency of the circuit is  $10^5 \text{ rad s}^{-1}$  and current amplitude at resonance is  $I_0$ . When the angular frequency of the source is  $\omega = 8 \times 10^4 \text{ rad s}^{-1}$ , the current amplitude in the circuit is  $0.05 I_0$ . If  $L = 50 \text{ mH}$ , match each entry in List-I with an appropriate value from List-II and choose the correct option.

**List-I**

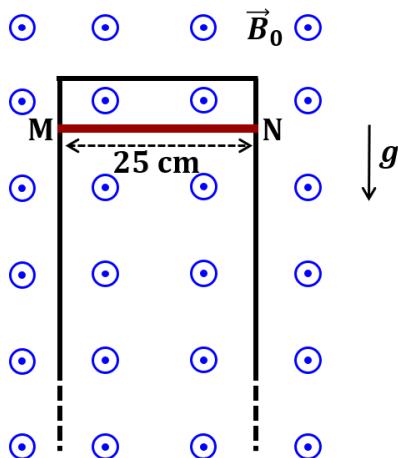
- (P)  $I_0$  in mA
  - (Q) The quality factor of the circuit
  - (R) The bandwidth of the circuit in  $\text{rad s}^{-1}$
  - (S) The peak power dissipated at resonance in Watt
- 
- (A)  $P \rightarrow 2, Q \rightarrow 3, R \rightarrow 5, S \rightarrow 1$
  - (B)  $P \rightarrow 3, Q \rightarrow 1, R \rightarrow 4, S \rightarrow 2$
  - (C)  $P \rightarrow 4, Q \rightarrow 5, R \rightarrow 3, S \rightarrow 1$
  - (D)  $P \rightarrow 4, Q \rightarrow 2, R \rightarrow 1, S \rightarrow 5$

**List-II**

- (1) 44.4
- (2) 18
- (3) 400
- (4) 2250
- (5) 500

- Q.17** A thin conducting rod MN of mass 20 gm, length 25 cm and resistance  $10 \Omega$  is held on frictionless, long, perfectly conducting vertical rails as shown in the figure. There is a uniform magnetic field  $B_0 = 4 \text{ T}$  directed perpendicular to the plane of the rod-rail arrangement. The rod is released from rest at time  $t = 0$  and it moves down along the rails. Assume air drag is negligible. Match each quantity in List-I with an appropriate value from List-II, and choose the correct option.

[Given: The acceleration due to gravity  $g = 10 \text{ m s}^{-2}$  and  $e^{-1} = 0.4$ ]

**List-I**

- (P) At  $t = 0.2 \text{ s}$ , the magnitude of the induced emf in Volt
  - (Q) At  $t = 0.2 \text{ s}$ , the magnitude of the magnetic force in Newton
  - (R) At  $t = 0.2 \text{ s}$ , the power dissipated as heat in Watt
  - (S) The magnitude of terminal velocity of the rod in  $\text{m s}^{-1}$
- 
- (A)  $P \rightarrow 5, Q \rightarrow 2, R \rightarrow 3, S \rightarrow 1$
  - (B)  $P \rightarrow 3, Q \rightarrow 1, R \rightarrow 4, S \rightarrow 5$
  - (C)  $P \rightarrow 4, Q \rightarrow 3, R \rightarrow 1, S \rightarrow 2$
  - (D)  $P \rightarrow 3, Q \rightarrow 4, R \rightarrow 2, S \rightarrow 5$

**List-II**

- (1) 0.07
- (2) 0.14
- (3) 1.20
- (4) 0.12
- (5) 2.00

**END OF THE QUESTION PAPER**

**Chemistry****SECTION 1 (Maximum Marks: 12)**

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;

*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;

*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;

*Zero Marks* : 0 If none of the options is chosen (i.e. the question is unanswered);

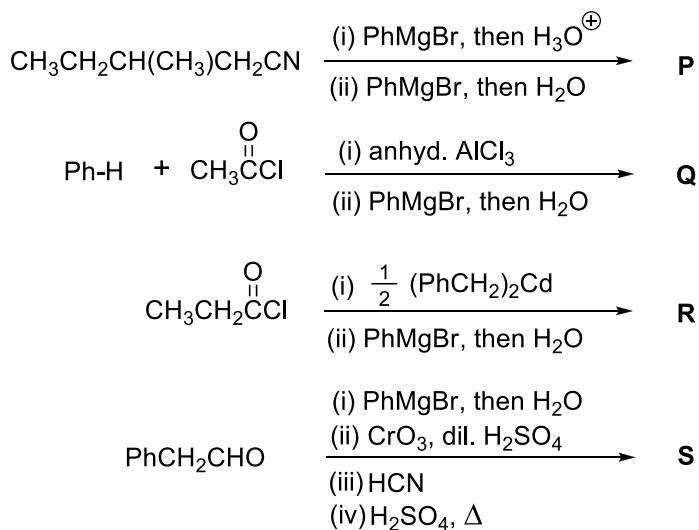
*Negative Marks* : -2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the **ONLY** three options corresponding to correct answers, then
  - choosing ONLY (A), (B) and (D) will get +4 marks;
  - choosing ONLY (A) and (B) will get +2 marks;
  - choosing ONLY (A) and (D) will get +2 marks;
  - choosing ONLY (B) and (D) will get +2 marks;
  - choosing ONLY (A) will get +1 mark;
  - choosing ONLY (B) will get +1 mark;
  - choosing ONLY (D) will get +1 mark;
  - choosing no option (i.e. the question is unanswered) will get 0 marks; and
  - choosing any other combination of options will get -2 marks.

Q.1 The correct statement(s) related to processes involved in the extraction of metals is(are)

- (A) Roasting of Malachite produces Cuprite.
- (B) Calcination of Calamine produces Zincite.
- (C) Copper pyrites is heated with silica in a reverberatory furnace to remove iron.
- (D) Impure silver is treated with aqueous KCN in the presence of oxygen followed by reduction with zinc metal.

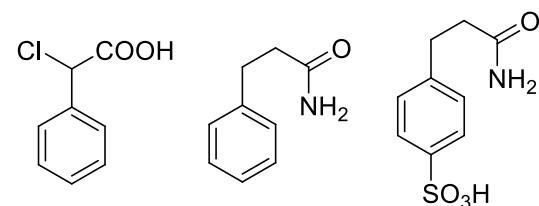
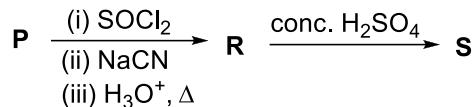
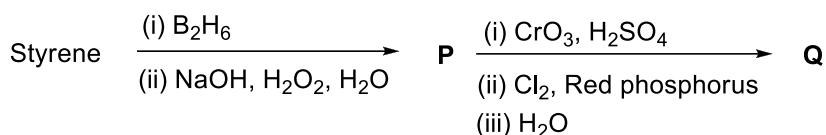
Q.2 In the following reactions, **P**, **Q**, **R**, and **S** are the major products.



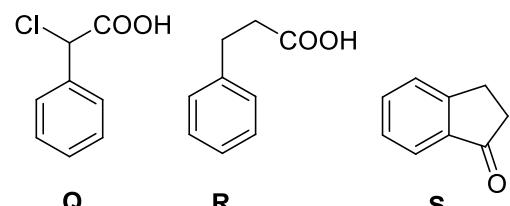
The correct statement(s) about **P**, **Q**, **R**, and **S** is(are)

- (A) Both **P** and **Q** have asymmetric carbon(s).
- (B) Both **Q** and **R** have asymmetric carbon(s).
- (C) Both **P** and **R** have asymmetric carbon(s).
- (D) **P** has asymmetric carbon(s), **S** does **not** have any asymmetric carbon.

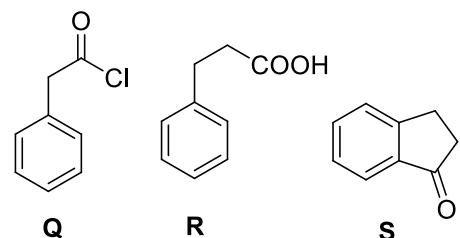
Q.3 Consider the following reaction scheme and choose the correct option(s) for the major products **Q**, **R** and **S**.



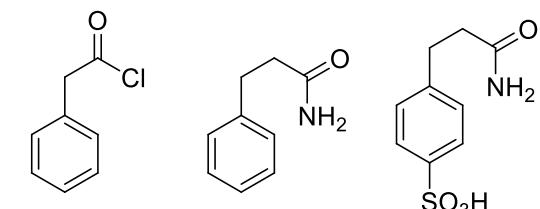
(A)      **Q**            **R**            **S**



(B)      **Q**            **R**            **S**



(C)      **Q**            **R**            **S**

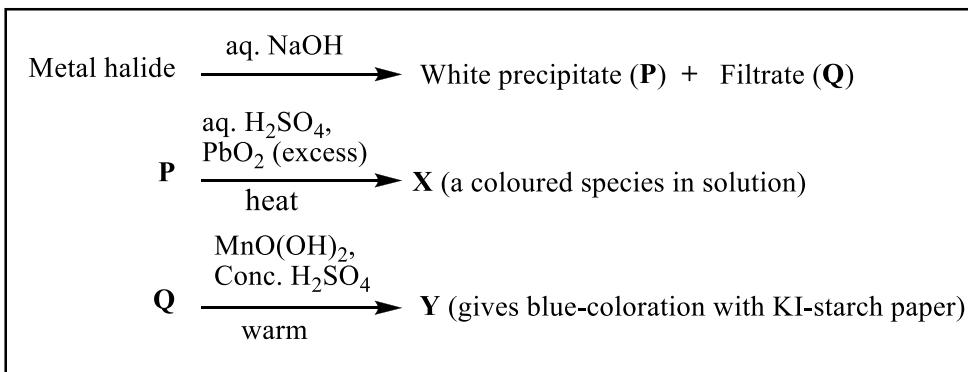


(D)      **Q**            **R**            **S**

**SECTION 2 (Maximum Marks: 12)**

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
  - Full Marks** : +3 If **ONLY** the correct option is chosen;
  - Zero Marks** : 0 If none of the options is chosen (i.e. the question is unanswered);
  - Negative Marks** : -1 In all other cases.

Q.4 In the scheme given below, **X** and **Y**, respectively, are



- (A)  $\text{CrO}_4^{2-}$  and  $\text{Br}_2$   
 (B)  $\text{MnO}_4^{2-}$  and  $\text{Cl}_2$   
 (C)  $\text{MnO}_4^-$  and  $\text{Cl}_2$   
 (D)  $\text{MnSO}_4$  and  $\text{HOCl}$

Q.5 Plotting  $1/\Lambda_m$  against  $c\Lambda_m$  for aqueous solutions of a monobasic weak acid (HX) resulted in a straight line with y-axis intercept of P and slope of S. The ratio P/S is

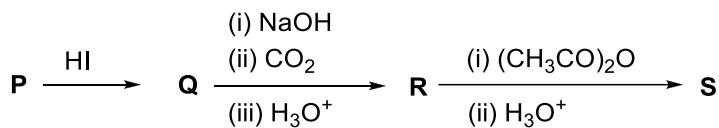
[ $\Lambda_m$  = molar conductivity  
 $\Lambda_m^0$  = limiting molar conductivity  
 $c$  = molar concentration  
 $K_a$  = dissociation constant of HX]

- (A)  $K_a \Lambda_m^0$   
 (B)  $K_a \Lambda_m^0/2$   
 (C)  $2 K_a \Lambda_m^0$   
 (D)  $1 / (K_a \Lambda_m^0)$

Q.6 On decreasing the *pH* from 7 to 2, the solubility of a sparingly soluble salt (MX) of a weak acid (HX) increased from  $10^{-4}$  mol L<sup>-1</sup> to  $10^{-3}$  mol L<sup>-1</sup>. The *pK<sub>a</sub>* of HX is

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

Q.7 In the given reaction scheme, **P** is a phenyl alkyl ether, **Q** is an aromatic compound; **R** and **S** are the major products.



