

# Answer & Solutions *for* JEE MAIN 2026

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**12** Ranks in  
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\*Includes students of classroom, digital & distance across all categories.



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## Top Ranks in JEE (Advanced) 2025

**13** Ranks in  
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## Aakashians Create History in International Olympiads

### Our Olympiads Results

**378** Classroom  
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**777** Classroom  
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Aakashians Qualified  
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**134** Classroom  
Students  
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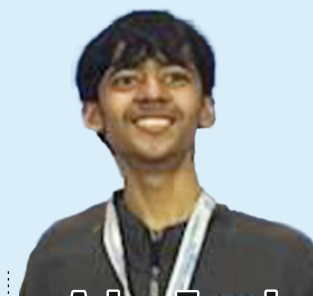
**Aarav Gupta**  
**Gold Medalist**

66th International  
Mathematical Olympiad  
(IMO) 2025



**Yug Gandhi**  
**Gold Medalist**

Singapore Math  
Olympiad 2025



**Arjun Tyagi**  
**Gold Medalist**

International Olympiad  
in Artificial Intelligence  
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**MATHEMATICS**

**SECTION - A**

**Multiple Choice Questions:** This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

**Choose the correct answer :**

1. For the function  $f : [1, \infty) \rightarrow [1, \infty)$  defined by  $f(x) = (x-1)^4 + 1$ , among the two statements:

(I) The set  $S = \{x \in [1, \infty) : f(x) = f^{-1}(x)\}$  contains exactly two elements, and

(II) The set  $S = \{x \in [1, \infty) : f(x) = f^{-1}(x+1)\}$  is an empty set,

- (1) only (I) is TRUE
- (2) only (II) is TRUE
- (3) both (I) and (II) are TRUE
- (4) neither (I) nor (II) is TRUE

**Answer (1)**

**Sol.**  $f(x) = (x-1)^4 + 1$

for  $x \geq 1$

$(x-1)^4$  is strictly increasing

Thus  $f(x)$  is one-one and onto function. Its Range  $[1, \infty)$

Now, Let  $y = (x-1)^4 + 1$

$$\Rightarrow (x-1)^4 = y - 1$$

$$\Rightarrow x = (y-1)^{1/4} + 1$$

$$f^{-1}(x) = (x-1)^{1/4} + 1$$

Statement I:  $S = \{x \in [1, \infty) : f(x) = f^{-1}(x)\}$

Point where a function meets its inverse on the line  $y = x$ ,

$$f(x) = x$$

$$\Rightarrow (x-1)^4 + 1 = x$$

$$\Rightarrow (x-1)^4 - (x-1) = 0$$

$$\Rightarrow (x-1)[(x-1)^3 - 1] = 0$$

$$x = 1 \text{ or } (x-1)^3 = 1 \Rightarrow x = 2$$

Set S contains two elements

**Statement II:**

$$S = \{x \in [1, \infty) : f(x) = f^{-1}(x+1)\}$$

Consider,  $f(f(x)) = x + 1$

Let  $g(x) = f(f(x)) - (x+1)$

At  $x = 1, g(1) = -1$

At  $x = 2, g(2) = -1$

As  $x \rightarrow \infty, f(f(x))$  grows much faster than  $x + 1$  so

$$g(x) \rightarrow \infty$$

$$\Rightarrow g(x) \text{ is unbounded}$$

$\therefore$  set is not empty

2. Let  $S = \{z \in \mathbb{C} : z^2 + 4z + 16 = 0\}$ .

Then  $\sum_{z \in S} |z + \sqrt{3}i|^2$  is equal to:

- (1) 42
- (2) 23
- (3) 27
- (4) 38

**Answer (4)**

**Sol.**  $\because z^2 + 4z + 16 = 0$

$$(z+2)^2 = -12$$

$$\therefore z = -2 + 2\sqrt{3}i, -2 - 2\sqrt{3}i$$

$$\therefore z + \sqrt{3}i = -2 + 3\sqrt{3}i, -2 - \sqrt{3}i$$

$$|z + \sqrt{3}i|^2 = |-2 + 3\sqrt{3}i|^2 \text{ and } |-2 - \sqrt{3}i|^2 = 31 \text{ and } 7$$

$$\therefore \sum_{z \in S} |z + \sqrt{3}i|^2 = 38$$

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3. If the system of equations:

$$x + y + z = 5$$

$$x + 2y + 3z = 9$$

$$x + 3y + \lambda z = \mu$$

has infinitely many solutions, then the value of  $\lambda + \mu$  is:

(1) 16 (2) 18

(3) 19 (4) 21

**Answer (2)**

**Sol.**  $\Delta = 0$

$$\begin{vmatrix} 1 & 1 & 1 \\ 1 & 2 & 3 \\ 1 & 3 & \lambda \end{vmatrix} = 0$$

$$(2\lambda - 9) - 1(\lambda - 3) + 1(3 - 2) = 0$$

$$2\lambda - 9 - \lambda + 3 + 1 = 0$$

$$\lambda - 5 = 0$$

$$\lambda = 5$$

and  $\Delta_3 = 0$

$$\begin{vmatrix} 1 & 1 & 5 \\ 1 & 2 & 9 \\ 1 & 3 & \mu \end{vmatrix} = 0$$

$$(2\mu - 27) - 1(\mu - 9) + 5(3 - 2) = 0$$

$$2\mu - 27 - \mu + 9 + 5 = 0$$

$$\mu - 13 = 0$$

$$\mu = 13$$

$$\lambda + \mu = 18$$

4. If  $\alpha = 1$  and  $\beta = 1 + i\sqrt{2}$ , where  $i = \sqrt{-1}$  are two roots of the equation  $x^3 + ax^2 + bx + c = 0, a, b, c \in \mathbb{R}$ ,

then  $\int_{-1}^1 (x^3 + ax^2 + bx + c) dx$  is equal to:

(1) -2 (2) -4

(3) -8 (4) -10

**Answer (3)**

**Sol.**  $\alpha = 1, \beta = 1 + i\sqrt{2}$  are roots of the equation

$$x^3 + ax^2 + bx + c = 0, a, b, c \in \mathbb{R}$$

$$x^3 + ax^2 + bx + c = (x - 1)(x - (1 + i\sqrt{2}))(x - (1 - i\sqrt{2}))$$

$$= (x - 1)((x - 1)^2 + 2)$$

$$= (x - 1)(x^2 - 2x + 3)$$

$$= x^3 - 3x^2 + 5x - 3$$

By Comparing we get  $a = -3, b = 5, c = -3$

$$\begin{aligned} \int_{-1}^1 (x^3 - 3x^2 + 5x - 3) dx &= \int_{-1}^1 x^3 dx - \int_{-1}^1 3x^2 dx \\ &+ \int_{-1}^1 5x dx - 3 \int_{-1}^1 dx \\ &= 2 \int_0^1 (-3x^2 - 3) dx \\ &= 2[-x^3 - 3x]_0^1 \\ &= 2(-1 - 3) \\ &= -8 \end{aligned}$$

5. If the quadratic equation  $(\lambda + 2)x^2 - 3\lambda x + 4\lambda = 0$ ,  $\lambda \neq -2$ , has two positive roots, then the number of possible integral values of  $\lambda$  is:

(1) 1 (2) 2

(3) 3 (4) 4

**Answer (2)**

**Sol.**  $x^2 - \frac{3\lambda}{\lambda + 2}x + \frac{4\lambda}{\lambda + 2} = 0$

It has two positive roots

$$\Rightarrow \frac{4\lambda}{\lambda + 2} > 0 \text{ and } \frac{3\lambda}{\lambda + 2} > 0$$

$$\Rightarrow \frac{\lambda}{\lambda + 2} > 0$$

$$\lambda \in (-\infty, -2) \cup (0, \infty) \dots(i)$$

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$$D \geq 0 \text{ and } 9\lambda^2 - 16\lambda(\lambda + 2) \geq 0$$

$$\lambda(7\lambda + 32) \leq 0 \quad \lambda \in \left[-\frac{32}{7}, 0\right] \quad \dots (2)$$

From (1) and (2)

⇒ Possible integral values of  $\lambda$  are  $-4, -3$

6. Let  $A = \begin{bmatrix} 1 & 2 & 7 \\ 4 & -2 & 8 \\ 3 & 8 & -7 \end{bmatrix}$  and  $\det(A - \alpha I) = 0$ , where

$\alpha$  is a real number. If the largest possible value of  $\alpha$  is  $p$ , then the circle  $(x - p)^2 + (y - 2p)^2 = 320$ , intersects the co-ordinate axes at

- (1) 1 point                      (2) 2 point  
 (3) 3 point                      (4) 4 point

**Answer (3)**

**Sol.**  $A = \begin{bmatrix} 1 & 2 & 7 \\ 4 & -2 & 8 \\ 3 & 8 & -7 \end{bmatrix}$

$$|A - \alpha I| = \begin{vmatrix} 1-\alpha & 2 & 7 \\ 4 & -2-\alpha & 8 \\ 3 & 8 & -7-\alpha \end{vmatrix}$$

$$\Rightarrow (1-\alpha)[(-2-\alpha)(-7-\alpha) - 64]$$

$$-2[-28 - 4\alpha - 24]$$

$$+7[32 + 6 + 3\alpha] = 0$$

$$(\alpha^2 + 9\alpha - 50) - 2(-4\alpha - 52)$$

$$+7(3\alpha + 38) = 0$$

$$\Rightarrow (1-\alpha)(\alpha^3 + 8\alpha^2 - 88\alpha - 32) = 0$$

$$\Rightarrow (\alpha - 8)(\alpha^2 + 16\alpha + 40) = 0$$

Longest possible value of  $\alpha$  is 8

$$\Rightarrow p = 8$$

Equation 7 of circle is  $(x - 8)^2 + (y - 16)^2 = 320$

It intersects  $x$ -axis at  $(x_1, 0)$

$$(x_1 - 8)^2 + 16 = 2$$

$$(x_1 - 8)^2 = 64$$

$$x_1 - 8 = \pm 8$$

$$x_1 = 0, 16$$

$$(0, 0), (16, 0)$$

and it intersect  $y$ -axis at  $(0, y_1)$

$$(0 - 8)^2 + (y_1 - 16)^2 = 320$$

$$(y_1 - 16)^2 = 256$$

$$y_1 - 16 = \pm 16$$

$$y_1 = 0, 32$$

So, the points are  $(0, 0), (16, 0), (0, 32)$

⇒ we are getting 3 points of intersection

7. Let  $\alpha = \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \dots \infty$  and  $\beta = \frac{1}{3} + \frac{1}{9} + \frac{1}{27} + \dots \infty$

. Then the value of  $(0.2)^{\log_{\sqrt{5}}(\alpha)} + (0.04)^{\log_5(\beta)}$  is equal to:

- (1) 4                                      (2) 5  
 (3) 8                                      (4) 25

