



## JEE Main Online Exam 2025

Questions & Solution  
24<sup>th</sup> January 2025 | Evening

### MATHEMATICS

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

- Q.1** The equation of the chord, of the ellipse  $\frac{x^2}{25} + \frac{y^2}{16} = 1$ , whose mid-point is (3,1) is :
- (1)  $48x + 25y = 169$                       (2)  $4x + 122y = 134$                       (3)  $25x + 101y = 176$                       (4)  $5x + 16y = 31$

**Ans.** [1]

**Sol.** Equation of chord with given middle point

$$T = S_1$$

$$\Rightarrow \frac{3x}{25} + \frac{y}{16} - 1 = \frac{9}{25} + \frac{1}{16} - 1$$

$$48x + 25y = 144 + 25$$

$$48x + 25y = 169 \text{ Ans.}$$

- Q.2** The function  $f : (-\infty, \infty) \rightarrow (-\infty, 1)$ , defined by  $f(x) = \frac{2^x - 2^{-x}}{2^x + 2^{-x}}$  is :

- (1) One-one but not onto                      (2) Onto but not one-one  
(3) Both one-one and onto                      (4) Neither one-one nor onto

**Ans.** [1]

**Sol.**  $f(x) = \frac{2^{2x} - 1}{2^{2x} + 1}$

$$= 1 - \frac{2}{2^{2x} + 1}$$

$$f'(x) = \frac{2}{(2^{2x} + 1)^2} \cdot 2 \cdot 2^{2x} \cdot \ln 2 \text{ i.e. always + ve}$$

so  $f(x)$  is  $\uparrow$  function

$$\therefore f(-\infty) = -1$$

$$f(\infty) = 1$$

$\therefore f(x) \in (-1, 1) \neq \text{co-domain}$

so function is one-one but not onto

- Q.3** If  $\alpha > \beta > \gamma > 0$ , then the expression

$$\cot^{-1} \left\{ \beta + \frac{(1 + \beta^2)}{(\alpha - \beta)} \right\} + \cot^{-1} \left\{ \gamma + \frac{(1 + \gamma^2)}{(\beta - \gamma)} \right\} + \cot^{-1} \left\{ \alpha + \frac{(1 + \alpha^2)}{(\gamma - \alpha)} \right\} \text{ is equal to :}$$

- (1)  $\frac{\pi}{2} - (\alpha + \beta + \gamma)$                       (2)  $3\pi$                       (3)  $0$                       (4)  $\pi$

Ans. [4]

Sol.  $\Rightarrow \cot^{-1} \left( \frac{\alpha\beta+1}{\alpha-\beta} \right) + \cot^{-1} \left( \frac{\beta\gamma+1}{\beta-\gamma} \right) + \cot^{-1} \left( \frac{\alpha\gamma+1}{\gamma-\alpha} \right)$   
 $\Rightarrow \tan^{-1} \left( \frac{\alpha-\beta}{1+\alpha\beta} \right) + \tan^{-1} \left( \frac{\beta-\gamma}{1+\beta\gamma} \right) + \pi + \tan^{-1} \left( \frac{\gamma-\alpha}{1+\gamma\alpha} \right)$   
 $\Rightarrow (\tan^{-1}\alpha - \tan^{-1}\beta) + (\tan^{-1}\beta - \tan^{-1}\gamma) + (\pi + \tan^{-1}\gamma - \tan^{-1}\alpha)$   
 $\Rightarrow \pi$

Q.4 Let  $f : (0, \infty) \rightarrow \mathbf{R}$  be a function which is differentiable at all points of its domain and satisfies the condition  $x^2 f'(x) = 2xf(x) + 3$ , with  $f(1) = 4$ . Then  $2f(2)$  is equal to :

(1) 29

(2) 19

(3) 39

(4) 23

Ans. [3]

Sol.  $x^2 f'(x) - 2xf(x) = 3$   
 $\left( \frac{x^2 f'(x) - 2xf(x)}{(x^2)^2} \right) = \frac{3}{(x^2)^2}$   
 $\Rightarrow \frac{d}{dx} \left( \frac{f(x)}{x^2} \right) = \frac{3}{x^4}$

Integrating both sides

$$\frac{f(x)}{x^2} = -\frac{1}{x^3} + C$$

$$f(x) = -\frac{1}{x} + Cx^2$$

put  $x = 1$

$$4 = -1 + C \Rightarrow C = 5$$

$$f(x) = -\frac{1}{x} + 5x^2$$

$$\text{Now } 2 \times f(2) = 2 \times \left[ -\frac{1}{2} + 5 \times 2^2 \right]$$
$$= 39$$

Q.5 Let  $A = \left\{ x \in (0, \pi) - \left\{ \frac{\pi}{2} \right\} : \log_{(2/\pi)} |\sin x| + \log_{(2/\pi)} |\cos x| = 2 \right\}$  and  $B = \left\{ x \geq 0 : \sqrt{x}(\sqrt{x}-4) - 3|\sqrt{x}-2| + 6 = 0 \right\}$ .