The correct statement about **S** is

- (A) It primarily inhibits noradrenaline degrading enzymes.
- (B) It inhibits the synthesis of prostaglandin.
- (C) It is a narcotic drug.
- (D) It is *ortho*-acetylbenzoic acid.

**SECTION 3 (Maximum Marks: 24)**

- This section contains **SIX (06)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +4 If **ONLY** the correct integer is entered;  
*Zero Marks* : 0 In all other cases.

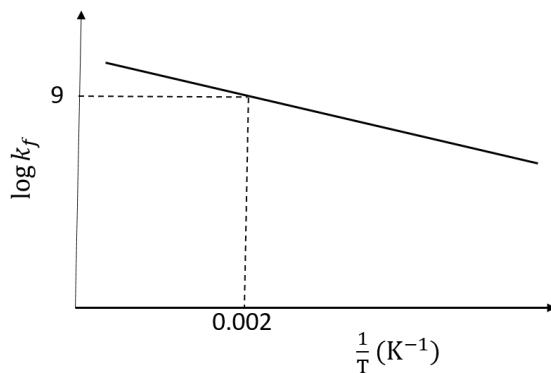
Q.8 The stoichiometric reaction of 516 g of dimethyldichlorosilane with water results in a tetrameric cyclic product **X** in 75% yield. The weight (in g) of **X** obtained is \_\_\_\_.

[Use, molar mass (g mol<sup>-1</sup>): H = 1, C = 12, O = 16, Si = 28, Cl = 35.5]

Q.9 A gas has a compressibility factor of 0.5 and a molar volume of 0.4 dm<sup>3</sup> mol<sup>-1</sup> at a temperature of 800 K and pressure **x** atm. If it shows ideal gas behaviour at the same temperature and pressure, the molar volume will be **y** dm<sup>3</sup> mol<sup>-1</sup>. The value of **x/y** is \_\_\_\_.

[Use: Gas constant, R = 8 × 10<sup>-2</sup> L atm K<sup>-1</sup> mol<sup>-1</sup>]

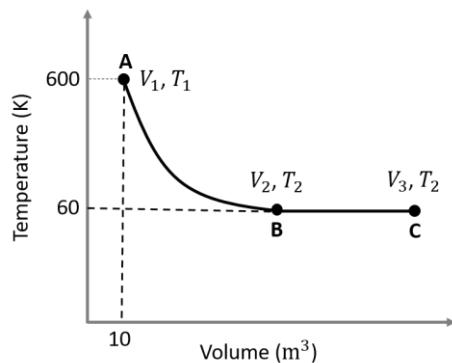
- Q.10 The plot of  $\log k_f$  versus  $1/T$  for a reversible reaction  $A(g) \rightleftharpoons P(g)$  is shown.



Pre-exponential factors for the forward and backward reactions are  $10^{15} \text{ s}^{-1}$  and  $10^{11} \text{ s}^{-1}$ , respectively. If the value of  $\log K$  for the reaction at 500 K is 6, the value of  $|\log k_b|$  at 250 K is \_\_\_\_.

[ $K$  = equilibrium constant of the reaction  
 $k_f$  = rate constant of forward reaction  
 $k_b$  = rate constant of backward reaction]

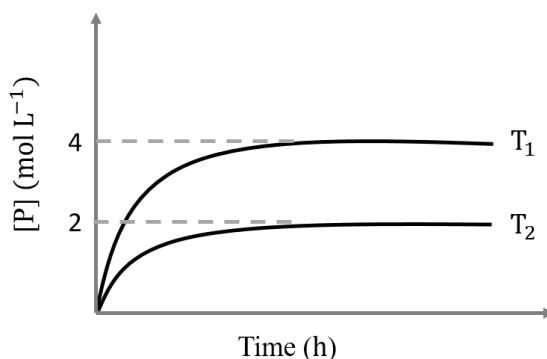
- Q.11 One mole of an ideal monoatomic gas undergoes two reversible processes (A  $\rightarrow$  B and B  $\rightarrow$  C) as shown in the given figure:



A  $\rightarrow$  B is an adiabatic process. If the total heat absorbed in the entire process (A  $\rightarrow$  B and B  $\rightarrow$  C) is  $RT_2 \ln 10$ , the value of  $2 \log V_3$  is \_\_\_\_.

[Use, molar heat capacity of the gas at constant pressure,  $C_{p,m} = \frac{5}{2} R$ ]

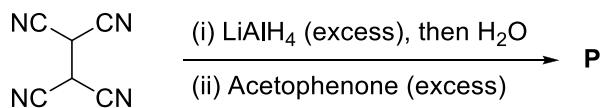
- Q.12 In a one-litre flask, 6 moles of A undergoes the reaction  $A(g) \rightleftharpoons P(g)$ . The progress of product formation at two temperatures (in Kelvin),  $T_1$  and  $T_2$ , is shown in the figure:



If  $T_1 = 2T_2$  and  $(\Delta G_2^\ominus - \Delta G_1^\ominus) = RT_2 \ln x$ , then the value of  $x$  is \_\_\_\_.

[ $\Delta G_1^\ominus$  and  $\Delta G_2^\ominus$  are standard Gibb's free energy change for the reaction at temperatures  $T_1$  and  $T_2$ , respectively.]

- Q.13 The total number of  $sp^2$  hybridised carbon atoms in the major product **P** (a non-heterocyclic compound) of the following reaction is \_\_\_\_.



**SECTION 4 (Maximum Marks: 12)**

- This section contains **FOUR (04)** Matching List Sets.
  - Each set has **ONE** Multiple Choice Question.
  - Each set has **TWO** lists: **List-I** and **List-II**.
  - **List-I** has **Four** entries (P), (Q), (R) and (S) and **List-II** has **Five** entries (1), (2), (3), (4) and (5).
  - **FOUR** options are given in each Multiple Choice Question based on **List-I** and **List-II** and **ONLY ONE** of these four options satisfies the condition asked in the Multiple Choice Question.
  - Answer to each question will be evaluated according to the following marking scheme:
- Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

Q.14 Match the reactions (in the given stoichiometry of the reactants) in List-I with one of their products given in List-II and choose the correct option.

**List-I**

- (P)  $\text{P}_2\text{O}_3 + 3\text{H}_2\text{O} \rightarrow$   
 (Q)  $\text{P}_4 + 3\text{NaOH} + 3\text{H}_2\text{O} \rightarrow$   
 (R)  $\text{PCl}_5 + \text{CH}_3\text{COOH} \rightarrow$   
 (S)  $\text{H}_3\text{PO}_2 + 2\text{H}_2\text{O} + 4\text{AgNO}_3 \rightarrow$

**List-II**

- (1)  $\text{P}(\text{O})(\text{OCH}_3)\text{Cl}_2$   
 (2)  $\text{H}_3\text{PO}_3$   
 (3)  $\text{PH}_3$   
 (4)  $\text{POCl}_3$   
 (5)  $\text{H}_3\text{PO}_4$

- (A) P → 2; Q → 3; R → 1; S → 5  
 (B) P → 3; Q → 5; R → 4; S → 2  
 (C) P → 5; Q → 2; R → 1; S → 3  
 (D) P → 2; Q → 3; R → 4; S → 5

**Q.15** Match the electronic configurations in List-I with appropriate metal complex ions in List-II and choose the correct option.

[Atomic Number: Fe = 26, Mn = 25, Co = 27]

**List-I**

- (P)  $t_{2g}^6 e_g^0$
- (Q)  $t_{2g}^3 e_g^2$
- (R)  $e^2 t_2^3$
- (S)  $t_{2g}^4 e_g^2$

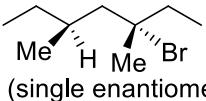
**List-II**

- (1)  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
- (2)  $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$
- (3)  $[\text{Co}(\text{NH}_3)_6]^{3+}$
- (4)  $[\text{FeCl}_4]^-$
- (5)  $[\text{CoCl}_4]^{2-}$

- (A) P  $\rightarrow$  1; Q  $\rightarrow$  4; R  $\rightarrow$  2; S  $\rightarrow$  3
- (B) P  $\rightarrow$  1; Q  $\rightarrow$  2; R  $\rightarrow$  4; S  $\rightarrow$  5
- (C) P  $\rightarrow$  3; Q  $\rightarrow$  2; R  $\rightarrow$  5; S  $\rightarrow$  1
- (D) P  $\rightarrow$  3; Q  $\rightarrow$  2; R  $\rightarrow$  4; S  $\rightarrow$  1

**Q.16** Match the reactions in List-I with the features of their products in List-II and choose the correct option.

**List-I**

- (P) (-)-1-Bromo-2-ethylpentane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}2 \text{ reaction}]{\text{aq. NaOH}}$
- (Q) (-)-2-Bromopentane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}2 \text{ reaction}]{\text{aq. NaOH}}$
- (R) (-)-3-Bromo-3-methylhexane  
(single enantiomer)  $\xrightarrow[\text{S}_{\text{N}}1 \text{ reaction}]{\text{aq. NaOH}}$
- (S)   $\xrightarrow[\text{S}_{\text{N}}1 \text{ reaction}]{\text{aq. NaOH}}$

**List-II**

- (1) Inversion of configuration
- (2) Retention of configuration
- (3) Mixture of enantiomers
- (4) Mixture of structural isomers
- (5) Mixture of diastereomers

- (A) P  $\rightarrow$  1; Q  $\rightarrow$  2; R  $\rightarrow$  5; S  $\rightarrow$  3
- (B) P  $\rightarrow$  2; Q  $\rightarrow$  1; R  $\rightarrow$  3; S  $\rightarrow$  5
- (C) P  $\rightarrow$  1; Q  $\rightarrow$  2; R  $\rightarrow$  5; S  $\rightarrow$  4
- (D) P  $\rightarrow$  2; Q  $\rightarrow$  4; R  $\rightarrow$  3; S  $\rightarrow$  5

**Q.17** The major products obtained from the reactions in List-II are the reactants for the named reactions mentioned in List-I. Match List-I with List-II and choose the correct option.

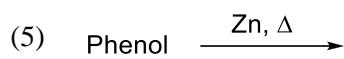
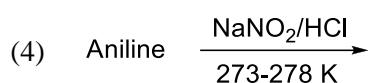
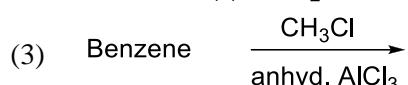
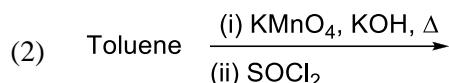
**List-I**

(P) Etard reaction

(Q) Gattermann reaction

(R) Gattermann-Koch reaction

(S) Rosenmund reduction

**List-II**

- (A) P → 2; Q → 4; R → 1; S → 3  
 (B) P → 1; Q → 3; R → 5; S → 2  
 (C) P → 3; Q → 2; R → 1; S → 4  
 (D) P → 3; Q → 4; R → 5; S → 2

**END OF THE QUESTION PAPER**

Common Entrance Examination for Design

# **CEED 2019**

## **Question Paper**



Indian Institute of Technology Bombay

## **INSTRUCTIONS**

1. The total duration of the examination is 3 hours. The question paper contains two parts - Part A and Part B. The duration of Part A is one hour. The duration of Part B is two hours. Part B will start only after Part A ends. Part A cannot be attempted after Part B commences.
2. Questions of Part A and Part B will appear on the computer. Answers to **Part A** have to be entered in the **computer**. Answers to **Part B** have to be given in the **answer booklet** provided by the invigilator.
3. Part A carries a total of 100 marks. It contains 3 sections. The following table summarises the number of questions in each section, type of questions, marks for correct answers, marks for wrong answers, marks for questions not attempted and total marks for the section:

<b>Part A Section</b>	<b>Type of questions</b>	<b>Number of questions</b>	<b>Marks for each correct answer</b>	<b>Marks for each wrong answer</b>	<b>Marks for each question not attempted</b>	<b>Total marks for the section</b>
I	Numerical Answer Type (NAT)	10	3	0	0	30
II	Multiple Select Question (MSQ)	10	2	0	0	20
III	Multiple Choice Question (MCQ)	25	2	-0.6	0	50

4. For each NAT question, the answer is a **real number with decimal digits up to two decimal places**. The answer needs to be entered using the virtual keyboard on the monitor. No choices will be shown for these questions. There is no negative or partial marking for NAT questions.
5. Each MSQ has four choices of which **one or more** is/are the correct answer(s). The marks will be awarded only if **all the correct choices** are selected. There is no negative or partial marking for MSQs.
6. Each MCQ has four choices of which **only one** is the correct answer. In MCQs, the correct answer will be awarded **2 marks** and wrong answer will be awarded **-0.6 marks**. Questions not attempted will be awarded zero marks.
7. Scribble pads will be provided for rough work for Part A. These have to be returned to the invigilator at the **end of the Part A exam**.
8. Part B carries a total of 100 marks. It contains 8 questions. You may choose to answer any ONE of Questions 1, 2, 3, 4 and 5. Questions 6, 7 and 8 are mandatory. Each question must be answered on the page(s) designated for that question in the answer booklet. Additional instructions to Part B questions are provided in the answer booklet.
9. In Part B, colour pencils, crayons, sketch pens etc. may be used unless otherwise specified in the questions.
10. Charts, graph sheets, mathematical tables, calculators, mobile phones, and other electronic gadgets are not allowed in the examination hall.