**Answer (3)**

**Sol.**  $\alpha = \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \dots$

$$\frac{\frac{1}{4}}{1 - \frac{1}{2}} = \frac{\frac{1}{4}}{\frac{1}{2}} = \frac{1}{2} = \alpha$$

$$\beta = \frac{1}{3} + \frac{1}{9} + \frac{1}{27} + \dots$$

$$\beta = \frac{\frac{1}{3}}{1 - \frac{1}{3}} = \frac{\frac{1}{3}}{\frac{2}{3}} = \frac{1}{2} = \beta$$

$$(0.2)^{\log_{\sqrt{5}} \frac{1}{2}} + (0.04)^{\log_5 \frac{1}{2}} = 8$$

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8. For 10 observations  $x_1, x_2, \dots, x_{10}$ , if  $\sum_{i=1}^{10} (x_i + 2)^2 = 180$  and  $\sum_{i=1}^{10} (x_i - 1)^2 = 90$ , then their standard deviation is:
- (1) 2                                      (2)  $\sqrt{3}$   
(3)  $2\sqrt{2}$                                 (4) 3

**Answer (4)**

**Sol.**  $\sum_{i=1}^{10} (x_i - 1)^2 = 90$

$$\sum_{i=1}^{10} x_i^2 - 2 \sum_{i=1}^{10} x_i + 10 = 90$$

$$\sum_{i=1}^{10} x_i^2 - 2 \sum_{i=1}^{10} x_i = 80 \quad \dots (1)$$

$$\sum_{i=1}^{10} (x_i + 2)^2 = 180$$

$$\sum_{i=1}^{10} x_i^2 + 4 \sum_{i=1}^{10} x_i + 40 = 180$$

$$\sum_{i=1}^{10} x_i^2 + 4 \sum_{i=1}^{10} x_i = 140 \quad \dots (2)$$

subtracting (1) from (2)

$$6 \sum_{i=1}^{10} x_i = 60$$

$$\sum_{i=1}^{10} x_i = 10$$

from equation (1)

$$\sum_{i=1}^{10} x_i^2 = 80 + 2(10) = 100$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{10} x_i^2}{10} - \left(\frac{\sum_{i=1}^{10} x_i}{10}\right)^2}$$

$$= \sqrt{10 - 1} = \sqrt{9}$$

$$\Rightarrow \sigma = 3$$

9. In the expansion of  $\left(9x - \frac{1}{3\sqrt{x}}\right)^{18}$ ,  $x > 0$ , if the term independent of  $x$  is  $(221)k$ , then  $k$  is equal to:
- (1) 84                                      (2) 78  
(3) 168                                    (4) 198

**Answer (1)**

**Sol.**  $\left(9x - \frac{1}{3\sqrt{x}}\right)^{18}$

$$T_{r+1} = {}^{18}C_r (9x)^{18-r} \left(\frac{-1}{3\sqrt{x}}\right)^r$$

$$= {}^{18}C_r 9^{18-r} \left(\frac{-1}{3}\right)^r x^{18-r-\frac{r}{2}}$$

Independent of  $x$

$$18 - r - \frac{r}{2} = 0$$

$$\Rightarrow \frac{3r}{2} = 18$$

$$\Rightarrow r = 12$$

$$T_{13} = {}^{18}C_{12} (9)^{18-12} \left(\frac{-1}{3}\right)^{12}$$

$$= 18564$$

$$\therefore k = 84$$

10. Let  $P(3\cos\alpha, 2\sin\alpha)$ ,  $\alpha \neq 0$ , be a point on the ellipse  $\frac{x^2}{9} + \frac{y^2}{4} = 1$ ,  $Q$  be a point on the circle  $x^2 + y^2 - 14x - 14y + 82 = 0$  and  $R$  be a point on the line  $x + y = 5$  such that the centroid of the triangle  $PQR$  is  $\left(2 + \cos\alpha, 3 + \frac{2}{3}\sin\alpha\right)$ . Then the sum of the ordinates of all possible points  $R$  is:
- (1) 6                                      (2) 2  
(3) 4                                      (4) 8

**Answer (4)**

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Sol.  $P(3\cos\alpha, 2\sin\alpha)$

$$C : (x - 7)^2 + (y - 7)^2 = 16$$

$$Q(7 + 4\cos\theta, 7 + 4\sin\theta)$$

$$R(a, 5 - a)$$

$$\frac{3\cos\alpha + 7 + 4\cos\theta + a}{3} = 2 + \cos\alpha \quad (1)$$

$$\frac{2\sin\alpha + 7 + 4\sin\theta + 5 - a}{3} = 3 + \frac{2}{3}\sin\alpha \quad (2)$$

From (1):

$$3\cos\alpha + 7 + 4\cos\theta + a = 6 + 3\cos\alpha$$

From (2):

$$2\sin\alpha + 7 + 4\sin\theta + 5 - a = 9 + 2\sin\alpha$$

Adding both:

$$3\cos\alpha + 2\sin\alpha + 14 + 4(\sin\theta + \cos\theta) + 5 = 15 + 3\cos\alpha + 2\sin\alpha$$

$$4(\sin\theta + \cos\theta) + 5 = 1$$

$$\sin\theta + \cos\theta = -1$$

$$1 + \sin 2\theta = 1$$

$$\sin 2\theta = 0$$

$$\Rightarrow \theta = \pi, \frac{3\pi}{2}$$

$$\therefore \sum y_i = 2 - 4\sin\theta$$

$$y_i = 2 + 6 = 8$$

11. Let  $H : \frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$  be a hyperbola such that the distance between its foci is 6 and the distance between its directrices is  $\frac{8}{3}$ . If the line  $x = \alpha$  intersects the hyperbola  $H$  at the points  $A$  and  $B$  such that the area of the triangle  $AOB$  is  $4\sqrt{15}$ , where  $O$  is the origin, then  $\alpha^2$  equals

(1) 12

(2) 16

(3) 24

(4) 25

Answer (2)

Sol.  $2ae = 6 \dots (i)$

$$2\frac{a}{e} = \frac{8}{3} \dots (ii)$$

$$\Rightarrow e^2 = \frac{18}{8} \text{ and } 4a^2 = 6 \times \frac{8}{3}$$

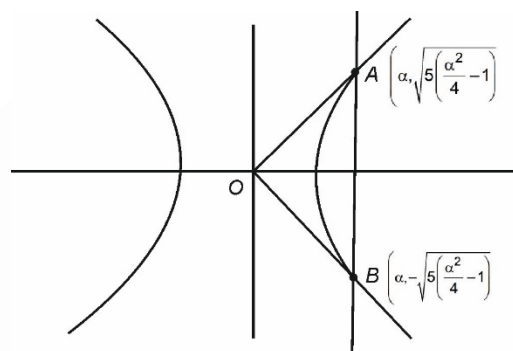
$$a^2 = 4$$

$$e^2 = 1 + \frac{b^2}{a^2}$$

$$\Rightarrow \frac{18}{8} = 1 + \frac{b^2}{4}$$

$$\frac{10}{8} = \frac{b^2}{4} \Rightarrow b^2 = 5$$

$$H : \frac{x^2}{4} - \frac{y^2}{5} = 1$$



At  $x = \alpha$

$$y^2 = 5\left(\frac{\alpha^2}{4} - 1\right)$$

$$y = \pm \sqrt{5\left(\frac{\alpha^2}{4} - 1\right)}$$

$$\text{Area} = \frac{1}{2} \times 2 \sqrt{5\left(\frac{\alpha^2}{4} - 1\right)} \times \alpha = 4\sqrt{15}$$

$$\Rightarrow 5\left(\frac{\alpha^2}{4} - 1\right)\alpha^2 = 16 \times 15$$

$$\alpha^2 = 16$$

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12.  $\max_{0 \leq x \leq \pi} \left( 16 \sin\left(\frac{x}{2}\right) \cos^3\left(\frac{x}{2}\right) \right)$  is equal to:

- (1)  $\frac{3\sqrt{3}}{2}$  (2)  $3\sqrt{3}$   
(3)  $4\sqrt{3}$  (4)  $6\sqrt{3}$

**Answer (2)**

**Sol.**  $E = 16 \sin\frac{x}{2} \cos^3\frac{x}{2}$

$$= (4 \sin x) \left( 2 \cos^2 \frac{x}{2} \right)$$

$$= 4 \sin x (1 + \cos x)$$

$$= 4 \sin x + 4 \sin x \cos x$$

$$E = 4 \sin x + 2 \sin 2x$$

$$E' = 4 \cos x + 4 \cos 2x = 0$$

$$\cos x + 2 \cos^2 x - 1 = 0$$

$$2 \cos^2 x + \cos x - 1 = 0$$

$$2 \cos^2 x + 2 \cos x - \cos x - 1 = 0$$

$$(2 \cos x - 1)(\cos x + 1) = 0$$

$$\Rightarrow \cos x = \frac{1}{2} \cos x = -1$$

$$\Rightarrow \sin x = \frac{\sqrt{3}}{2}$$

$$E_{\max} = 4 \times \frac{\sqrt{3}}{2} + 4 \times \frac{\sqrt{3}}{2} \times \frac{1}{2}$$

$$= 2\sqrt{3} + \sqrt{3}$$

$$= 3\sqrt{3}$$

13. The shortest distance between the lines

$$\vec{r} = \left( \frac{1}{3} \hat{i} + 2\hat{j} + \frac{8}{3} \hat{k} \right) + \lambda (2\hat{i} - 5\hat{j} + 6\hat{k})$$

and  $\vec{r} = \left( -\frac{2}{3} \hat{i} - \frac{1}{3} \hat{k} \right) + \mu (\hat{j} - \hat{k}), \lambda, \mu \in \mathbb{R}$ , is:

- (1)  $\sqrt{5}$  (2) 3  
(3)  $2\sqrt{3}$  (4)  $\sqrt{15}$

**Answer (2)**

**Sol.**  $\vec{r} = \left( \frac{1}{3} \hat{i} + 2\hat{j} + \frac{8}{3} \hat{k} \right) + \lambda (2\hat{i} - 5\hat{j} + 6\hat{k})$

$$\vec{r} = \left( -\frac{2}{3} \hat{i} - \frac{1}{3} \hat{k} \right) + \mu (\hat{j} - \hat{k})$$

$$\vec{b}_1 \times \vec{b}_2 = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -5 & 6 \\ 0 & 1 & -1 \end{vmatrix}$$

$$= -\hat{i} + 2\hat{j} + 2\hat{k}$$

$$\vec{d} = \frac{(\vec{a}_2 - \vec{a}_1) \cdot (\vec{b}_1 \times \vec{b}_2)}{|\vec{b}_1 \times \vec{b}_2|}$$

$$= \frac{(\hat{i} + 2\hat{j} + 3\hat{k}) \cdot (-\hat{i} + 2\hat{j} + 2\hat{k})}{|\hat{i} + 2\hat{j} + 2\hat{k}|}$$

$$= \frac{-1 + 4 + 6}{3} = \frac{9}{3} = 3$$

14. If  $\left( 2\alpha + 1, \alpha^2 - 3\alpha, \frac{\alpha - 1}{2} \right)$  is the image of  $(\alpha, 2\alpha, 1)$

in the line  $\frac{x-2}{3} = \frac{y-1}{2} = \frac{z}{1}$ , then the possible value(s) of  $\alpha$  is (are)