Then  $n(A \cup B)$  is equal to :

(1) 4

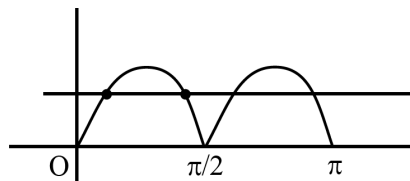
(2) 2

(3) 8

(4) 6

Ans. [3]

Sol.  $A : \log_{2/\pi} |\sin x| + \log_{2/\pi} |\cos x| = 2$   
 $\Rightarrow \log_{2/\pi} (|\sin x \cdot \cos x|) = 2$   
 $\Rightarrow |\sin 2x| = \frac{8}{\pi^2}$





Number of solution 4

B : let  $\sqrt{x} = t < 2$

Then  $\sqrt{x} (\sqrt{x} - 4) + 3 (\sqrt{x} - 2) + 6 = 0$

$$\Rightarrow t^2 - 4t + 3t - 6 + 6 = 0$$

$$\Rightarrow t^2 - t = 0, t = 0, t = 1$$

$$x = 0, x = 1$$

again let  $\sqrt{x} = t > 2$

then  $t^2 - 4t - 3t + 6 + 6 = 0$

$$\Rightarrow t^2 - 7t + 12 = 0$$

$$\Rightarrow t = 3, 4$$

$$x = 9, 16$$

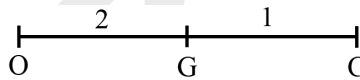
Total number of solutions

$$n(A \cup B) = 4 + 4 = 8$$

- Q.6** Let the position vectors of three vertices of a triangle be  $4\vec{p} + \vec{q} - 3\vec{r}$ ,  $-5\vec{p} + \vec{q} + 2\vec{r}$  and  $2\vec{p} - \vec{q} + 2\vec{r}$ . If the position vectors of the orthocenter and the circumcenter of the triangle are  $\frac{\vec{p} + \vec{q} + \vec{r}}{4}$  and  $\alpha\vec{p} + \beta\vec{q} + \gamma\vec{r}$  respectively, then  $\alpha + 2\beta + 5\gamma$  is equal to :
- (1) 3 (2) 1 (3) 6 (4) 4

**Ans.** [1]

**Sol.** We know that



O (orthocentre)  $\frac{\vec{p} + \vec{q} + \vec{r}}{4}$

C (circum centre)  $\alpha\vec{p} + \beta\vec{q} + \gamma\vec{r}$

G (centroid) =  $\frac{\vec{p} + \vec{q} + \vec{r}}{3}$

by relation

$$\Rightarrow 2(\alpha\vec{p} + \beta\vec{q} + \gamma\vec{r}) + \frac{\vec{p} + \vec{q} + \vec{r}}{4} = 3 \left( \frac{\vec{p} + \vec{q} + \vec{r}}{3} \right)$$

$$\Rightarrow 8(\alpha\vec{p} + \beta\vec{q} + \gamma\vec{r}) = 3(\vec{p} + \vec{q} + \vec{r})$$

$$\Rightarrow 8\alpha = 3, 8\beta = 3, 8\gamma = 3$$

$$\alpha = \frac{3}{8}, \beta = \frac{3}{8}, \gamma = \frac{3}{8}$$

$$\therefore \alpha + 2\beta + 3\gamma$$

$$\frac{3}{8} + \frac{6}{8} + \frac{15}{8} = \frac{24}{8} = 3$$

- Q.7** Let  $[x]$  denote the greatest integer function, and let  $m$  and  $n$  respectively be the numbers of the points, where the function  $f(x) = [x] + |x - 2|$ ,  $-2 < x < 3$ , is not continuous and not differentiable. Then  $m + n$  is equal to:  
 (1) 6 (2) 9 (3) 8 (4) 7

**Ans.** [3]

**Sol.**

$$f(x) = [x] + |x - 2| \quad -2 < x < 3$$

$$f(x) = \begin{cases} -x, & -2 < x < -1 \\ -x + 1, & -1 \leq x < 0 \\ -x + 2, & 0 \leq x < 1 \\ -x + 3, & 1 \leq x < 2 \\ x, & 2 \leq x < 3 \end{cases}$$

So  $f(x)$  is not continuous at 4 points and not differentiable at 4 point  
 So  $m + n = 4 + 4 = 8$