## **Part A – Section I: Numerical Answer Type Questions**

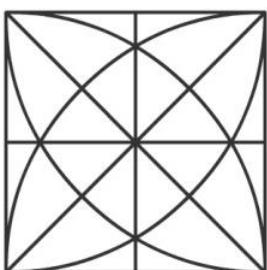
**Q.01** All the four-digit numbers except one is written using a single font. Identify the number that does not use the same font as the other numbers.

5116	4458	1379	5897
5758	4859	7565	8597
3261	9365	6535	5786
8637	1785	7388	2440
9116	1914	7451	1947

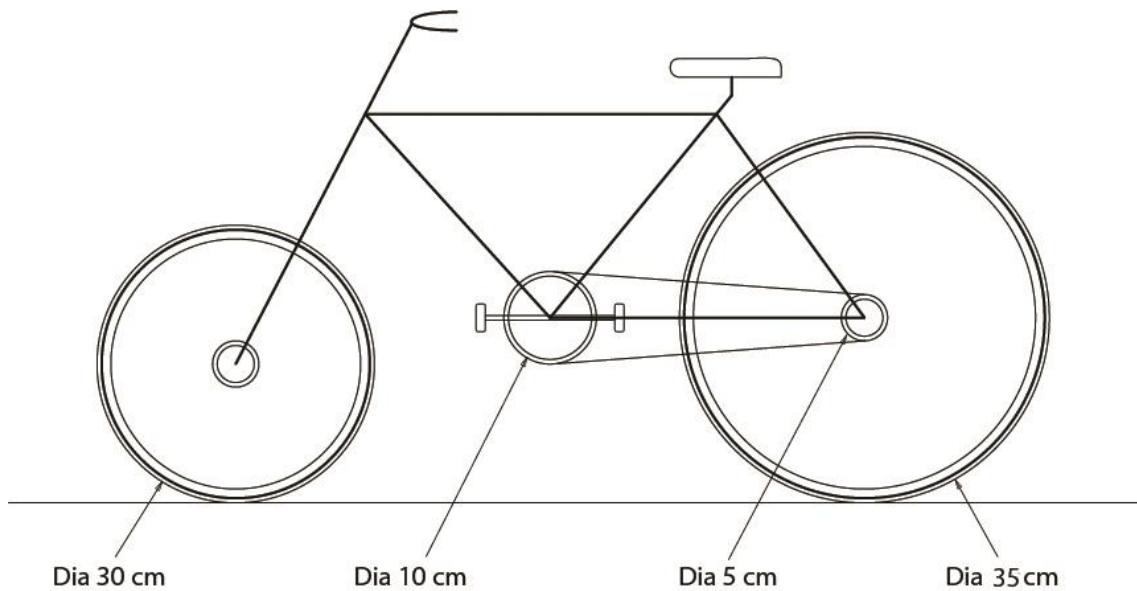
**Q.02** Find the number which will replace the question mark.

2	4	5
1	3	3
5	4	8
1	1	1
3	4	6
2	3	4
5	3	7
4	4	?

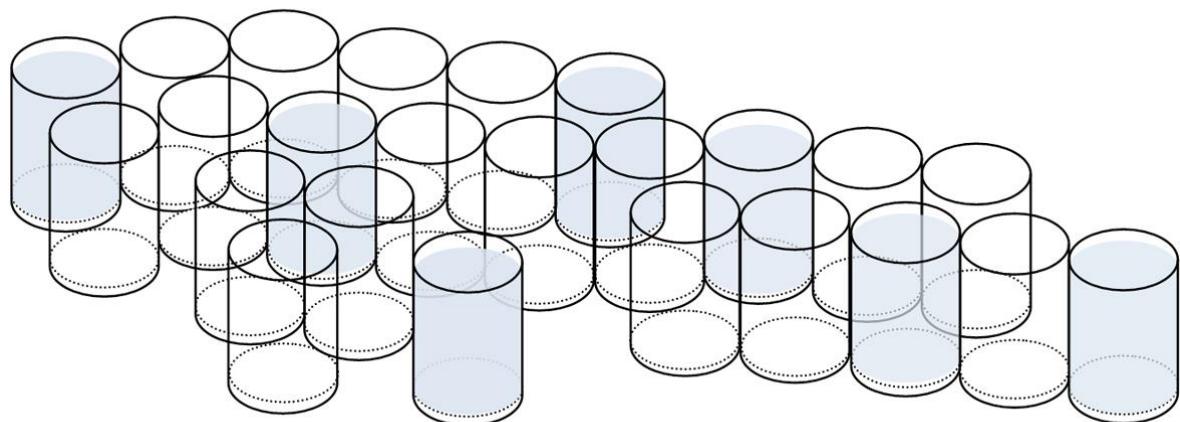
**Q.03** An intersection is a point where two or more lines/curves meet or cross. How many intersections are there in the figure given below?



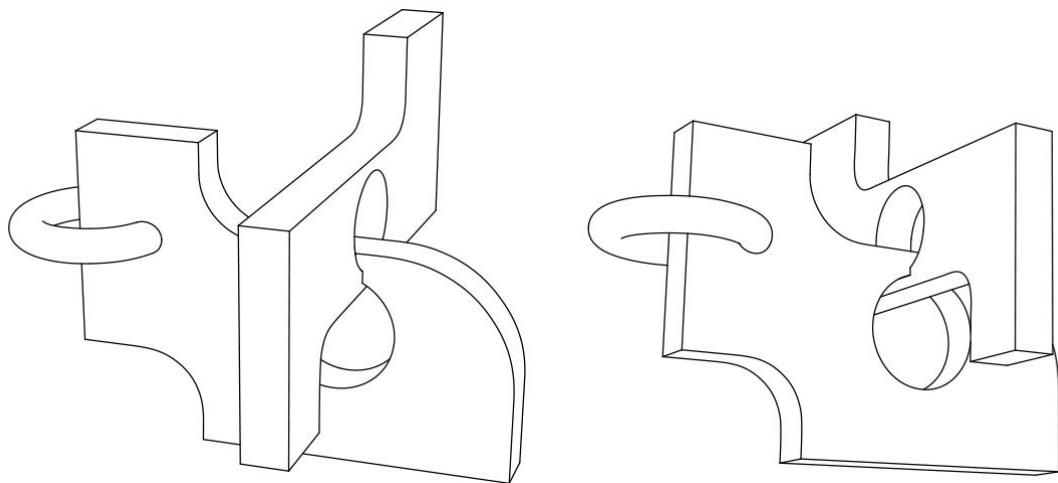
**Q.04** How much distance (in cm) will the bicycle shown below travel, if the pedal makes 1.5 revolutions? (Assume  $\pi = 22/7$ ).



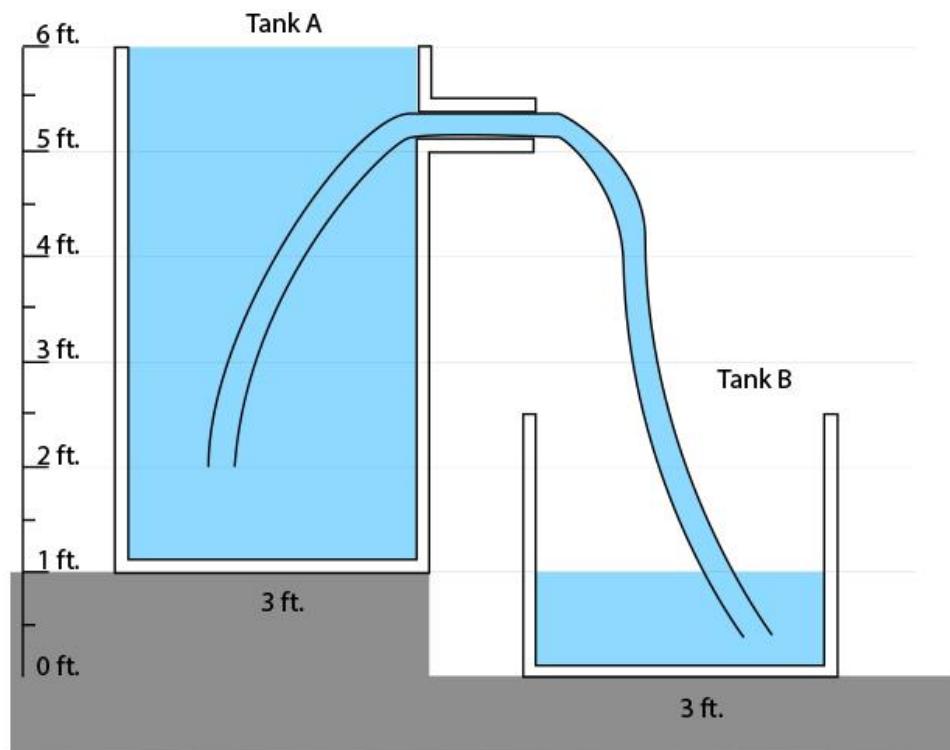
**Q.05** How many glasses will remain empty if you half-fill some of the empty glasses, from the given set of filled glasses?



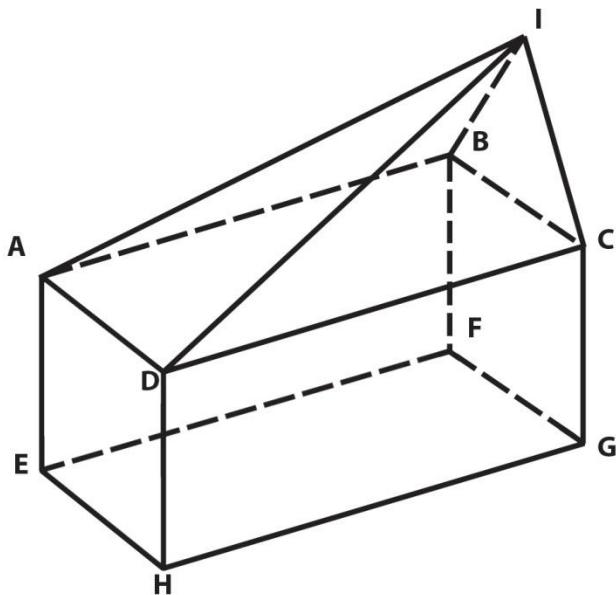
**Q.06** Two perspective views of the same solid object are shown below. How many surfaces does the object contain? Assume hidden surfaces to be flat.