- (1) Only 3 (2) Only 3 and -1  
(3) Only 3,  $\frac{1}{4}$  and -1 (4) Only 3 and  $\frac{1}{4}$

**Answer (1)**

**Sol.** Mid point :  $\left( \frac{3\alpha + 1}{2}, \frac{\alpha^2 - \alpha}{2}, \frac{\alpha + 1}{4} \right)$  lies on line

$$\frac{\frac{3\alpha + 1}{2} - 2}{3} = \frac{\frac{\alpha^2 - \alpha}{2} - 1}{2} = \frac{\alpha + 1}{4}$$

Equating these two terms =  $\alpha = 3$

15. Let  $\hat{u}$  and  $\hat{v}$  be unit vectors inclined at an acute angle such that  $|\hat{u} \times \hat{v}| = \frac{\sqrt{3}}{2}$ . If  $\vec{A} = \lambda \hat{u} + \hat{v} + (\hat{u} \times \hat{v})$ , then  $\lambda$  is equal to:

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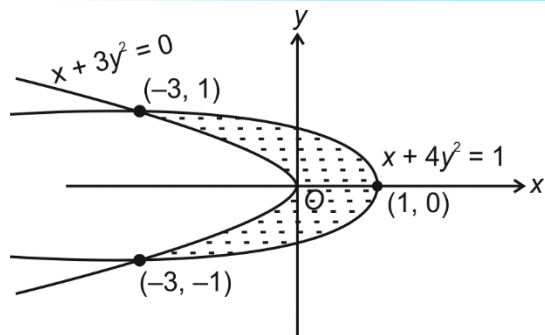


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Sol.



$$\text{Area} = 2 \left[ \int_{-3}^1 \left( \frac{1}{2} \sqrt{1-x} \right) dx - \int_{-3}^0 \sqrt{-\frac{x}{3}} dx \right]$$

$$= \frac{4}{3}$$

19. Let  $y = y(x)$  be the solution of the differential equation:

$$\frac{dy}{dx} + \left( \frac{6x^2 + (3x^2 + 2x^3 + 4)e^{-2x}}{(x^3 + 2)(2 + e^{-2x})} \right) y = 2 + e^{-2x},$$

$x \in (-1, 2)$ , satisfying  $y(0) = \frac{3}{2}$ . If  $y(1) = \alpha(2 + e^{-2})$ ,

then  $\alpha$  is equal to:

- (1)  $\frac{13}{8}$
- (2)  $\frac{6}{13}$
- (3)  $\frac{12}{13}$
- (4)  $\frac{13}{12}$

**Answer (4)**

Sol.  $\frac{dy}{dx} + P(x)y = Q(x) = 2 + e^{-2x}$

$$P(x) = \frac{3x^2(2 + e^{-2x}) + 2e^{-2x}(x^3 + 2)}{(x^3 + 2)(2 + e^{-2x})}$$

$$= \frac{3x^2}{x^3 + 2} + \frac{2e^{-2x}}{2 + e^{-2x}}$$

$$\Rightarrow \text{I.F.} = (x^3 + 2) \times \frac{1}{2 + e^{-2x}}$$

$$\Rightarrow \frac{y \cdot (x^3 + 2)}{2 + e^{-2x}} = \int (x^3 + 2) dx + C = \frac{x^4}{4} + 2x + C$$

$$\therefore y(0) = \frac{3}{2} \Rightarrow C = 1$$

$$\Rightarrow \frac{y(1) \cdot 3}{2 + e^{-2}} = \frac{13}{4}$$

$$\Rightarrow y(1) = \frac{13}{12}(2 + e^{-2}) \Rightarrow \alpha = \frac{13}{12}$$

20. The integral  $\int_0^1 \cot^{-1}(1 + x + x^2) dx$  is equal to :

- (1)  $2 \tan^{-1} 2 + \frac{1}{2} \log_e \left( \frac{5}{4} \right) + \frac{\pi}{2}$
- (2)  $2 \tan^{-1} 2 + \frac{1}{2} \log_e \left( \frac{5}{4} \right) - \frac{\pi}{2}$
- (3)  $2 \tan^{-1} 2 - \frac{1}{2} \log_e \left( \frac{5}{4} \right) + \frac{\pi}{2}$
- (4)  $2 \tan^{-1} 2 - \frac{1}{2} \log_e \left( \frac{5}{4} \right) - \frac{\pi}{2}$

**Answer (4)**

Sol.  $I = \int_0^1 \cot^{-1}(1 + x + x^2) dx = \int_0^1 \tan^{-1} \left( \frac{1}{1 + x + x^2} \right) dx$

$$= \int_0^1 \tan^{-1} \left( \frac{x+1-x}{1+x(x+1)} \right) dx$$

$$I = \int_0^1 \tan^{-1}(x+1) dx - \int_0^1 \tan^{-1} x dx$$

$$= \int_1^2 \tan^{-1} x dx - \int_0^1 \tan^{-1} x dx$$

$$\therefore \int \tan^{-1} x dx = x \tan^{-1} x - \frac{1}{2} \ln(1 + x^2)$$

$$\Rightarrow I = 2 \tan^{-1} 2 - \frac{1}{2} \ln \left( \frac{5}{4} \right) - \frac{\pi}{2}$$

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**SECTION - B**

**Numerical Value Type Questions:** This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

21. From a month of 31 days, 3 different dates are selected at random. If the probability that these dates are in an increasing A.P. is equal to  $\frac{a}{b}$ , where  $a, b \in \mathbb{N}$  and  $\gcd(a, b) = 1$ , then  $a + b$  is equal to \_\_\_\_\_.

**Answer (944)**

**Sol.**  $n(S) = {}^{31}C_3 = 4495$

$n(d)$  denotes the number of ways when common difference is  $d$

$\Rightarrow n(1) = 29, n(2) = 27, n(3) = 25, \dots, n(15) = 1, n(d) = 0 \forall d \geq 15$

$n(E) = 29 + 27 + 25 + \dots + 1 = 225$

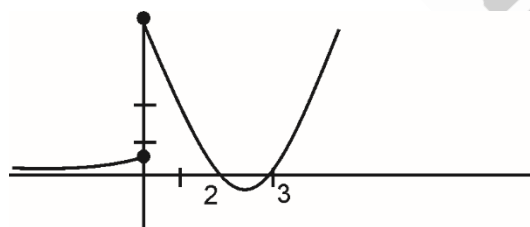
$p(E) = \frac{n(E)}{n(S)} = \frac{45}{899} \Rightarrow a + b = 944$

22. Let  $f(x) = \begin{cases} e^{x-1}, & x < 0 \\ x^2 - 5x + 6, & x \geq 0 \end{cases}$  and

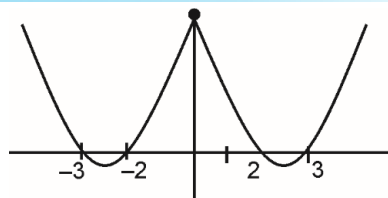
$g(x) = f(|x|) + |f(x)|$ . If the number of points where  $g$  is not continuous and is not differentiable are  $\alpha$  and  $\beta$  respectively, then  $\alpha + \beta$  is equal to \_\_\_\_\_

**Answer (4)**

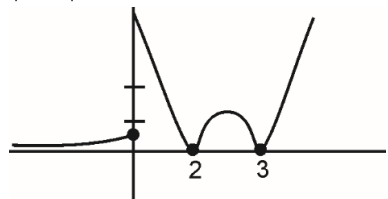
**Sol.**  $f(x) = \begin{cases} e^{x-1}, & x < 0 \\ x^2 - 5x + 6, & x \geq 0 \end{cases}$



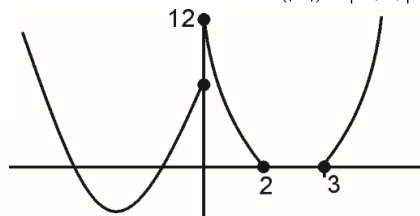
$|f(x)|$



$f(x)$



Consider sum of  $f(|x|) + |f(x)|$



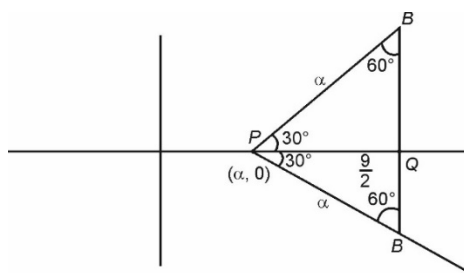
Points of discontinuity is  $x = 0$   
 Points of non-differentiability  
 $= x = 0$  (due to discontinuity) 2 and 3  
 $\Rightarrow \alpha + \beta = (1) + (3) = 4$

23. Let  $A, B$  be points on the two half-lines  $x - \sqrt{3}|y| = \alpha, \alpha > 0$  at a distance of  $\alpha$  from their point of intersection  $P$ . The line segment  $AB$  meets the angle bisector of the given half-lines at the point  $Q$ . If  $PQ = \frac{9}{2}$  and  $R$  is the radius of the circumcircle

of  $\triangle PAB$ , then  $\frac{\alpha^2}{R}$  is equal to \_\_\_\_\_

**Answer (9)**

**Sol.**



$\cos 30^\circ = \frac{9}{2\alpha} = \frac{\sqrt{3}}{2} \Rightarrow \alpha = 3\sqrt{3}$

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$$R = \frac{abc}{4\Delta} = \frac{\alpha^3}{4 \times \frac{1}{2} \times \alpha \times \alpha \times \frac{\sqrt{3}}{2}}$$

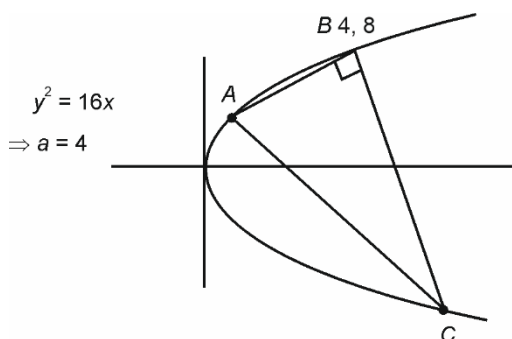
$$R = \frac{\alpha}{\sqrt{3}} \Rightarrow R = 3$$

$$\Rightarrow \frac{\alpha^2}{R} = \frac{27}{3} = 9$$

24. Let  $A$ ,  $B$  and  $C$  be the vertices of a variable right angled triangle inscribed in the parabola  $y^2 = 16x$ . Let the vertex  $B$  containing the right angle be  $(4, 8)$  and the locus of the centroid of  $\triangle ABC$  be a conic  $C_0$ . Then three times the length of latus rectum of  $C_0$  is \_\_\_\_\_