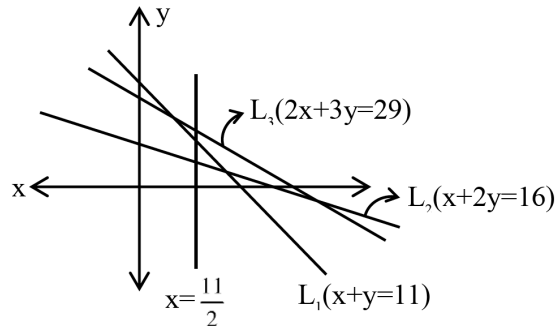
- Q.8** Let the points  $\left(\frac{11}{2}, \alpha\right)$  lie on or inside the triangle with sides  $x + y = 11$ ,  $x + 2y = 16$  and  $2x + 3y = 29$ .

Then the product of the smallest and the largest values of  $\alpha$  is equal to :

- (1) 22 (2) 44 (3) 33 (4) 55

**Ans.** [3]

**Sol.**



Point of intersection of  $x = \frac{11}{2}$  with  $L_1$  &  $L_3$  gives,  $\alpha_{\min} = \frac{11}{2}$  and  $\alpha_{\max} = 6$

$$\therefore \alpha_{\min} \cdot \alpha_{\max} = \frac{11}{2} \times 6 = 33$$

- Q.9** In an arithmetic progression, if  $S_{40} = 1030$  and  $S_{12} = 57$ , then  $S_{30} - S_{10}$  is equal to :

- (1) 510 (2) 515 (3) 525 (4) 505

**Ans.** [2]

**Sol.**

Let  $a$  &  $d$  are first term and common diff of an AP.

$$S_{40} = \frac{40}{2} [2a + 39d] = 1030 \quad \dots(1)$$

$$S_{12} = \frac{12}{2} [2a + 11d] = 57 \quad \dots(2)$$

by (1) & (2)

$$a = -\frac{7}{2} \quad d = \frac{3}{2}$$

$$\begin{aligned} \therefore S_{30} - S_{10} &= \frac{30}{2} [2a + 29d] - \frac{10}{2} [2a + 9d] \\ &= 20a - 390d \\ &= 515 \end{aligned}$$

**Q.10** If  $7 = 5 + \frac{1}{7}(5 + \alpha) + \frac{1}{7^2}(5 + 2\alpha) + \frac{1}{7^3}(5 + 3\alpha) + \dots \infty$ , then the value of  $\alpha$  is :

- (1) 1                                  (2)  $\frac{6}{7}$                                   (3) 6                                  (4)  $\frac{1}{7}$

**Ans.** [3]

**Sol.** Let  $S = 5 + \frac{1}{7}(5 + \alpha) + \frac{1}{7^2}(5 + 2\alpha) + \dots$

$$\frac{1}{7}S = \frac{1}{7}(5) + \frac{1}{7^2}(5 + \alpha) + \dots \infty$$

$$\frac{6}{7}(S) = 5 + \frac{1}{7}\alpha \left( \frac{1}{1 - \frac{1}{7}} \right)$$

$$6 = 5 + \frac{\alpha}{6} \Rightarrow \alpha = 6$$

**Q.11** If the system of equations

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

$$2x + \lambda y + 5z = 5$$

$$14x + 3y + \mu z = 33$$

has infinitely many solutions, then  $\lambda + \mu$  is equal to :

- (1) 13                                  (2) 10                                  (3) 11                                  (4) 12

**Ans.** [4]

**Sol.**  $D = \begin{vmatrix} 1 & 2 & -3 \\ 2 & \lambda & 5 \\ 14 & 3 & \mu \end{vmatrix} = 0, \lambda\mu + 42\lambda - 4\mu + 107 = 0$

$$D_1 = 2\lambda\mu + 99\lambda - 10\mu + 255$$

$$D_2 = 13 - \mu$$

$$D_3 = 5\lambda + 5$$

$$D_2 = 0 \Rightarrow \mu = 13 \text{ \& } D_3 = 0 \Rightarrow \lambda = -1$$

check & verify for these values  $D_1$  &  $D_2 = 0$

**Q.12** Let  $(2, 3)$  be the largest open interval in which the function  $f(x) = 2 \log_e(x - 2) - x^2 + ax + 1$  is strictly increasing and  $(b, c)$  be the largest open interval, in which the function  $g(x) = (x - 1)^3(x + 2 - a)^2$  is strictly decreasing. Then  $100(a + b - c)$  is equal to :

- (1) 280                                  (2) 360                                  (3) 420                                  (4) 160