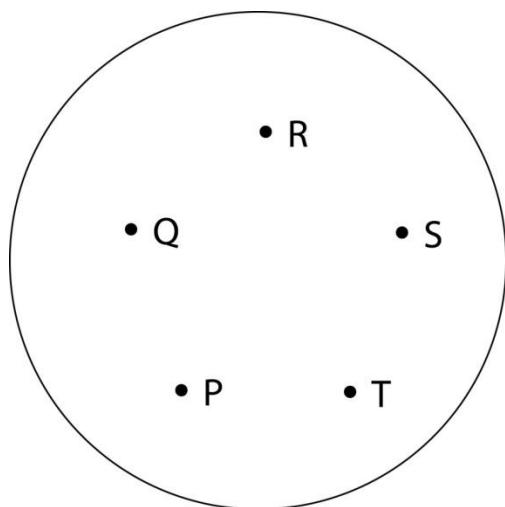
**Q.07** Two water tanks A and B of equal square base of sides 3 feet are shown below. Water flows from tank A to tank B through a tube. What will be the volume (in cubic feet) of water in Tank A when the water stops flowing?



**Q.08** A solid is shown in the figure below. The vertices ABCDEFGH form a  $4\text{ cm} \times 2\text{ cm} \times 2\text{ cm}$  cuboid. The segments AI and DI are both of length 5 cm, and points ICGFB are coplanar. What is the height (in cm) of point I from the base rectangle EFGH?



**Q.09** The figure shows the front view of a convex lens, which originally had only one edge. Five holes of different shapes, namely triangle, square, pentagon, hexagon and circle, were drilled through it at points P, Q, R, S and T in such a way that the holes were parallel to each other, perpendicular to the edge and all the holes were still within the lens edge. What is the total number of edges in the lens after the holes were drilled?



**Q.10** In terms of calories, 20 jamuns and 3 bananas combined are equivalent to one mango and one papaya combined, and 2 mangoes and 5 bananas combined are equivalent to 4 papayas and 80 jamuns combined. Then 8 papayas and 2 mangoes are equivalent to how many bananas?

## **Part A – Section II: Multiple Select Questions**

**Q.11** A designer has designed a logo. The form is shown on the left and its accompanying text is shown on the right. Which of the following statements about this logo is/are TRUE?



**Adgula**  
**अडगुल**

- A. If this logo is printed on an envelope with a 60 DPI dot-matrix printer, such that the total height of the logo is 2 cm, then the logo will retain its original form.
- B. If this logo is printed on a flex sheet with a 720 DPI flex printer such that the total height of the logo is 15 ft, then the logo will retain its original form.
- C. This logo can be reproduced as shown above by using a four colour screen printing process.
- D. The visual properties of the English font match the visual properties of the Hindi font.

**Q.12** Image P shows a portion of a larger photograph. Some operations have been done on that photograph using an image manipulation software. Image Q shows a portion of the resulting photograph. Identify the option(s) that specifies/specify the correct operations.



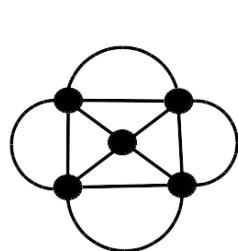
P



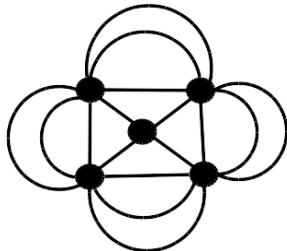
Q

- A. Rotate clockwise by 45 degrees, flip horizontally, then rotate clockwise by 90 degrees
- B. Rotate clockwise by 135 degrees, flip horizontally
- C. Rotate clockwise by 135 degrees, flip vertically
- D. Rotate clockwise by 90 degrees, flip horizontally, then rotate clockwise by 45 degrees

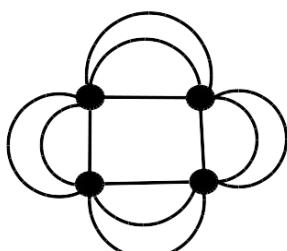
**Q.13** If you are asked to draw the following four figures with the following constraints: They must be drawn in a single stroke (without lifting the pen from paper), and each line is drawn only once. Which of the options can be drawn?



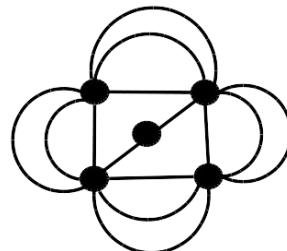
**A**



**B**

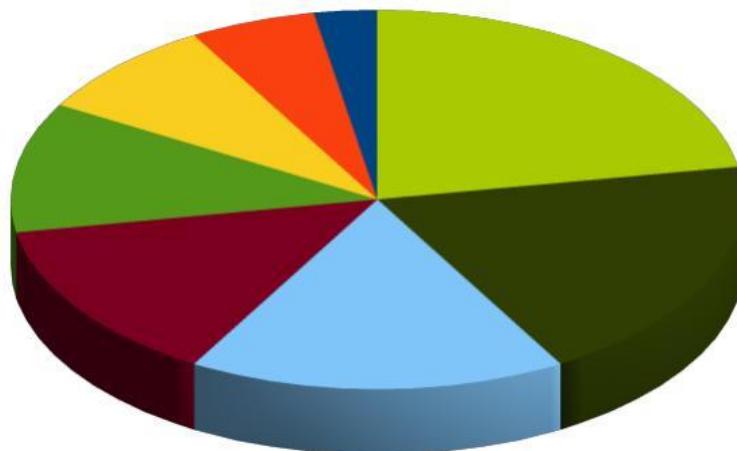


**C**



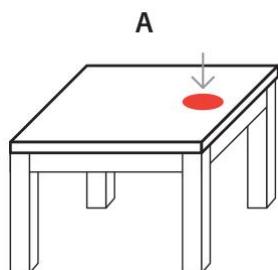
**D**

**Q.14** The pie chart shows proportions of income tax paid by a population of eight individuals. Each individual's tax share is shown in a different slice of the pie. Which of the statements can be derived from the chart shown below?

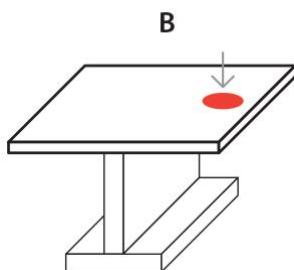


- A. About half the total tax is paid by less than half of the population.
- B. About half the total tax is paid by more than half of the population.
- C. About three-fourth of the tax is paid by three-fourth of the population.
- D. Some individuals paid more than double the taxes as compared to some others.

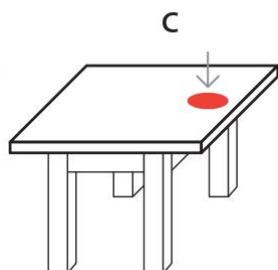
**Q.15** Four square table-tops of the same dimensions are shown below. Only the designs of their supports are different from each other. If a person stands upright on the red mark on each of the table, which of the tables will topple?



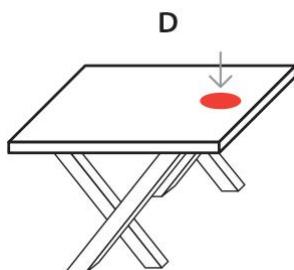
**A**



**B**

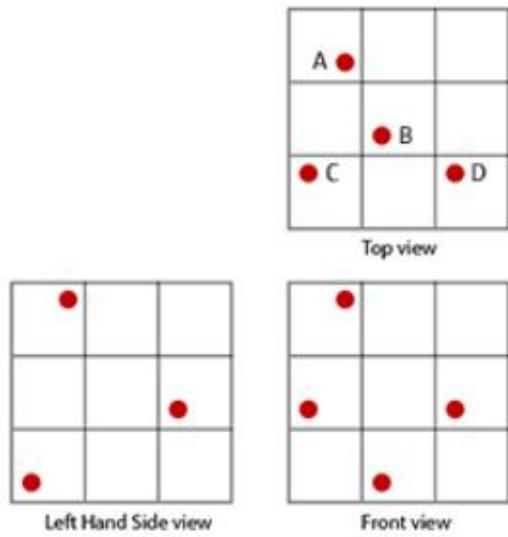


**C**

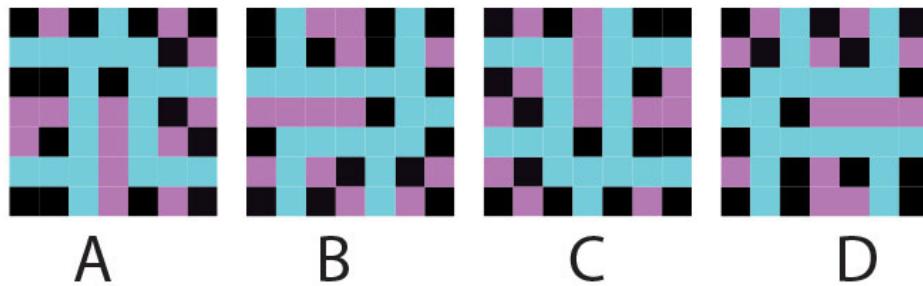


**D**

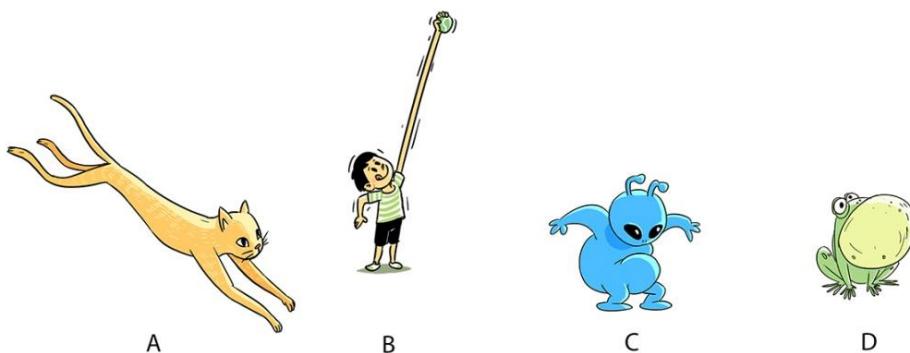
**Q.16** A glass cube with 27 equal compartments is filled with water. There are a few red balls floating inside the compartments. Three views of the cube are shown below. Identify the red ball(s) that is/are represented incorrectly in the top view.



**Q.17** Which of the options is/are simple rotations of the figure given below?



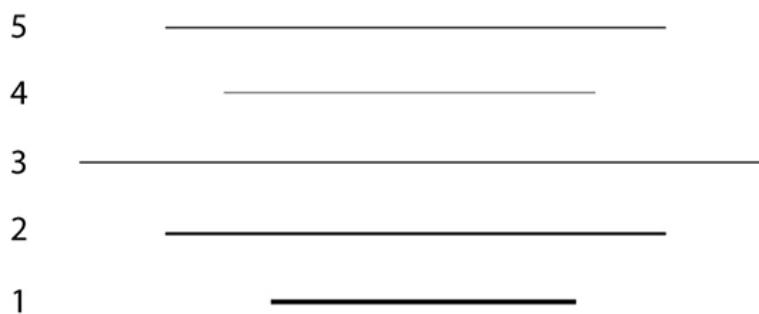
**Q.18** Which of the following drawings illustrate(s) the use of the animation principle of “Squash and Stretch”?



**Q.19** Monitors with different resolutions can be attached to a computer. The computer can also render a video at various resolutions. Assuming that the videos are played at 1:1 resolution, which of the following options is/are TRUE?