**Answer (16)**

**Sol.**



$$A \equiv (4t_1^2, 8t_1), B \equiv (4t_2^2, 8t_2)$$

$$\angle ABC = 90^\circ \Rightarrow \left( \frac{8-8t_2}{4-4t_2^2} \right) \left( \frac{8-8t_1}{4-4t_1^2} \right) = -1$$

$$\Rightarrow (1+t_2)(1+t_1) = -4$$

$$\text{Now, } (h, k) \text{ be centroid} \Rightarrow \begin{aligned} 3h &= 4 + (t_1^2 + t_2^2)4 \\ 3k &= 8(1+t_1+t_2) \end{aligned}$$

$$\frac{3h}{4} = 1 + t_1^2 + t_2^2, \quad \frac{3k}{8} = 1 + t_1 + t_2$$

$$t_1 t_2 + t_1 + t_2 = -5$$

$$\Rightarrow \frac{-\left(\frac{3h-4}{4}\right) + \left(\frac{3k-8}{8}\right)^2 + \left(\frac{3k-8}{8}\right)}{2} = -5$$

$$\Rightarrow y^2 = \frac{16}{3} \left( x - \frac{40}{3} \right)$$

$$\Rightarrow \text{Latus rectum} = \frac{16}{3}$$

$$\Rightarrow 3 \text{ times } LR = 16$$

25. Let  $f$  be a twice differentiable function such that

$$f(x) = \int_0^x \tan(t-x) dt - \int_0^x f(t) \tan t dt, \quad x \in \left( -\frac{\pi}{2}, \frac{\pi}{2} \right)$$

Then  $f''\left(\frac{\pi}{6}\right) + 12f'\left(-\frac{\pi}{6}\right) + f\left(\frac{\pi}{6}\right)$  is equal to \_\_\_\_\_

**Answer (5)**

$$\text{Sol. } f(x) = \int_0^x \tan(t-x) dt - \int_0^x f(t) \tan t dt, \quad x \in \left( -\frac{\pi}{2}, \frac{\pi}{2} \right)$$

$$I = \int_0^x \tan(t-x) dt = \frac{-\ln|\cos t|}{-1} \Big|_0^x$$

$$= \ln(\cos x) - \ln 1 = \ln(\cos x)$$

$$f(x) = \ln(\cos x) - \int_0^x f(t) \tan t dt$$

$$f'(x) = \frac{1}{\cos x} \times (-\sin x) - f(x) \tan(x)$$

$$= (-\tan x)(1 + f(x))$$

$$f''(x) = (1 + f(x))(-\sec^2 x) + (-\tan x)(f'(x))$$

$$f''(x) = (1 + f(x))[\tan^2 x - \sec^2 x] = -1 - f(x)$$

$$\Rightarrow f(x) + f''(x) = -1$$

$$\int \frac{f'(x)}{1+f(x)} dx = \int -\tan x dx = \ln(1+f(x))$$

$$= \ln|\cos x| + C$$

$$f(0) = 0$$

$$\Rightarrow f(x) = \cos x - 1$$

$$\Rightarrow f'(x) = -\sin x$$

$$\Rightarrow \left( f''\left(\frac{\pi}{6}\right) + f\left(\frac{\pi}{6}\right) \right) + 12f'\left(-\frac{\pi}{6}\right)$$

$$= (-1) + 12 \times \left( -\sin\left(-\frac{\pi}{6}\right) \right)$$

$$= (-1) + 12 \times \frac{1}{2} = 5$$

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**PHYSICS**

**SECTION - A**

**Multiple Choice Questions:** This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

**Choose the correct answer :**

26. Match the **LIST-I** with **LIST-II**

List-I		List-II	
A.	Planck's constant	I.	$ML^2 T^{-2}$
B.	Stopping potential	II.	$T^{-1}$
C.	Work function	III.	$ML^2 T^{-1}$
D.	Threshold frequency	IV.	$ML^2 T^{-3} A^{-1}$

Choose the **correct** answer from the options given below:

- (1) All, B-IV, C-I, D-II
- (2) A-I, B-II, C-III, D-IV
- (3) A-IV, B-III, C-I, D-II
- (4) A-I, B-IV, C-III, D-II

**Answer (1)**

**Sol.** For Planck's constant  $E = hv$

$$\Rightarrow ML^2T^{-2}T = [h] = ML^2T^{-1}$$

For Stopping potential  $V = \frac{u}{q} = \frac{ML^2T^{-2}}{AT}$

$$\Rightarrow [V] = ML^2T^{-3}A^{-1}$$

For work function  $[\phi] = [E] = ML^2T^{-2}$

For Threshold frequency  $[v] = T^{-1}$

27. Two cars *A* and *B* are moving in the same direction along a straight line with speeds 100 km/h and 80 km/h, respectively such that car *A* is moving ahead of car *B*. A person in car *B* throws a stone with a speed *v* so that it hits the car *A* with a speed of 5 m/s. The value of *v* is \_\_\_\_\_ km/h.

- (1) 18
- (2) 28
- (3) 38
- (4) 48

**Answer (3)**

**Sol.** Questions statement is slightly confusing.

Hence the solution is for case "When the stone hits the car *A* with relative velocity (w.r.t. *A*) of 5 m/s. Then what is the relative velocity of stone w.r.t. (*B*) in km/h".

Clearly 5 m/s = 18 km/h

So velocity of stone w.r.t. ground = 118 km/h

So velocity of stone w.r.t. *B* is 118 – 80 = 38 km/h.

28. At  $t = 0$ , a body of mass 100 g starts moving under the influence of a force  $(5\hat{i} + 10\hat{j})$  N. After 2 s its position is  $(2x\hat{i} + 5y\hat{j})$  m. The ratio  $x : y$  is \_\_\_\_\_.

- (1) 1 : 2
- (2) 2 : 5
- (3) 5 : 2
- (4) 5 : 4

**Answer (4)**

**Sol.**  $m = \frac{1}{10}$  kg                       $\vec{F} = (5\hat{i} + 10\hat{j})$  N.

$a_x = 50$  m/s<sup>2</sup> so,  $X = 2x = \frac{1}{2} \times 50 \times 4 = 100$

$a_y = 100$  m/s<sup>2</sup> so,  $Y = 5y = \frac{1}{2} \times 100 \times 4 = 200$

$$\Rightarrow \frac{2x}{5y} = \frac{1}{2} \qquad \Rightarrow \frac{x}{y} = \frac{5}{4}$$

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29. If  $x$  and  $y$  coordinates of a projectile as a function of time ( $t$ ) are given as  $24t$  and  $43.6t - 4.9t^2$ , respectively, then the angle (in degrees) made by the projectile with horizontal when  $t = 2$  s is \_\_\_\_\_.

- (1) 60 (2) 45  
(3) 30 (4) 75

**Answer (2)**

**Sol.**  $x = 24t$  so  $u_x = 24$  m/s  
 $y = 43.6t - 4.9t^2 \Rightarrow u_y = 43.6$  m/s;  $a_y = -9.8$

$$\text{So } \tan \theta = \frac{u_y}{u_x} = \frac{(43.6 - 9.8t)}{24}$$

$$\Rightarrow \tan \theta = \frac{u_y}{u_x} = \frac{24}{24} = 1$$

$$\Rightarrow \theta = 45^\circ$$

30. The height in terms of radius of the earth ( $R$ ), at which the acceleration due to gravity becomes  $\frac{g}{9}$ , where  $g$  is acceleration due to gravity on earth's surface, is \_\_\_\_\_.

- (1)  $\sqrt{3}R$  (2)  $2\sqrt{2}R$   
(3)  $2R$  (4)  $\frac{4}{9}R$

**Answer (3)**

**Sol.**  $\frac{1}{9} \frac{GM}{R^2} = \frac{GM}{(R+h)^2}$

$$\Rightarrow R+h = 3R$$

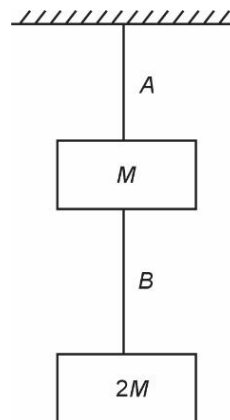
$$\Rightarrow h = 2R$$

31. A metal string  $A$  is suspended from a rigid support and its free end is attached to a block of mass  $M$ . Second block having mass  $2M$  is suspended at the bottom of the first block using a string  $B$ . The area of cross sections of strings  $A$  and  $B$  are same. The ratio of lengths of strings of  $A$  to  $B$  is 2 and the ratio of their Young's moduli ( $Y_A / Y_B$ ) is 0.5. The ratio of elongations in  $A$  to  $BA$  is \_\_\_\_\_.

- (1) 1 (2) 4  
(3) 8 (4) 6

**Answer (4)**

**Sol.**



$$\frac{\Delta l_{(A)}}{\Delta l_{(B)}} = \frac{F_1 l_1 A_2 Y_2}{A_1 Y_1 F_2 l_2}$$

$$\frac{\Delta l_{(A)}}{\Delta l_{(B)}} = \frac{3}{2} \times 2 \times 2 = 6$$

32. A water spray gun is attached to a hose of cross-sectional area  $30 \text{ cm}^2$ . The gun comprises of 10 perforations each of cross-sectional area of  $15 \text{ mm}^2$ . If the water flows in the hose with the speed of  $50 \text{ cm/s}$ , calculate the speed at which the water flows out from each perforation. (Neglect any edge effects)

- (1) 100 m/s  
(2) 10 m/s  
(3) 1000 m/s  
(4)  $15 \times 10^2$  m/s

**Answer (2)**

**Sol.**  $A_1 v_1 = \Sigma a_i v_i$

$$\Rightarrow 30 \text{ cm}^2 \times 50 \text{ cm/s} = 10 \times 15 \times 10^{-2} \text{ cm}^2 \times v$$

$$\Rightarrow v = 1000 \text{ cm/s} = 10 \text{ m/s}$$

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33. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**  
**Assertion A:** If the average kinetic energy of  $H_2$  and  $O_2$  molecules, kept in two different sized containers are same, then their temperatures will be same.

**Reason R:** The r.m.s. speed of  $H_2$  and  $O_2$  molecules are same at same temperature.

Choose the **correct** answer from the options given below.

- (1) Both **A** and **R** are true and **R** is the correct explanation of **A**
- (2) Both **A** and **R** are true but **R** is NOT the correct explanation of **A**
- (3) **A** is true but **R** is false
- (4) **A** is false but **R** is true

**Answer (3)**

**Sol.** Avg.  $KE \propto T$

$$\frac{1}{2}mv^2 \propto T$$

$$\text{So, } v_{rms}^2 = \frac{2T}{m}$$

**A** is correct and **R** is false.

34. The temperature of a metal strip having coefficient of linear expansion  $\alpha$  is increased from  $T_1$  to  $T_2$  resulting in increase of its length by  $\Delta L_1$ . The temperature is further increased from  $T_2$  to  $T_3$  such that the increase in its length is  $\Delta L_2$ .