- A. Given a video, a monitor with a higher resolution will display it in a smaller size than a monitor with lower resolution.
- B. Given a video, a monitor with a higher resolution will display it in a bigger size than a monitor with lower resolution.
- C. Given a monitor, a video with higher resolution will be visible in a smaller size than a video with a lower resolution.
- D. Given a monitor, a video with higher resolution will be visible in a bigger size than a video with a lower resolution.

**Q.20** If all the lines in the image below are of the same length but of different thickness and are drawn in perspective with respect to their distance from the viewer, which of the following statements will be TRUE?



- A. Line 1 is the thickest line of all
- B. Four lines are of same thickness
- C. Line 2 and line 3 have same thickness
- D. Line 3 is the closest line of all to the viewer

## **Part A – Section III: Multiple Choice Questions**

**Q.21** Identify the correct font used for Parle-G biscuits.

**Parle-G**

A

**Parle-G**

B

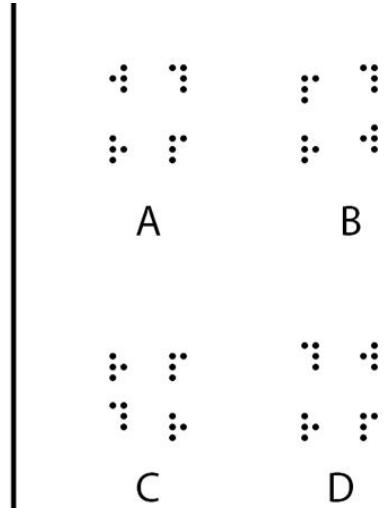
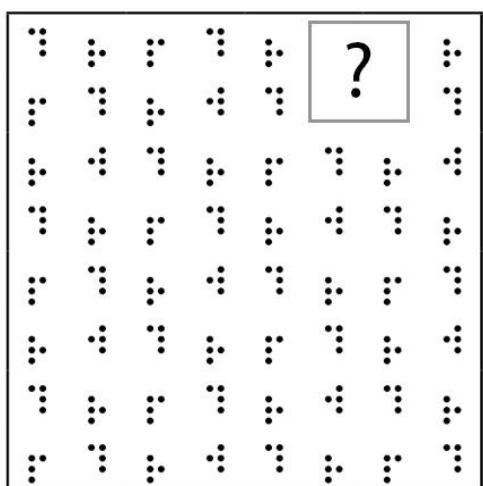
**Parle-G**

C

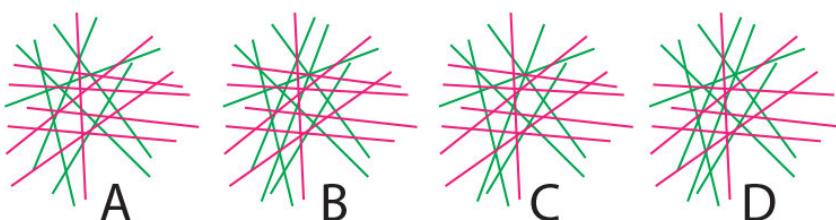
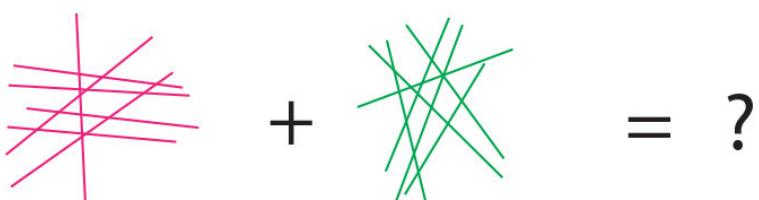
**Parle-G**

D

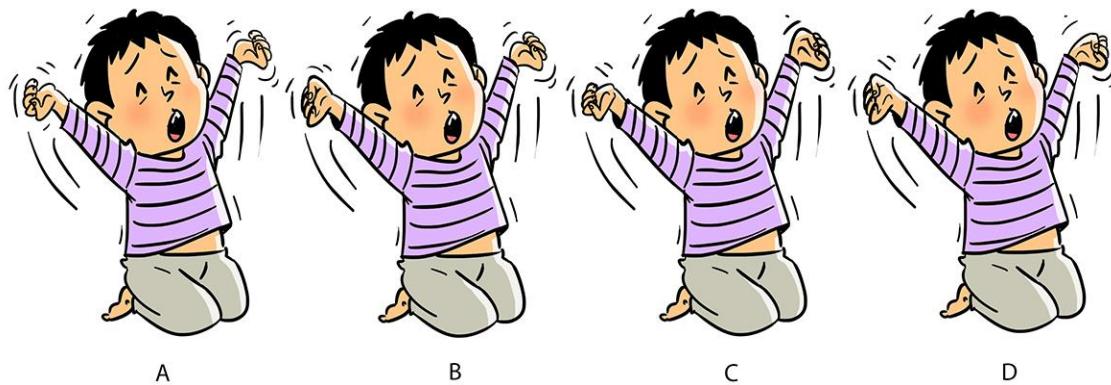
**Q.22** Identify the option that will replace the question mark.



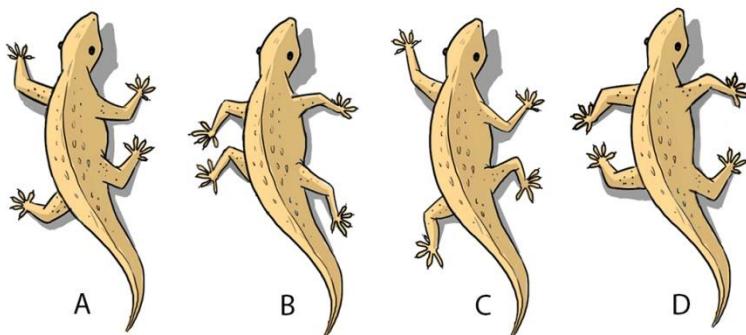
**Q.23** Identify the option that will replace the question mark.



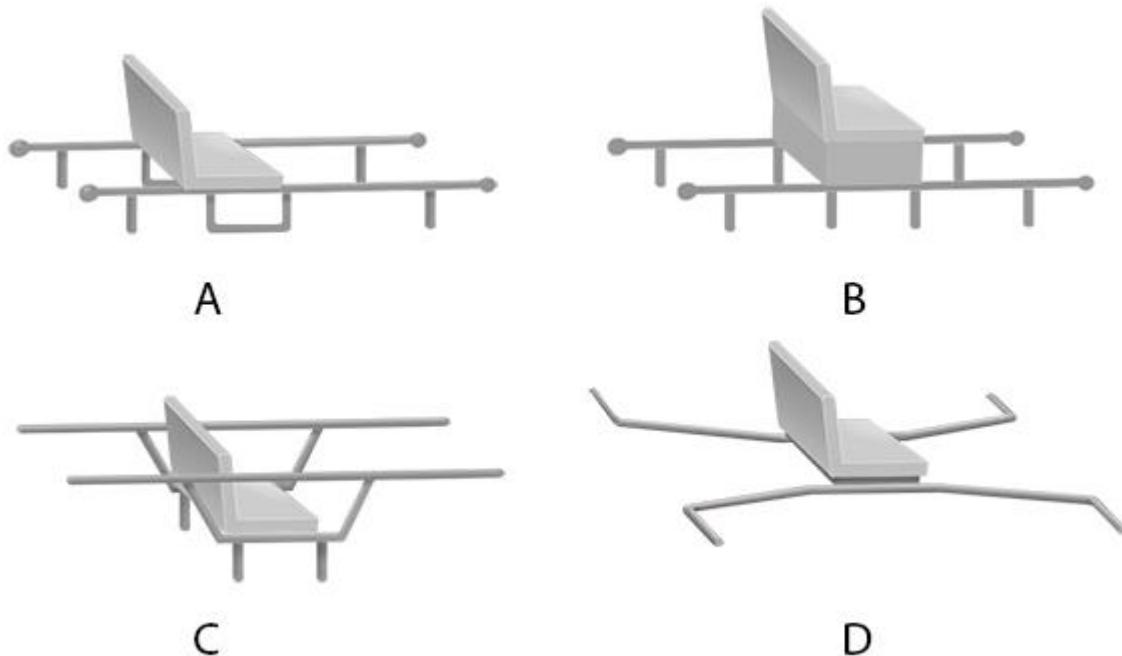
**Q.24** Shahid is feeling very sleepy. He yawns and stretches. Identify the correct image.



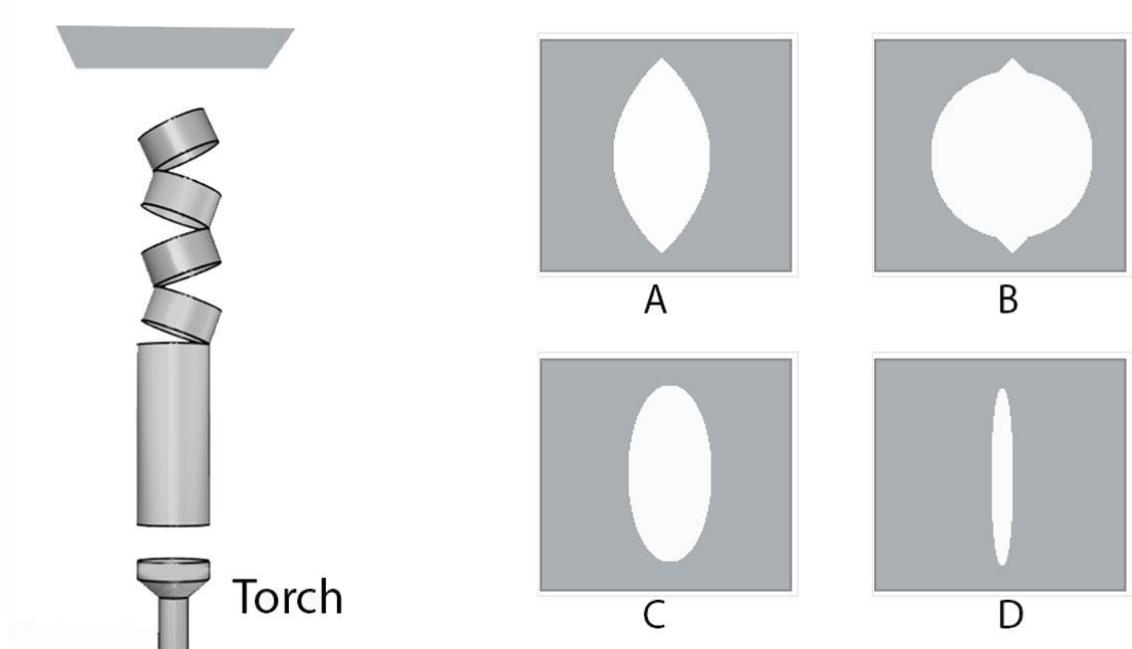
**Q.25** Which is the correct representation of the posture of a house lizard as it climbs a wall?



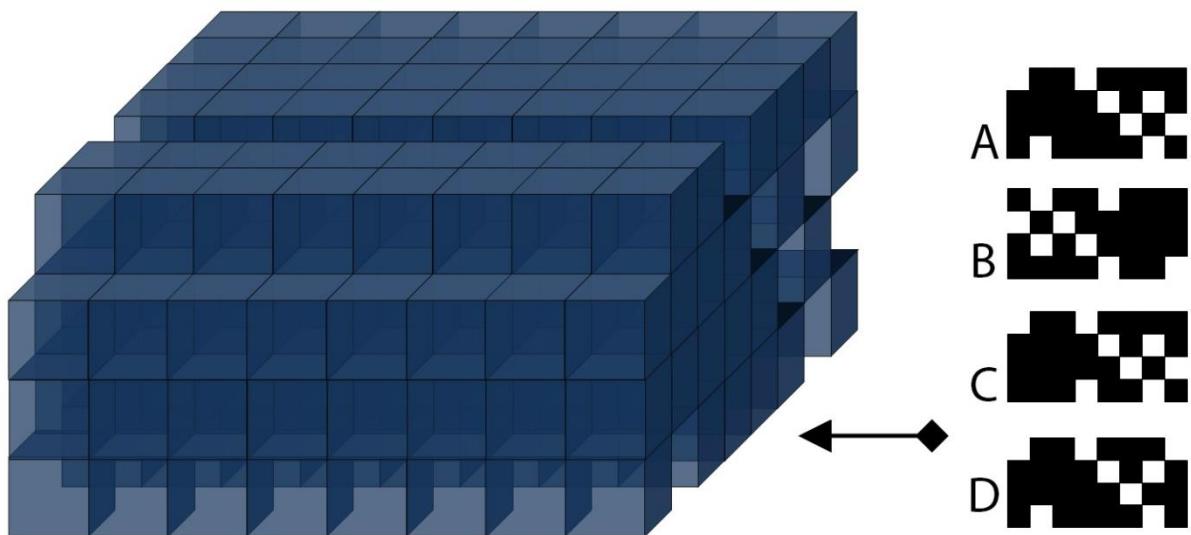
**Q.26** Which of the given configurations of *Palki* (Pallanquin) will work the best for the traveller as well as for the labourers carrying the traveller?



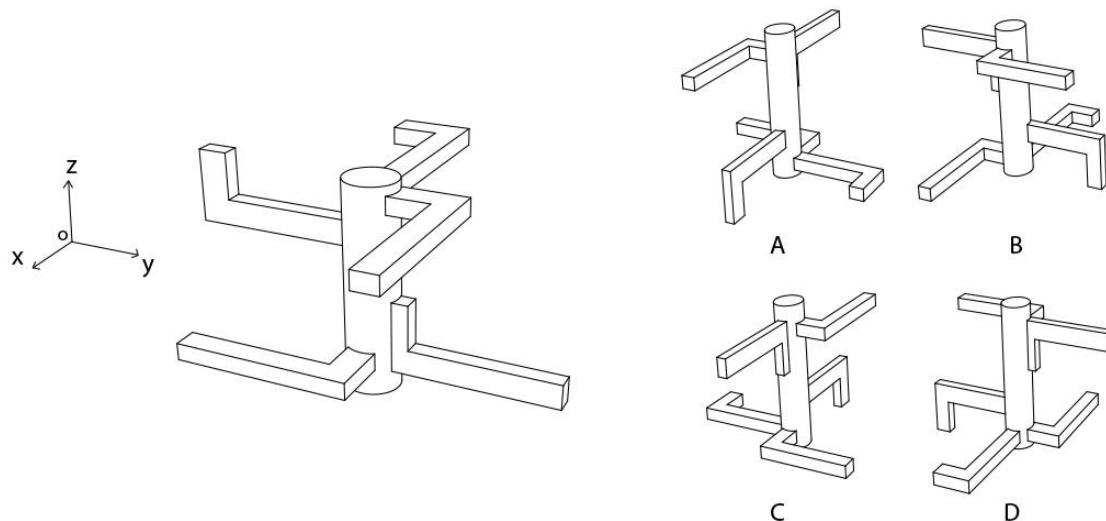
**Q.27** A hollow circular pipe with non-reflective inner surface is cut into 5 pieces and arranged as shown in the figure below. If it is illuminated from below using a torch as shown in the figure, what would be the profile of the light falling on the sheet kept above?



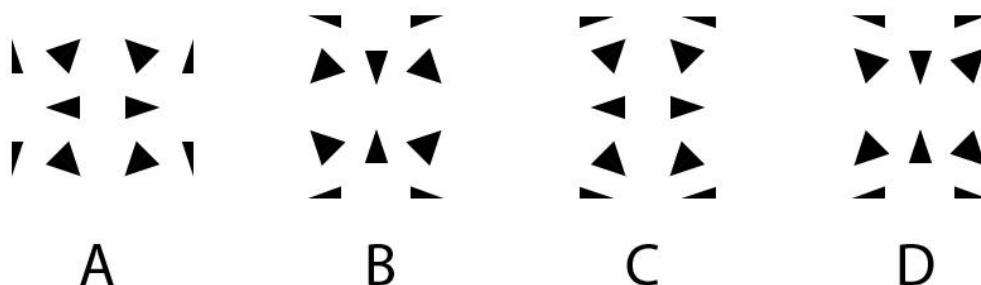
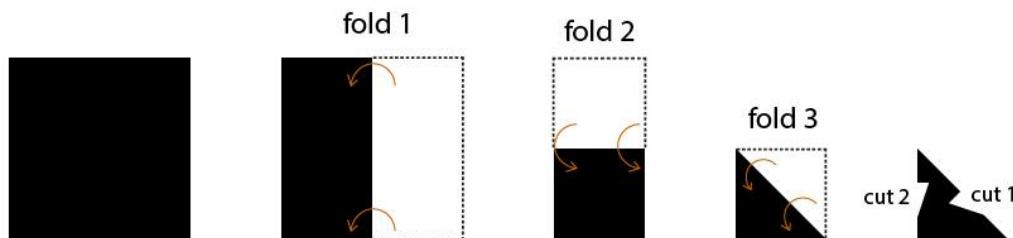
**Q.28** From a 3-dimensional structure made of cubes, eight rows of cubes have been removed as shown below. Select the correct pattern that will emerge from the side shown with an arrow.



**Q.29** Perspective view of an object is shown below. The object is rotated 90 degrees anticlockwise about z-axis (when viewed from a point on the positive z-axis towards the origin) and then rotated 180 degrees about x-axis (when viewed from a point on the positive x-axis towards the origin). Which one of the following perspective view options will be the result of the rotations?



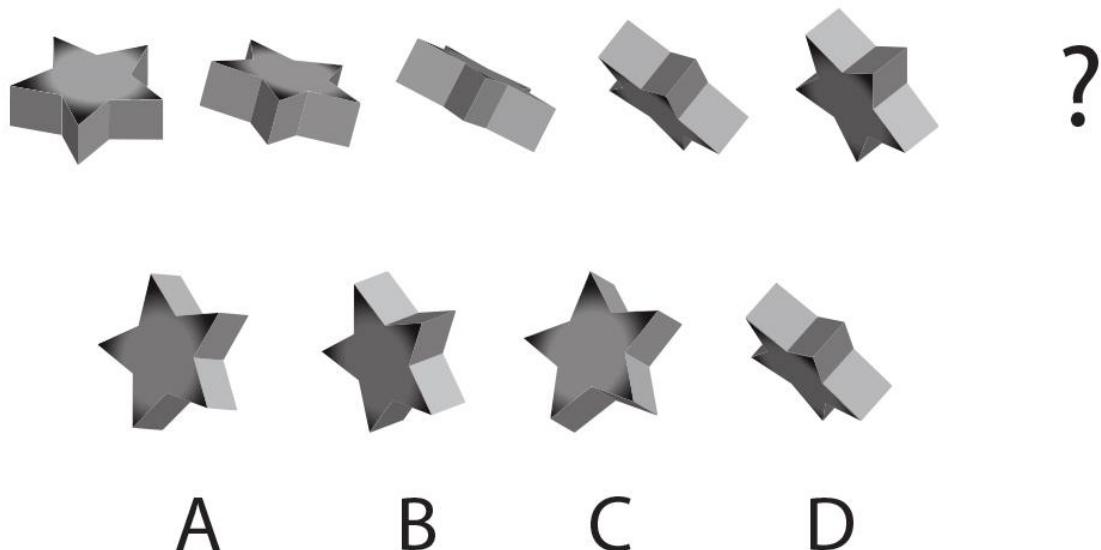
**Q.30** A square paper is folded and cut as shown below. The paper is then used as a template to spray-paint a white wall with black paint. Which pattern would be created using this template?



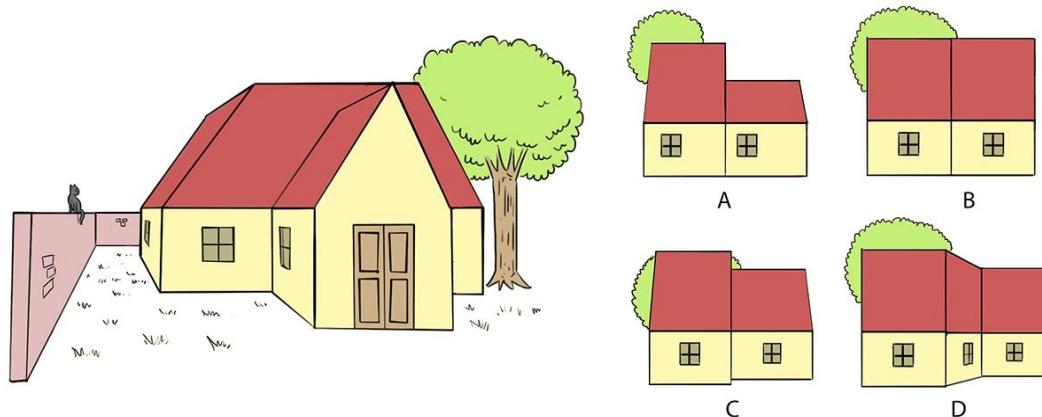
**Q.31** In a camera, the opening through which light enters the camera is called aperture. The distance between the closest and the farthest part of a view captured on a photograph, which is in focus, is called depth of field. Given that all other settings remain the same, which of the following is TRUE?

- The larger the aperture, the larger the depth of field
- The smaller the aperture, the larger the depth of field
- The depth of field is not affected by the aperture size
- Larger the aperture, the larger the image captured

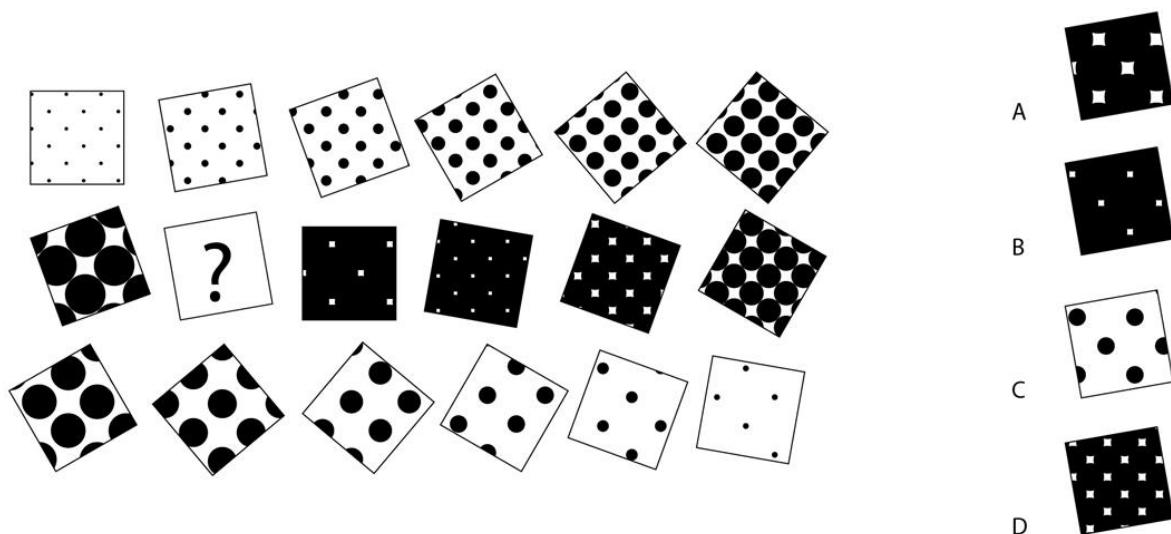
**Q.32** Identify the option that will replace the question mark.



**Q.33** A cat is sitting on a wall on the left side of a house. Identify the correct option that shows the cat's point of view as it looks at the house?



**Q.34** Identify the option that will replace the question mark.



**Q.35** Images of traditional products of certain states of India are shown below. Identify the correct set of states to which these belong. Names of the states are in a random sequence. The products are made out of clay, willow/wicker, wood and brass.