Given  $T_3 + T_1 = 2T_2$  and  $T_2 - T_1 = \Delta T$ , the value of  $\Delta L_2$  is

- (1)  $\Delta L_1 [1 + 2\alpha^2(\Delta T)^2]$
- (2)  $\Delta L_1 [1 + \alpha^2(\Delta T)^2]$
- (3)  $\Delta L_1 [1 + 2\alpha\Delta T]$
- (4)  $\Delta L_1 [1 + \alpha\Delta T]$

**Answer (4)**

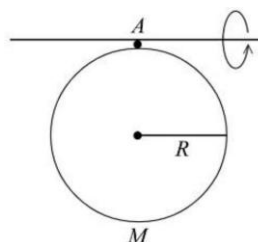
**Sol.**  $\Delta L_1 = L \alpha \Delta T$

$$\Delta L_2 = (L + L \alpha \Delta T)(1 + \alpha \Delta T) - (L + L \alpha \Delta T)$$

$$\Rightarrow \Delta L_2 = (L + L \alpha \Delta T)(\alpha \Delta T)$$

$$\Rightarrow \Delta L_2 = \Delta L_1(1 + \alpha \Delta T)$$

35. A uniform disc of radius  $R$  and mass  $M$  is free to oscillate about the axis  $A$  as shown in the figure. For small oscillations the time period is \_\_\_\_\_ . ( $g$  is acceleration due to gravity)



(1)  $2\pi\sqrt{\frac{5R}{4g}}$                       (2)  $2\pi\sqrt{\frac{2R}{3g}}$

(3)  $2\pi\sqrt{\frac{3R}{2g}}$                       (4)  $2\pi\sqrt{\frac{3R}{g}}$

**Answer (1)**

**Sol.**  $\tau = MgR\theta$  (Restoring)

$$\text{So, } \omega^2\theta = |\alpha| = 4 \frac{MgR\theta}{5MR^2} = \frac{4g}{5R}\theta$$

$$T = 2\pi\sqrt{\frac{5R}{4g}}$$

36. A rigid dipole undergoes a simple harmonic motion about its centre in the presence of an electric field  $\vec{E}_1 = E_0 \hat{x}$ . If another electric field  $\vec{E}_2 = 2E_0 (\hat{y} + \hat{z})$  is introduced to the system, what will be the percentage change in the frequency of the oscillation (approximate)?

- (1) 73%
- (2) 63%
- (3) 83%
- (4) 53%

**Answer (1)**

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Sol. In 1<sup>st</sup> case  $\tau_1 = |\vec{P}| E_0 \sin \theta$

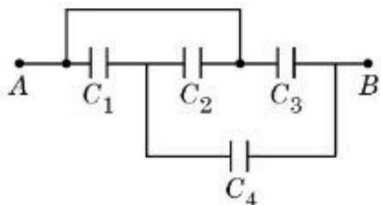
In 2<sup>nd</sup> case  $|\tau_2| = 3 |\vec{P}| E_0 \sin \theta$

$$\omega_1 = \sqrt{\frac{|\vec{P}| E_0}{I}} \quad \& \quad \omega_2 = \sqrt{\frac{3 |\vec{P}| E_0}{I}}$$

$$\Delta\omega = \sqrt{\frac{|\vec{P}| E_0}{I}} (\sqrt{3} - 1)$$

$$\text{So, } \left( \frac{\Delta\omega}{\omega_1} \times 100 \right) = (\sqrt{3} - 1) \times 100 \approx 73\%$$

37. From the circuit given below, the capacitance between terminals A and B shown in the circuit is \_\_\_\_\_  $\mu F$ .

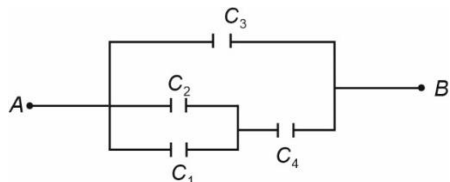


(Take  $C_1 = C_2 = C_3 = 1 \mu F$  and  $C_4 = 2 \mu F$ .)

- (1) 2
- (2) 7/2
- (3) 7/3
- (4) 5/2

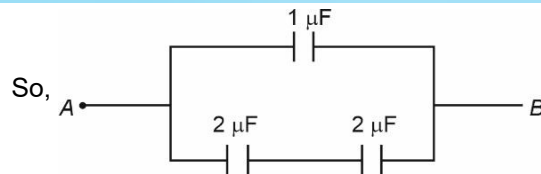
**Answer (1)**

Sol. Reduced circuit is



$C_1 = C_2 = C_3 = 1 \mu F$

and  $C_4 = 2 \mu F$



$$\Rightarrow C_{eq} = 2 \mu F$$

38. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**  
**Assertion A:** In electrostatics, a conductor does not store any net charge inside.

**Reason R:** Inside the capacitor (with no dielectric medium), the free charge carriers, if placed between the plates of capacitor, experience force and drift.

Choose the **correct** answer from the options given below

- (1) Both **A** and **R** are true and **R** is the correct explanation of **A**
- (2) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**
- (3) **A** is true but **R** is false
- (4) **A** is false but **R** is true

**Answer (3)**

Sol. Conductor well inside the capacitor does not experience any force (if end effects are neglected.) And electrostatic field inside the conductor is zero. And it does not hold any charge.

39. A solenoid has a core made of material with relative permeability 400. The magnetic field produced in the interior of solenoid is 1.0 T. The magnetic intensity in SI units is  $\alpha \times 10^5$ . The value of  $\alpha$  is \_\_\_\_\_.

(Free space permeability  $\mu_0 = 4\pi \times 10^{-7}$  SI units.)

- (1)  $\frac{25}{\pi}$
- (2)  $\frac{1}{16\pi}$
- (3)  $\frac{1}{\pi}$
- (4)  $\frac{1}{4\pi}$

**Answer (2)**

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Sol.  $B = \mu_r \cdot \mu_0 H$

$$\text{So, } H = \frac{\bar{B}}{\mu_r \cdot \mu_0} = \frac{1 \times 10^7}{400 \times 4\pi} \approx 1989.44$$

$$\Rightarrow H \approx 0.02 \times 10^5 \text{ (SI unit)} = \frac{10^5}{16\pi}$$

40. A magnetic field vector in an electromagnetic wave is represented by  $\vec{B} = B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{j}$ . Its associated electric field vector is \_\_\_\_\_.

(1)  $\vec{E} = -v\lambda B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{k}$

(2)  $\vec{E} = -v\lambda B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{i}$

(3)  $\vec{E} = v\lambda B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{k}$

(4)  $\vec{E} = v\lambda B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{i}$

Answer (1)

Sol.  $\vec{B} = B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{j}$

Phase should be same & direction of propagation is along +x-direction

Also  $\vec{E} \times \vec{B}$  will be along +x-direction

so,  $\vec{E}$  will be along -z direction

and magnitude of  $|\vec{E}| = |\vec{C}B_0|$

So,  $E = -CB_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{k}$

and  $C = \frac{2\pi\nu\lambda}{2\pi} = v\lambda$

So,  $\vec{E} = -v\lambda B_0 \sin\left(2\pi\nu t - \frac{2\pi x}{\lambda}\right) \hat{k}$

41. A convex lens is made from glass material having refractive index of 1.4 with same radius of curvature on both sides. The ratio of its focal length and radius of curvature is \_\_\_\_\_.

(1) 0.5

(2) 2.5

(3) 0.8

(4) 1.25

Answer (4)

Sol.  $\frac{1}{f} = (u-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$\Rightarrow \frac{1}{f} = \frac{0.8}{R}$$

$$\therefore \frac{f}{R} = \frac{5}{4}$$

42. An unpolarized light of certain intensity passes through a combination of two polarizers whose transmission axes are at  $30^\circ$  and  $90^\circ$ , respectively, with respect to the horizontal axis. A third polarizer with its transmission axis at  $60^\circ$  with the horizontal axis is placed between the two existing polarizers. The ratio of the output intensities with and without the third polarizer is \_\_\_\_\_.

(1) 3/4

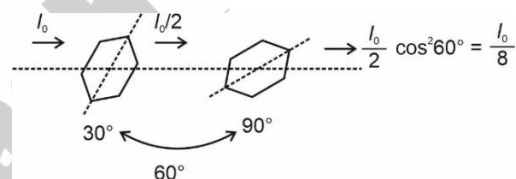
(2) 4/3

(3) 9/4

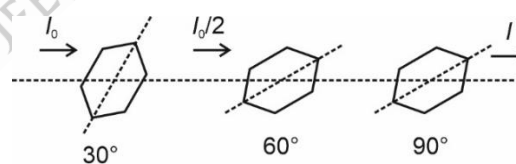
(4) 4/9

Answer (3)

Sol. Without third polariser :



With third polariser



$$I = \frac{I_0}{2} \cos^2 30^\circ \cdot \cos^2 30^\circ$$

$$\Rightarrow I = \frac{9}{32} I_0$$

$$\text{Ratio} = \frac{9I_0}{\frac{32}{I_0}} = \frac{9}{4}$$

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43. In Rutherford's alpha-particle scattering experiment, only a few alpha particles rebound back because
- The size of gold nucleus is very small as compared to the size of gold atom.
  - Alpha particle and gold nucleus have equal charge.
  - The impact parameter is minimum for a few alpha particles.
  - A few alpha particles have very high kinetic energy.
  - Only a few alpha particles undergo head-on collision with the nuclei.

Choose the correct answer from the options given below:

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

**Answer (4)**

**Sol.** Because nucleus is very small, therefore only few alpha particles will have head on collision with the nucleus.

44. The de Broglie wavelength associated with an electron accelerated through a potential difference  $V$  is  $\lambda_e$  and the de Broglie wavelength associated with a proton accelerated through the same potential difference is  $\lambda_p$ . If their corresponding masses are  $m_e$  and  $m_p$ , respectively, then the

ratio of their de Broglie wavelengths  $\left(\frac{\lambda_e}{\lambda_p}\right)$  is \_\_\_\_\_.

- (1)  $\sqrt{\frac{m_p}{m_e}}$                       (2)  $\sqrt{\frac{m_e}{m_p}}$   
(3)  $\frac{m_p}{m_e}$                       (4)  $\left(\frac{m_p}{m_e}\right)^2$

**Answer (1)**

**Sol.**  $\lambda = \frac{h}{\sqrt{2 m e V}}$

$\therefore \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$

45. Given below are two statements: one is labelled as **Assertion A** and the other is labelled as **Reason R**  
**Assertion A** : A diode under reverse-biased condition provides very small current which is nearly independent of voltage until a critical limit at which the current increases drastically.

**Reason R** : Below the critical voltage limit, only majority charge carriers flow which increases drastically above critical voltage.

choose the **correct** answer from the options given below

- (1) Both **A** and **R** are true and **R** is the correct explanation of **A**  
(2) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**  
(3) **A** is true but **R** is false  
(4) **A** is false but **R** is true

**Answer (3)**

**Sol.** Assertion is true since it is correct description of behaviour of diode in reverse biased.

Reason is false since in reverse biased, current is due to minority charge carriers

**SECTION - B**

**Numerical Value Type Questions:** This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

46. A diode has Zener voltage of 10 V and maximum power dissipation of 0.5 W, then the minimum resistance to be used in series with this diode for safety when it is connected to a 25 V power supply is \_\_\_\_\_  $\Omega$ .

**Answer (300)**

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Sol.  $V_z = 10 \text{ V}$

$$P_{\max} = 0.5 = 10 i_m$$

$$i_m = 0.05 \text{ A}$$

$$\therefore R_{\min} = \frac{25 - 10}{0.05}$$

$$\Rightarrow R_{\min} = 300 \Omega$$

47. A gun mounted on the ground fires bullets in all directions with same speed. The farthest distance the bullets could reach is 6.4 m. The speed of the bullets from the gun is \_\_\_\_\_ m/s.

(take  $g = 10 \text{ m/s}^2$ )

**Answer (8)**

Sol.  $R_{\max} = \frac{u^2}{g}$

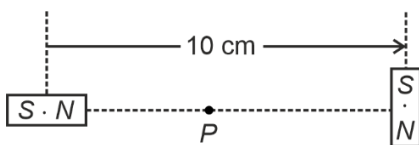
$$6.4 = \frac{u^2}{10}$$

$$u = \sqrt{64}$$

$$\Rightarrow u = 8 \text{ m/s}$$

48. Two identical small bar magnets each of dipole moment  $3\sqrt{5} \text{ J/T}$  are placed at a center to center separation of 10 cm, with their axes perpendicular to each other as shown in figure. The value of magnetic field at the point  $P$  midway between the magnets is  $\alpha \times 10^{-3} \text{ T}$ . The value of  $\alpha$  is \_\_\_\_\_.

( $\mu_0 = 4\pi \times 10^{-7} \text{ Tm/A}$ )



**Answer (12)**

Sol.  $B_P = \sqrt{B_a^2 + B_e^2}$

$$\Rightarrow B_P = \frac{KM}{r^3} \sqrt{5}$$

$$\Rightarrow B_P = \frac{10^{-7} \times 3\sqrt{5} \times \sqrt{5}}{125 \times 10^{-6}}$$

$$B_P = 12 \times 10^{-3} \text{ T}$$

49. A circular coil of radius 2 cm and 125 turns carries a current of 1 A. The coil is placed in a uniform magnetic field of magnitude 0.4 T. The axis of the coil makes an angle of  $30^\circ$  with the direction of the magnetic field. The torque acting on the coil is  $\alpha \times 10^{-4} \text{ N.m}$ . The value of  $\alpha$  is \_\_\_\_\_.

( $\pi = 3.14$ )

**Answer (314)**

Sol.  $\tau = MB \sin \theta$

$$\Rightarrow \tau = NIAB \sin \theta$$

$$\Rightarrow \tau = 125 \times 1 \times \pi \times 4 \times 10^{-4} \times 0.4 \times \sin 30^\circ$$

$$\Rightarrow \tau = 314 \times 10^{-4} \text{ N-m}$$

50. In a double slit experiment, when one of the slits is covered by a transparent mica sheet of refractive index 1.56, the central fringe shifts to the position of 7<sup>th</sup> bright fringe, obtained with both slits uncovered. If the light source wavelength is 450 nm, the thickness of mica sheet is  $\alpha \times 10^{-9} \text{ m}$ . The value of  $\alpha$  is \_\_\_\_\_.

**Answer (5625)**

Sol.  $(u-1)t = \frac{d}{D} \times \frac{7\lambda D}{d}$

$$\Rightarrow t = \frac{7\lambda}{u-1}$$

$$\Rightarrow t = \frac{7 \times 450 \times 10^{-9}}{0.56}$$

$$\Rightarrow t = 5625 \times 10^{-9} \text{ m}$$

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**CHEMISTRY**

**SECTION - A**

**Multiple Choice Questions:** This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

**Choose the correct answer:**

51. The correct order of total number of atoms present in

- (A) 2 moles of cyclohexane  
 (B) 684 g of sucrose  
 (C) 90.8 L of dihydrogen at STP  
 (1)  $C > A > B$                       (2)  $C > B > A$   
 (3)  $B > C > A$                       (4)  $B > A > C$

**Answer (4)**

**Sol.** (A)  $C_6H_{12}$  (cyclohexane)

1 mol contain  $18 N_A$  atoms

2 mol contain  $36 N_A$  atoms

(B)  $C_{12}H_{22}O_{11}$  (sucrose)

mol of sucrose =  $\frac{684}{342}$  mol = 2 mol

Number of atom =  $2 \times 45 N_A = 90 N_A$

(C) 90.8 L  $H_2$  at STP

mol of  $H_2 = \frac{90.8}{22.7} = 4$  mol

Number of atoms =  $2 \times 4 N_A = 8 N_A$

52. The species having identical radii according to the Bohr's theory are:

- A. H (first orbit)  
 B.  $He^+$  (first orbit)  
 C.  $He^+$  (Second orbit)  
 D.  $Li^{2+}$  (first orbit)  
 E.  $Be^{3+}$  (Second orbit)

Choose the correct answer from the options given below:

- (1) A and C Only                      (2) A and E Only  
 (3) B and E Only                      (4) C and D Only

**Answer (2)**

**Sol.**  $r_n = a_0 \frac{n^2}{Z} \text{ \AA}$

(A)  $H \Rightarrow a_0 \frac{1^2}{1} = a_0$

(B)  $He^+ \Rightarrow a_0 \frac{1^2}{2} = 0.5a_0$

(C)  $He^+ \Rightarrow a_0 \frac{2^2}{2} = 2a_0$

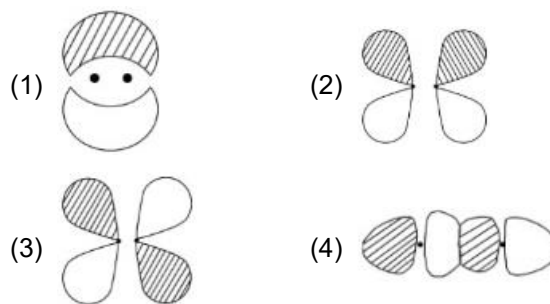
(D)  $Li^{2+} \Rightarrow a_0 \frac{1^2}{3} = 0.33a_0$

(E)  $B^{3+} \Rightarrow a_0 \frac{4}{4} = a_0$

A and E only have same radius

53. Which of the following pictorial diagram most correctly represents the  $\pi^*$  ( $\pi$ -antibonding) molecular orbital between two atoms if the internuclear axis is taken to be in the z-direction

( $\xrightarrow{\text{z-axis}}$ ) ?



**Answer (3)**

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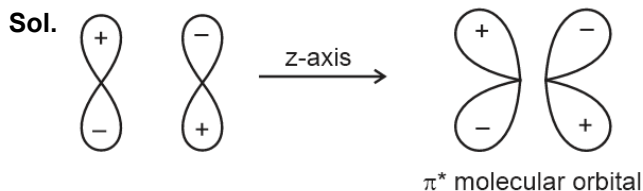


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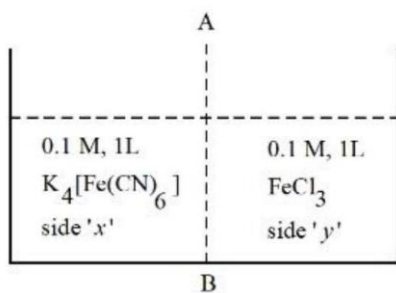


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54. At  $27^\circ\text{C}$ ,  $0.1\text{M}$ ,  $1\text{L}$   $\text{K}_4[\text{Fe}(\text{CN})_6]$  aqueous solution and  $0.1\text{M}$ ,  $1\text{L}$   $\text{FeCl}_3$  aqueous solution are placed in a container separated by a semi permeable membrane AB. Assume complete dissociation of both the solutes. Which of the following statement is **correct**?



- (1) Blue color is formed on both sides.
- (2) Ionic solutes in aqueous solution can pass through semi-permeable membrane.
- (3) Solution on side 'y' is hypotonic.
- (4) To cause the reverse flow of solvent during osmosis, external pressure (any value) should be applied to side 'x'.

**Answer (3)**

**Sol. Side x**

$$i = 5$$

**Side y**

$$i = 4$$

$$\pi \propto iCRT$$

$$\pi_x > \pi_y$$

Side x is hypertonic and side y is hypotonic.

55. 20 mL of a solution of acetic acid required 28.4 mL of  $0.1\text{M}$   $\text{NaOH}$  for its neutralization. A solution (X) was prepared by mixing 20 mL of the above acetic acid and 14.2 mL of  $0.1\text{M}$   $\text{NaOH}$  solution. What is the pH of the solution (X) ? ( $\text{pK}_a$  value of acetic acid is 4.75).