- A. Maharashtra, Nagaland, Jammu & Kashmir, Chhattisgarh
- B. Nagaland, Jammu & Kashmir, Chhattisgarh, Andhra Pradesh
- C. Jammu & Kashmir, Kerala, Andhra Pradesh, Haryana
- D. Maharashtra, Kerala, Andhra Pradesh, Haryana

**Q.36** Refer to the following image of a wooden artefact made using traditional manual tools, skills and processes. Identify the correct set of operations required to make it. The operations in the options are in a random order.



- A. Drilling, Chiselling, Casting, Cutting
- B. Chiselling, Milling, Punching, Forming
- C. Drilling, Chiselling, Cutting, Finishing
- D. Finishing, Sanding, Forming, Punching

**Q.37** Refer to the chairs shown below. Which of the following statements is TRUE?



P



Q



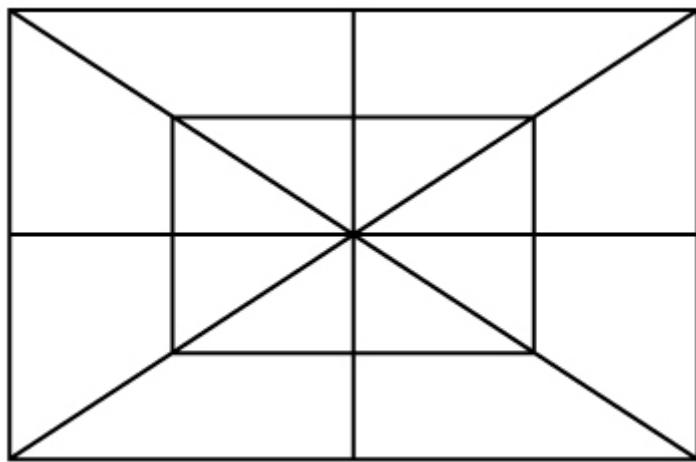
R



S

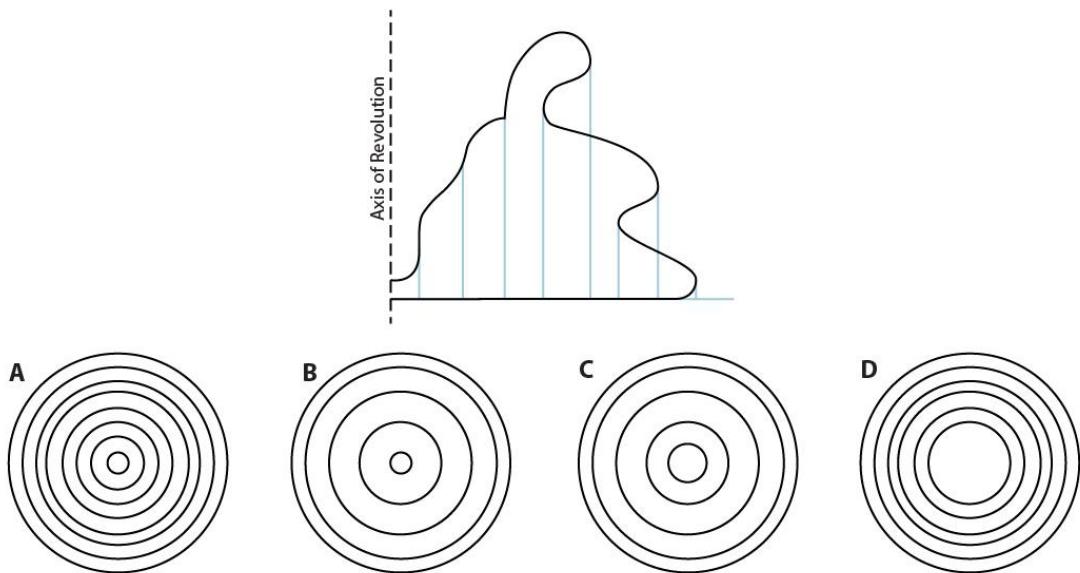
- A. R has deer elements, Q has bird elements, only P has human elements
- B. Only Q has bird elements, R has deer elements, only S and P have human elements
- C. Only Q and S have curved surfaces, Q has bird elements, only S has human elements
- D. R and S have animal elements , Q has bird, only P has human elements

**Q.38** How many right-angled triangles are there in the given image?

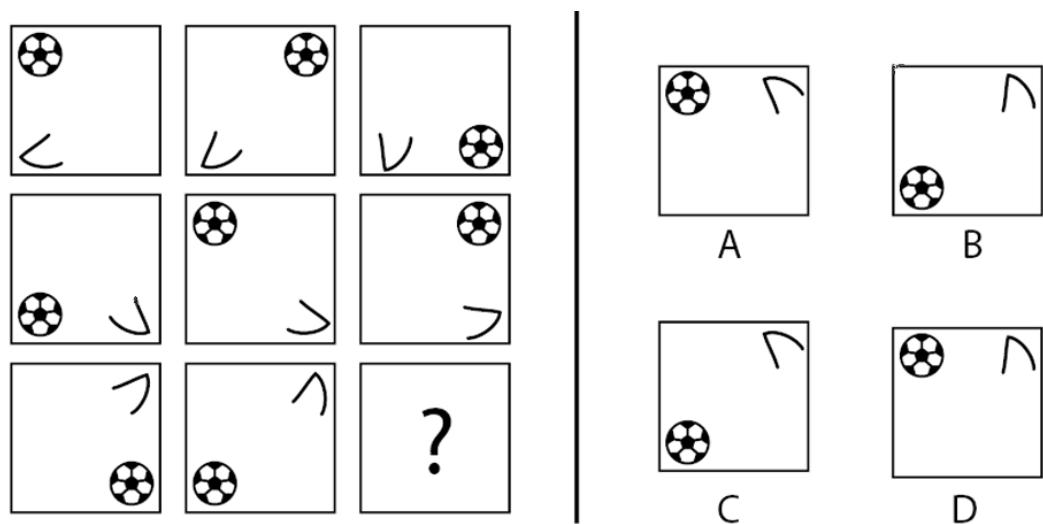


- A. 20
- B. 24
- C. 28
- D. 32

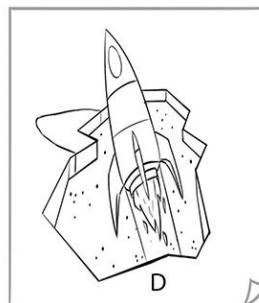
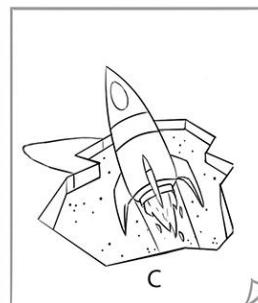
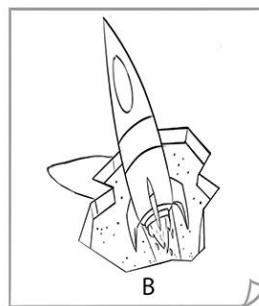
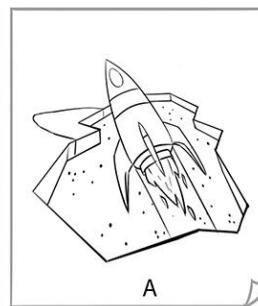
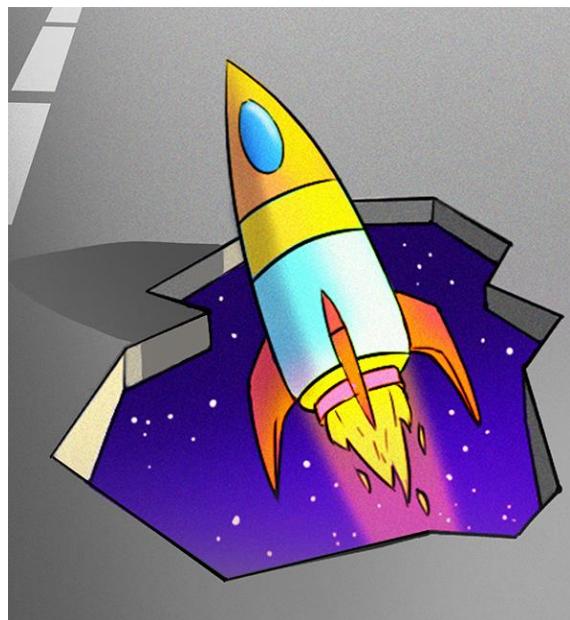
**Q.39** A solid created by rotating a planar-shape about an axis is called a “Surface of Revolution”. The figure below shows a shape and the axis of revolution which is used to create such a solid. Which of the options would be the correct top view of this solid?



**Q.40** Identify the option that will replace the question mark.



**Q.41** A 3D illusion painting is created on a road. Shown on the left is how it appears to a viewer in perspective. If this illusion has to be sketched on paper, before it is painted, which one of the options on the right would be correct?

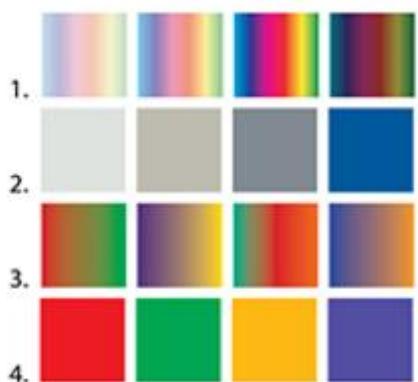


**Q.42** Fill in the blanks to keep the sentence grammatically correct as well as meaningful.

..... the facts, she proceeded with her decision, finally ending up with a ..... situation.

- A. Nevertheless, happy
- B. Apparently, initially
- C. However, noteworthy
- D. Notwithstanding, sad

**Q.43** Match the following.



P. Complementary

Q. Spectrum

R. Cool

S. Harmony

1Q, 2S, 3R, 4P

1Q, 2R, 3S, 4P

1R, 2P, 3Q, 4S

1P, 2R, 3S, 4Q

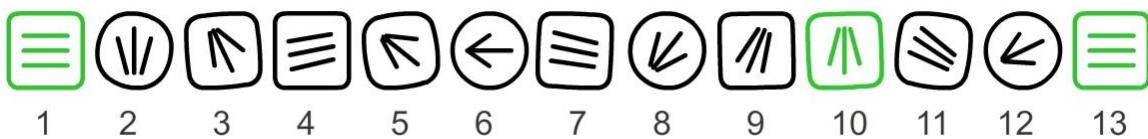
A

B

C

D

**Q.44** A micro-interaction has been designed for a ‘menu’ icon. On clicking this icon, it changes into a different icon representing ‘back’, depicted by an arrow. On another click it changes back to the menu icon. Shown below are 13 key-frames of this animation. Their order is incorrect, but the ones in green are in the correct position. Identify the correct order of this animation.



- A. 1, 7, 11, 2, 12, 8, 6, 3, 5, 10, 9, 4, 13
- B. 1, 4, 9, 3, 5, 6, 12, 8, 2, 10, 11, 7, 13
- C. 1, 7, 11, 2, 8, 12, 6, 5, 3, 10, 9, 4, 13
- D. 1, 4, 9, 3, 5, 6, 8, 12, 2, 10, 11, 7, 13

**Q.45** Imagine a possibility of an emergency evacuation scenario in a domestic household in India. The height at which the inside latch of the exit-door should be installed is to be finalised. It is required to disallow opening of the door accidentally by children. Which option will determine the height at which the latch should be fixed? Assume the height of the tallest child is lower than that of the shortest adult.

- A. The height of the tallest adult in the family.
- B. The height of the shortest adult in the family.
- C. The average height of the child in the family.
- D. The average height of the tallest adult male and tallest adult female.