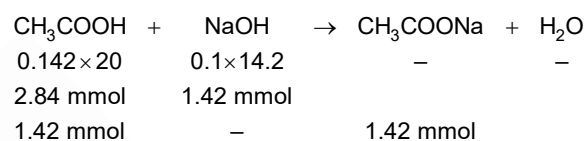
- (1) 7.0
- (2) 4.75
- (3) 3.5
- (4) 4.82

**Answer (2)**

$$\text{Sol. } (M \times V \times n_f)_{\text{CH}_3\text{COOH}} = (M \times V \times n_f)_{\text{NaOH}}$$

$$M \times 20 \times 1 = 0.1 \times 28.4 \times 1$$

$$m_{\text{CH}_3\text{COOH}} = \frac{2.84}{20} \text{ M} = 0.142 \text{ M}$$



$$\text{pH} = 4.75 + \log \frac{1.42}{1.42} = 4.75$$

56. Match the LIST-I with LIST-II

List-I Reaction		List-II Mechanism	
A.	Williamson Synthesis	I.	Electrophilic addition
B.	Friedel Craft Reaction	II.	Free radical substitution
C.	Bromination of vinyl benzene	III.	Nucleophilic substitution
D.	Chlorination of toluene in light	IV.	Electrophilic substitution

Choose the **correct** answer from the options given below:

- (1) A-III, B-I, C-II, D-IV
- (2) A-III, B-IV, C-II, D-I
- (3) A-III, B-IV, C-I, D-II
- (4) A-I, B-III, C-IV, D-II

**Answer (3)**

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- Sol.** A  $\Rightarrow$  Nucleophilic substitution (III)  
 B  $\Rightarrow$  Electrophilic substitution (IV)  
 C  $\Rightarrow$  Electrophilic addition (I)  
 D  $\Rightarrow$  Free radical substitution (II)
57. The 1<sup>st</sup> ionization enthalpy for Mg is +737 kJ/mol. The most probable estimated value of the 2<sup>nd</sup> ionization enthalpy of Mg is \_\_\_\_\_.  
 (1) -906 kJ/mol      (2) -856 kJ/mol  
 (3) +1450 kJ/mol      (4) +590 kJ/mol

**Answer (3)**

- Sol.** Successive ionisation enthalpy always increases  
 $IE_1 < IE_2$   
 $IE_2$  of Mg = 1450 kJ/mol
58. The electronegativity of a group 13 element 'E' is same as that of Ge (on Pauling scale and upto one decimal point). The **CORRECT** statements about  $E^{3+}$  are  
 A. It can act as a reducing agent.  
 B. It can act as an oxidizing agent.  
 C.  $E^{3+}$  is more stable than  $E^+$ .  
 D. The standard electrode potential value for  $E^{3+}/E$  is positive.  
 Choose the correct answer from the options given below:  
 (1) A and C Only      (2) B and C Only  
 (3) B and D Only      (4) A and D Only

**Answer (3)**

- Sol.** Electronegativity of Ge = 1.8  
 Electronegativity of Tl = 1.8  
 $Tl^{3+}$  is an strong oxidising agent due to inert pair effect  
 $E_{Tl^{3+}/Tl}^\circ = 0.72 V$

59. Pairs of elements with the same number of electrons in their respective 4f orbital are  
 [Atomic number. Eu-63, Gd-64, Dy-66, Ho-67, Tm-69, Yb-70, Lu-71, Hf-72]  
 A. (Eu and Gd)  
 B. (Dy and Ho)  
 C. (Yb and Hf)  
 D. (Lu and Tm)

Choose the correct answer from the options given below:

- (1) B and C Only      (2) A and B Only  
 (3) A and D Only      (4) A and C Only

**Answer (4)**

- Sol.** Eu =  $4f^7 6s^2$   
 Gd =  $4f^7 5d^1 6s^2$   
 Dy =  $4f^{10} 6s^2$   
 Ho =  $4f^{11} 6s^2$   
 Yb =  $4f^{14} 6s^2$   
 Hf =  $4f^{14} 5d^2 6s^2$   
 Lu =  $4f^{14} 5d^1 6s^2$   
 Tm =  $4f^{13} 6s^2$
60. Consider the metal complexes  $[Ni(en)_3]^{2+}$  (A),  $[NiCl_4]^{2-}$  (B) and  $[Ni(NH_3)_6]^{2+}$  (C). Choose the **CORRECT** option by considering the number of unpaired electrons present in (A), (B) and (C) respectively and the order of frequency of absorption.  
 (1) 2, 2, 2 and (A) > (C) > (B)  
 (2) 0, 2, 0 and (A) > (C) > (B)  
 (3) 2, 2, 0 and (B) > (C) > (A)  
 (4) 2, 2, 2 and (C) > (A) > (B)

**Answer (1)**

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Sol.  $Ni^{2+} \Rightarrow en \Rightarrow sp^3d^2 \Rightarrow n = 2$

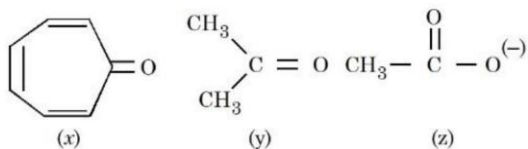
$Ni^{2+} \Rightarrow Cl^- \Rightarrow sp^3 \Rightarrow n = 2$

$Ni^{2+} \Rightarrow NH_3 \Rightarrow sp^3d^2 \Rightarrow n = 2$

Ligand strength  $en > NH_3 > Cl^-$

Order of frequency of adsorption  $A > C > B$

61. Consider the following molecules/species:

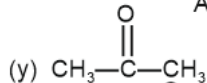
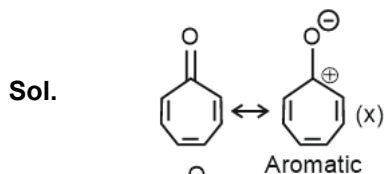


The correct order of carbon - oxygen double bond length is:

(1)  $x > y > z$                       (2)  $y > z > x$

(3)  $z > x > y$                       (4)  $x > z > y$

**Answer (4)**



62. Consider  $|x|$  is the difference in oxidation states of Mn in highest manganese fluoride and highest manganese oxide. The ions with  $|x|$  number of unpaired electrons from the following are:

A.  $Sc^{3+}$

B.  $Zn^{2+}$

C.  $V^{2+}$

D.  $Fe^{2+}$

E.  $Co^{2+}$

Choose the correct answer from the options given below:

(1) A and B Only

(2) C, D and E Only

(3) C and E Only

(4) B and E Only

**Answer (3)**

Sol.  $MnF_4 \Rightarrow Mn^{+4}$

$Mn^{2+}O_7 \Rightarrow Mn^{+7}$

$|x| = |7 - 4| = 3$

Unpaired electron

(A)  $Sc^{3+} \Rightarrow 0$

(B)  $Zn^{2+} \Rightarrow 0$

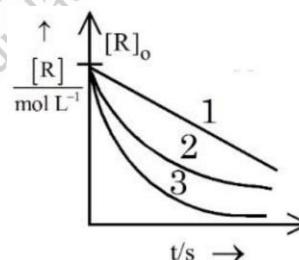
(C)  $V^{2+} \Rightarrow 3$

(D)  $Fe^{3+} \Rightarrow 4$

(E)  $Co^{2+} \Rightarrow 3$

63. Consider the given graph showing variation of reactant concentration with time.

Three different reactions were started with identical initial concentration of reactants. Which of the following statement is correct?



(1) The order of all the three reactions is same.

(2) The rate constant of reaction 3 is larger than the rate constant of reaction 2 if the order of reaction is same for both.

(3) The SI unit of rate constant of reaction 1 is  $s^{-1}$ .

(4) Thermal decomposition of HI on gold surface is an example of reaction 2.

**Answer (2)**

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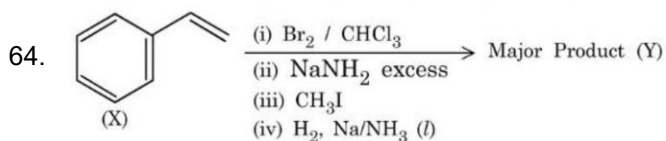
**Sol.** 1  $\Rightarrow$  zero order reaction

2 and 3  $\Rightarrow$  first order reaction

$$R = R_0 e^{-kt}$$

$$k_3 > k_2$$

Thermal decomposition of HI on gold surface follow zero order kinetics.

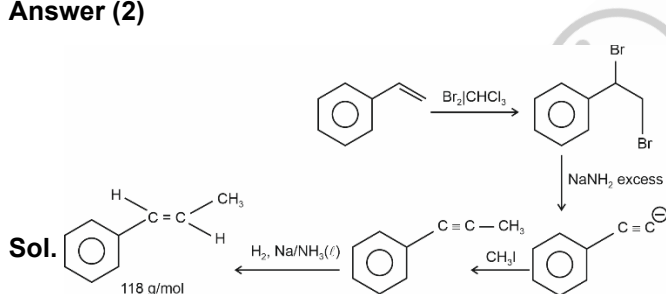


Compound (X) is subjected to the sequence of reactions as shown above. Molar mass of the major product (Y) formed is \_\_\_\_\_ g mol<sup>-1</sup>.

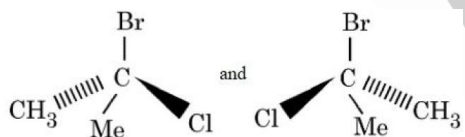
(Given molar mass in g mol<sup>-1</sup> C : 12, H : 1, O : 16 )

- (1) 90                                      (2) 118  
(3) 160                                      (4) 125

**Answer (2)**



65. The following structures are



- (1) enantiomers.  
(2) identical molecules.  
(3) diastereomers.  
(4) meso compounds.

**Answer (2)**

**Sol.** Both molecule does not contain chiral centre, Hence both are identical.

66. The descending order of acidity among the following compounds is:



Choose the correct answer from the options given below:

- (1) B > D > E > A > C  
(2) D > B > E > A > C  
(3) C > A > B > D > E  
(4) D > E > B > A > C

**Answer (4)**

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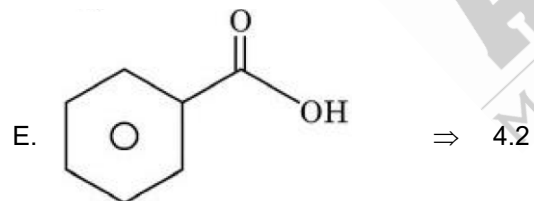
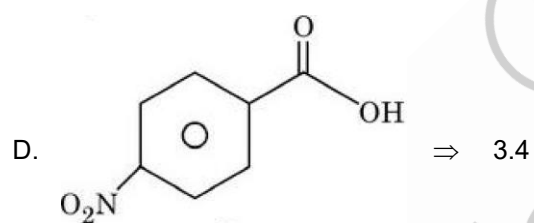
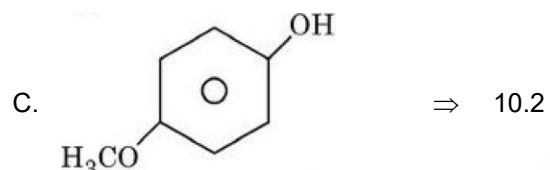
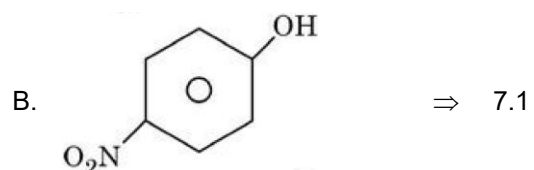
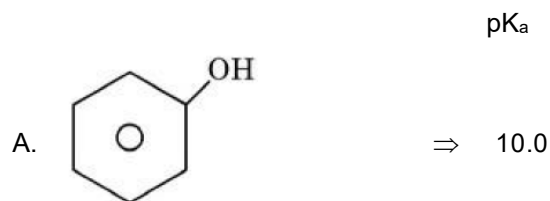
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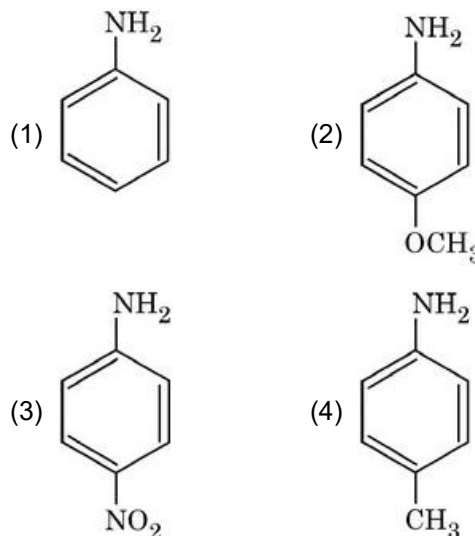
Sol. Carboxylic acids are more acidic than phenol and its derivatives



More stable the conjugate base, more will be the acidic strength.

D > E > B > A > C

67. The strongest conjugate acid will result from:



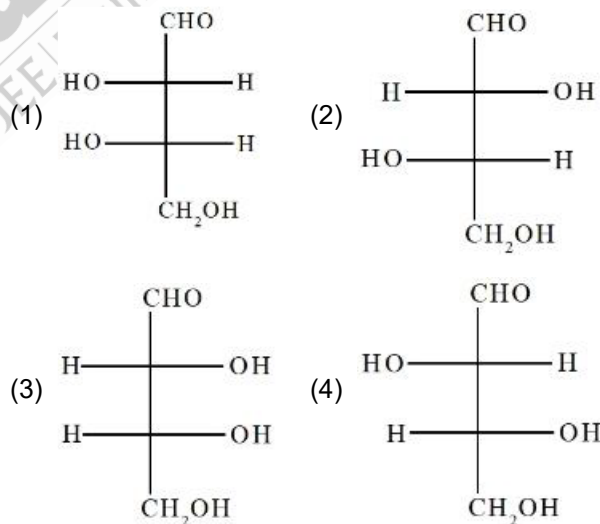
Answer (3)

Sol. Strong base  $\Rightarrow$  Weak conjugate acid

Weak base  $\Rightarrow$  Strong conjugate acid

Due to -M effect of  $-\text{NO}_2$  group p-nitroaniline is weakest base.

68. A D-aldotetrose on oxidation with concentrated  $\text{HNO}_3$  resulted in optically inactive dicarboxylic acid. The structure of the D-aldotetrose is:



Answer (3)

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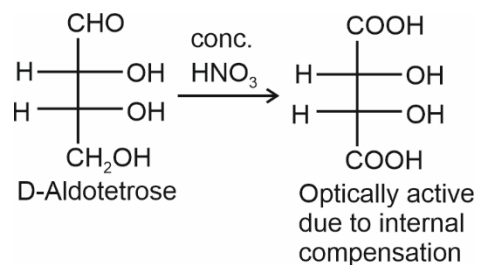
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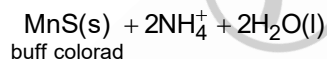
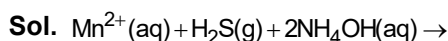
Sol.



69. Among  $\text{Fe}^{3+}$ ,  $\text{Pb}^{2+}$ ,  $\text{Cu}^{2+}$  and  $\text{Mn}^{2+}$ , identify the one that gets precipitated out while passing  $\text{H}_2\text{S}$  in presence of  $\text{NH}_4\text{OH}$  as group reagent. The highest possible oxidation state of the corresponding metal is

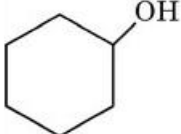
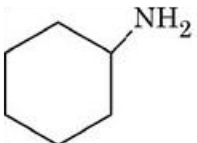
- (1) +3  
(2) +4  
(3) +2  
(4) +7

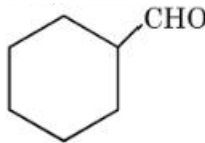
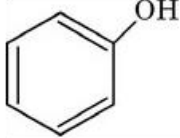
Answer (4)



Mn can show maximum upto +7 oxidation state.

70. Match the LIST-I with LIST-II

List-I Compound		List-II Test	
A.		I.	Hinsberg's reagent test
B.		II.	Phthalein dye test

C.		III.	Lucas test
D.		IV.	Tollen's test

Choose the **correct** answer from the options given below:

- (1) A-III, B-I, C-IV, D-II (2) A-III, B-IV, C-I, D-II  
(3) A-I, B-III, C-II, D-IV (4) A-I, B-II, C-III, D-IV

Answer (1)

Sol.

A	→	III.	Lucas test
B	→	I.	Hinsberg's reagent test
C	→	IV.	Tollen's test
D	→	II.	Phthalein dye test

### SECTION - B

**Numerical Value Type Questions:** This section contains 5 Numerical based questions. The answer to each question should be rounded-off to the nearest integer.

71. If 3.365 g of ethanol (l) is burnt completely in a bomb calorimeter at 298.15 K, the heat produced is 99.472 kJ. The  $|\Delta H_f^\circ|$  of ethanol at 298.15 K is \_\_\_\_\_  $\times 10^2$  kJ mol<sup>-1</sup>. (Nearest integer)

Given: Standard enthalpy for combustion of graphite =  $-393.5$  kJ mol<sup>-1</sup>

Standard enthalpy of formation of water (l) =  $-285.8$  kJ mol<sup>-1</sup>

Molar mass in g mol<sup>-1</sup> of C, H, O are 12, 1 and 16 respectively

Answer (282)

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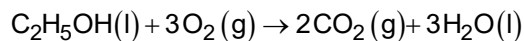
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Sol. Mole of  $C_2H_5OH = \frac{3.365}{46}$   
 $= 0.07315 \text{ mol}$

$$\Delta U = \frac{-99.472}{0.07315}$$

$$= -1360 \text{ kJ/mol}$$



$$\Delta n_g = -1$$

$$\Delta H_c^\circ = \Delta U_c^\circ + \Delta n_g RT$$

$$= -1360 - 1 \times 8.314 \times 10^{-3} \times 298.15$$

$$= -1362.48 \text{ kJ/mol}$$

$$\Delta H_f^\circ(CO_2) = -393.5 \text{ kJmol}^{-1}$$

$$\Delta H_f^\circ(H_2O) = -285.8 \text{ kJmol}^{-1}$$

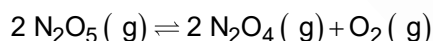
$$\Delta H_c^\circ = 2\Delta H_f^\circ CO_2 + 3\Delta H_f^\circ H_2O - \Delta H_f^\circ C_2H_5OH$$

$$\Delta H_f^\circ C_2H_5OH = -1644.4 + 1362.48$$

$$= -281.92 \text{ kJmol}^{-1}$$

$$(\Delta H_f^\circ) C_2H_5OH \approx 282 \text{ kJ/mol}$$

72. For the following reaction at  $50^\circ C$  and at 2 atm pressure,



$N_2O_5$  is 50% dissociated.

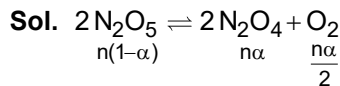
The magnitude of standard free energy change at this temperature is x.

$$x = \text{_____ J mol}^{-1} \text{ [Nearest integer].}$$

Given:  $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ ,  $\log 2 = 0.30$ ,

$\log 3 = 0.48$ ,  $\ln 10 = 2.303$ ,  $^\circ C + 273 = K$

Answer (2474)



$$\alpha = 0.5$$

$$n_T = 1.25n$$

$$p_{N_2O_5} = \frac{0.5n}{1.25n} \times 2 = 0.8 \text{ atm}$$

$$p_{N_2O_4} = \frac{0.5n}{1.25n} \times 2 = 0.8 \text{ atm}$$

$$p_{O_2} = \frac{0.25n}{1.25n} \times 2 = 0.4 \text{ atm}$$

$$K_p = \frac{(0.8)^2 (0.4)}{(0.8)^2}$$

$$= 0.4$$

$$\Delta G^\circ = -RT \ln K_p$$

$$= -2.303 RT \log K_p$$

$$T = 273 + 50 = 323 K$$

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\Delta G^\circ = -2.303 \times 8.314 \times 323 \times \log 0.4$$

$$\Delta G^\circ = 2473.79$$

$$\approx 2474 \text{ J/mol}$$

73. An electrochemical cell, consist of the following two

redox couples,  $M^{X+}(aq)/M(s) [E_{red}^\ominus = +0.15 \text{ V}]$

and  $Fe^{3+}(aq)/Fe(s) [E_{red}^\ominus = -0.036 \text{ V}]$ . The cell

EMF ( $E_{cell}$ ) is recorded to be 0.2057 V. If the

reaction quotient of the electrochemical reaction is

found to be  $10^{-2}$ , then the value of x is \_\_\_\_\_.

(Nearest integer)

[Given : M is a p-block metal and

$$\frac{2.303RT}{F} = 0.059 \text{ V}]$$

Answer (2)

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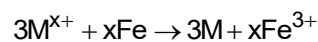
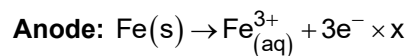
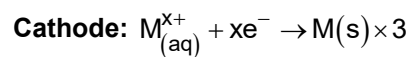
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**Sol.**  $E_{M^{x+}/M}^0 = +0.15V$

$E_{Fe^{3+}/Fe}^0 = -0.036V$

$E_{cell}^0 = 0.15 - (-0.036) = 0.186V$



$E_{cell} = E_{cell}^0 - \frac{0.059}{3x} \log Q$

$0.2057 = 0.186 - \frac{0.059}{3x} \log(10^{-2})$

$0.0197 = \frac{0.118}{3x} \Rightarrow x = 1.996 \approx 2$

74. For a first order reaction  $A \rightarrow B$

t/min	[A]/M
0	0.6500
x	0.0650
20	0.00065

x = \_\_\_\_\_ min. (Nearest integer)

**Answer (7)**

**Sol.**  $k = \frac{1}{t} \ln \frac{0.65}{0.00065}$

$k = \frac{1}{20} \ln 10^3$

$k = \frac{3}{20} \ln 10$

$k = \frac{1}{x} \ln \frac{0.65}{0.065} = \frac{3}{20} \ln 10$

$\frac{1}{x} \ln 10 = \frac{3}{20} \ln 10$

$3x = 20 \Rightarrow x = \frac{20}{3} = 6.67$

75. In sulphur estimation,  $2.0 \times 10^{-3}$  mol of an organic compound (X) (molar mass  $76 \text{ g mol}^{-1}$ ) gave 0.4813 g of barium sulphate (molar mass  $233 \text{ g mol}^{-1}$ ). The percentage of sulphur in the compound (X) is \_\_\_\_\_  $\times 10^{-1}\%$  (Nearest integer)

**Answer (435)**

**Sol.** Mass of organic compound

$= 2 \times 10^{-3} \times 76 \text{ g} = 0.152 \text{ g}$

Mole of  $BaSO_4 = \text{mol of S} = \frac{0.4813}{233} \text{ mol}$

$= 0.0021 \text{ mol}$

Mass of S =  $0.0021 \times 32 \text{ g} = 0.0661 \text{ g}$

$\% \text{ S} = \frac{0.0661}{0.152} \times 100 = 43.48\% \approx 434.8 \times 10^{-1}\%$



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