## **Part B**

Answer **ANY ONE** question out of the question numbers 1, 2, 3, 4, and 5. (40 marks)

### **Q.1 Industrial Design**

During the monsoon season, drying of washed clothes at home takes a long time. The interior of the house is usually very damp. It is observed that people tend to spread the wet clothes on a chair or other furniture below a ceiling fan, to dry them. Such temporary arrangements help them cope with the problem.

A leading fan manufacturing company sees a business opportunity. The company approaches you to design a product for drying clothes. The manufacturer proposes to sell this product (which is to be used during monsoons) along with a fan.

The manufacturer wants the following objectives to be met in the design:

- a) The product uses a fan for drying clothes.
- b) The fan must be integrated with the product during its use in rainy season and must be usable as a “normal fan” during other seasons.
- c) The product should be foldable and compact for storage.

Design the product as per the objectives listed above.

1. Present three ideas of design alternatives through rough sketches. (10 marks)  
**Evaluation Criteria:** Quality of creative ideas and neatness of sketches.
2. List ten critical factors (key words only) you will consider for designing. (10 marks)  
**Evaluation Criteria:** Understanding of the situation and product use.
3. Select one of your ideas and develop it into a final product. Make a neat sketch of the same. Indicate all the parts, material and features on this sketch. (20 marks)  
**Evaluation Criteria:** Sketching quality, details, product features and usability issues.

Answer **ANY ONE** question out of the question numbers 1, 2, 3, 4, and 5. (40 marks)

### **Q.2 Communication Design**

Cricket is a popular sport in India. The 12th Cricket World Cup tournament is to be held in England and Wales in 2019. India has already been a champion twice. To win the tournament for a third time, the team needs the support and wishes of a billion Indians.

Design a visual campaign for the Indian cricket team to gather support and encouragement from Indians. As part of the campaign, design a 30 feet x 20 feet hoarding to be placed at prominent locations in various cities and towns.

**Task:**

1. Through sketches present three completely different concepts/ideas. (10 marks)  
**Evaluation criteria:** Originality and diversity of ideas, creativity, understanding of scale and proportion.
2. Design three slogans for the campaign in English or in any Indian language (with a mention of the language used). (10 marks)  
**Evaluation criteria:** Clarity of message and literary creativity.
3. Make a detailed design of one hoarding with slogan. (20 marks)  
**Evaluation criteria:** Visualisation, quality of lines, composition, colour combinations and detailing.

Answer **ANY ONE** question out of the question numbers 1, 2, 3, 4, and 5. (40 marks)

### **Q.3 Animation Design**

An animation film for children is in the pre-production stage. The film is based on the relationship that develops between a baby and a dog as the baby grows up and the dog gets old. Given below is one scene from the film.

The scene begins with a shot of a dog observing a baby. The baby is hungry and crying.

Suddenly the baby sees something and stops.

On a table, is the baby's milk bottle (and other stuff).

Baby crawls towards the table followed by the curious dog.

The baby reaches out and manages to grab a corner of the table cloth and starts pulling.

The dog's expression changes to one of alarm, as he sees the stuff on the table moving towards the edge.

He leaps forward and grabs the end of the baby's diaper.

Just as the bottle and the other items start toppling over the edge, he pulls the baby away from danger.

The baby is safe, but everything falls on the poor dog.

The mother's scream is heard, "Tommy!! BAD DOG!!" and the dog is seen sheepishly peeping out from under the table cloth, with all the mess around him.

#### **Part 1 (30 marks)**

Illustrate (create storyboard of) the above shots as a series of picture frames (at least 10 frames).

You may use more than one frame per shot if you want to. Approximate shape of the frame is shown below.

**Note:** *The image of the frame did not appear on screen during the examination. Therefore, frames of any proportion will be considered for evaluation.*

**Evaluation Criteria:** Communication of the narrative through the sequential pictures, shot composition (long shot, close up, top angle, low angle, etc.) and perspective.

#### **Part 2 (10 marks)**

Design an image for the poster of the film showing the two characters – the baby and the dog. Your drawings should depict the character and the essence of the film so that it is a good reference for animation and an inspiring image for the animation team.

**Evaluation criteria:** Illustration skills, the attitude and the expressions, and design of the details in the characters (keeping in mind that this will be used for animation). Your style can be realistic or stylised.

Answer **ANY ONE** question out of the question numbers 1, 2, 3, 4, and 5. (40 marks)

#### **Q.4 Interaction Design**

A bicycle manufacturing company has developed a device that will help cyclists find routes and navigate. The device has a colour-display screen (not a touch screen), 7 physical buttons, a speaker, a microphone, a global positioning system (GPS), and a wireless internet connection. The device is water-proof and the display is bright enough to be readable in bright sunlight. The battery of the device gets charged as the cyclist rides the bicycle.

Design a version of this device to be mounted on bicycles for 12 year old children. Your task is to do the following:

- Create a storyboard in 5 steps showing the user interface that enables the user to specify a new destination that he/she has not been to previously. (10 marks)  
**Evaluation criteria:** Appropriateness of the user interface, integration of the hardware and the software and appropriate use of media.
- Present a detailed screenshot showing the information design that helps the user to navigate while riding the bicycle. (10 marks)  
**Evaluation criteria:** Originality, appropriateness of the information design and appropriate use of media.
- Illustrate the shape, size, and position of the screen, the 7 buttons, the speaker, the microphone, and the place where the device will be mounted on the bicycle. (10 marks)  
**Evaluation criteria:** Form, originality and rendering quality.
- Illustrate a scenario in which the device is used for purposes other than the one mentioned above. (10 marks)  
**Evaluation criteria:** Originality, ability to understand the needs and constraints of the users.

Answer **ANY ONE** question out of the question numbers 1, 2, 3, 4, and 5. (40 marks)

### **Q.5 Mobility and Vehicle Design**

There are many local innovative transportation solutions that mostly operate in rural India. These vehicles are flexible to carry large number of people, smaller machine equipments, agro-machinery and even livestock like cattle, goat, etc. These transport systems are neither safe nor comfortable but are indispensable in rural scenarios. At times, these are the only modes of transportation available.

You are expected to think about the context, the target users (needs and expectations), and the purpose of the vehicle, along with aesthetic and safety considerations. Your observations and insights should lead to the development of original solutions. You are free to choose one concept over others, develop the final rendering and detail the key features of the final concept.

#### **Task:**

Design a **context sensitive, safe, workable and pleasing 4-wheeler vehicle** for hilly regions that fulfils the following criteria:

- a) Carrying capacity of at least 6 passengers, including the driver.
- b) Has a convertible space that can be used to carry at least 1 cattle/small machine/milk cans/fuel drums and a tool kit. If no goods are transported, the space can also be used to take passengers.
- c) Provides protection with respect to weather conditions (such as sunshades).
- d) Has provisions for easy maintenance.

Present your design proposal as follows:

- Create concept explorations through four good quality design sketches that represent unique design insights. (10 Marks)  
**Evaluation criteria:** Context-sensitivity, identification of problems and challenges, ability to showcase unique design insights, ability to sketch and creation of exploratory concepts.
- Draw a neat freehand perspective sketch of the proposed vehicle concept showing the overall form and its features. (10 marks)  
**Evaluation criteria:** Ability to sketch an automobile in perspective and detail out the final concept.
- Draw a neat rendering of the side elevation of the final concept. (10 marks)  
**Evaluation criteria:** Scale, proportion, neatness of the sketch and ability to make a rendering
- Draw an interior sketch highlighting design details and material finishes. (10 marks)  
**Evaluation criteria:** Ability to communicate details through sketch and rendering of material finishes.

Mandatory question (Question 6. in the Answer Booklet)

**Q.6 Sketching** (20 marks)

Draw a perspective view of a kitchen interior with a stove, kitchen utensils (such as pressure cooker, cooking pans, sauce pans etc.), dining utensils (such as ceramic plates, cups, glasses etc.), a wash basin, storage racks with stored cooking ingredients (such as spices in small plastic bottles), fresh cut vegetables kept beside the stove and at least two kitchen gadgets.

Make a **freehand perspective drawing** of this setup, showing all the elements listed above, as seen from the point of view of a 5  $\frac{1}{2}$  feet tall person.

**Evaluation criteria:**

- a) Quality of composition.
- b) Observation and drawing skills.
- c) Sense of perspective.
- d) Scale and relative proportions.
- e) Use of light, shade and surface finish.

**Note:**

- Use only pencils.
- Do not use any drawing instrument such as a ruler, compass, set-square etc.
- Do not use any kind of colour.

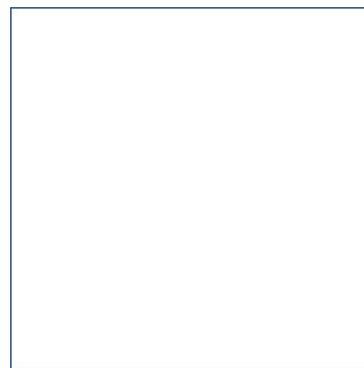
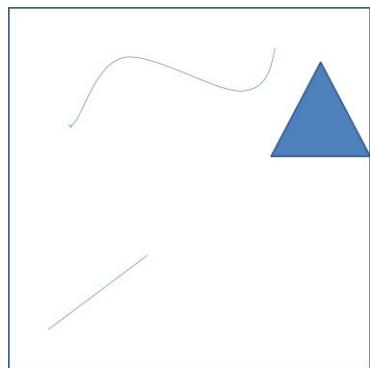
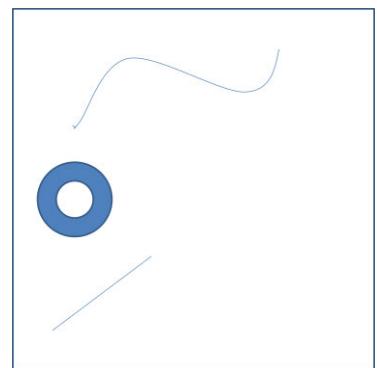
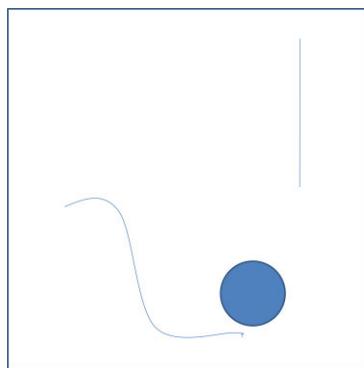
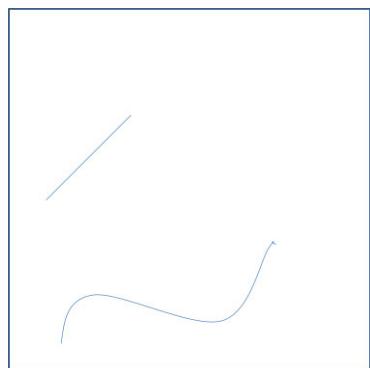
Mandatory question (Question 7. in the Answer Booklet)

**Q.7 Creativity** (20 marks)

Imagination is the power of the mind. Some visual elements can come together to create a bigger picture. Observe the visual elements that you see in the boxes provided in your answer booklet.

Complete the visual elements based on your imagination. It may be a character, a product, a landscape, etc. Using the given elements complete the first four frames to reflect what you imagined. Choose ANY THREE ELEMENTS given in the first four frames, and complete the fifth frame. Sketch only within the boundaries of the boxes.

**Evaluation criteria:** Originality and diversity of your ideas, clarity and neatness of your sketches.  
(4 marks for each frame)



Mandatory question (Question 8. in the Answer Booklet)

**Q.8 Visualization (20 marks)**

Shown below is a part of a “S shaped motif”. Dotted lines indicate the incomplete part of the motif. Visualize the remaining motif and draw the complete motif with a height of 15 cm. DO NOT draw the dotted lines.

**Evaluation criteria:**

- Faithful reproduction of the given part of the motif in the required size. (5 Marks)
- Consistency with the existing visual language, harmony, and balance in the imagined part of the motif. (10 Marks)
- Rendering quality of the final form. (5 Marks)