**Ans.** [2]

**Sol.**  $f'(x) = \frac{2}{x-2} - 2x + a \geq 0$

$$f''(x) = \frac{-2}{(x-2)^2} - 2 < 0$$

$$f'(x) \downarrow$$

$$f'(3) \geq 0$$

$$2 - 6 + a \geq 0$$

$$a \geq 4$$

$$\begin{aligned}
 a_{\min} &= 4 \\
 g(x) &= (x-1)^3(x+2-a)^2 \\
 g(x) &= (x-1)^3(x-2)^2 \\
 g'(x) &= (x-1)^3 \cdot 2(x-2) + (x-2)^2 \cdot 3(x-1)^2 \\
 &= (x-1)^2(x-2)(2x-2+3x-6) \\
 &= (x-1)^2(x-2)(5x-8) < 0 \\
 x &\in \left(\frac{8}{5}, 2\right)
 \end{aligned}$$

$$100(a+b-c) = 100\left(4 + \frac{8}{5} - 2\right) = 360$$

**Q.13** Suppose A and B are the coefficients of  $30^{\text{th}}$  and  $12^{\text{th}}$  terms respectively in the binomial expansion of  $(1+x)^{2n-1}$ . If  $2A = 5B$ , then n is equal to :

- (1) 22                                      (2) 21                                      (3) 20                                      (4) 19

**Ans.** [2]

**Sol.**  $A = {}^{2n-1}C_{29}$   $B = {}^{2n-1}C_{11}$   
 $2 {}^{2n-1}C_{29} = 5 {}^{2n-1}C_{11}$

$$2 \frac{(2n-1)!}{29!(2n-30)!} = 5 \frac{(2n-1)!}{(2n-12)!11!}$$

$$\frac{1}{29 \dots 12 \cdot 5} = \frac{1}{(2n-12)(2n-13) \dots (2n-29)2}$$

$$\frac{1}{30 \cdot 29 \dots 12} = \frac{1}{(2n-12)(2n-13) \dots (2n-29)12}$$

$$2n-12 = 30$$

$$n = 21$$

**Q.14** Let  $\vec{a} = 3\hat{i} - \hat{j} + 2\hat{k}$ ,  $\vec{b} = \vec{a} \times (\hat{i} - 2\hat{k})$  and  $\vec{c} = \vec{b} \times \hat{k}$ . Then the projection of  $\vec{c} - 2\hat{j}$  on  $\vec{a}$  is :

- (1)  $3\sqrt{7}$                                       (2)  $\sqrt{14}$                                       (3)  $2\sqrt{14}$                                       (4)  $2\sqrt{7}$

**Ans.** [3]

**Sol.**  $\vec{b} = \vec{a} \times (\hat{i} - 3\hat{k})$

$$= \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -1 & 2 \\ 1 & 0 & -2 \end{vmatrix} = 2\hat{i} + 8\hat{j} + \hat{k}$$

$$\vec{c} = \vec{b} \times \hat{k} = 8\hat{i} - 2\hat{j}$$

$$\vec{c} - 2\hat{j} = 8\hat{i} - 4\hat{j}$$

Projection of  $(\vec{c} - 2\hat{j})$  on  $\vec{a}$

$$(\vec{c} - 2\hat{j}) \cdot \vec{a} = \frac{(8, -4, 0) \cdot (3, -1, 2)}{\sqrt{14}}$$

$$= \frac{28}{\sqrt{14}} = 2\sqrt{14}$$

Q.15 For some a, b, let

$$f(x) = \begin{vmatrix} a + \frac{\sin x}{x} & 1 & b \\ a & 1 + \frac{\sin x}{x} & b \\ a & 1 & b + \frac{\sin x}{x} \end{vmatrix}, x \neq 0,$$

$\lim_{x \rightarrow 0} f(x) = \lambda + \mu a + \nu b$ . Then  $(\lambda + \mu + \nu)^2$  is equal to :

(1) 25

(2) 9

(3) 36

(4) 16

Ans. [4]

Sol.  $\lim_{x \rightarrow 0} f(x) = \begin{vmatrix} a+1 & 1 & b \\ a & 1+1 & b \\ a & 1 & b+1 \end{vmatrix}$

$$= (a+1)(2(b+1) - b) + 1(ab - a(b+1)) + ba$$

$$= (a+1)(b+2) - a + ab$$

$$= b + a + 2 = \lambda + \mu a + \nu b$$

$$\lambda = 2, \mu = 1, \nu = 1 \Rightarrow (\lambda + \mu + \nu)^2 = 16$$

Q.16 Group A consists of 7 boys and 3 girls, while group B consists of 6 boys and 5 girls. The number of ways, 4 boys and 4 girls can be invited for a picnic if 5 of them must be from group A and the remaining 3 from group B, is equal to :

(1) 8575

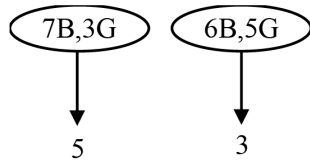
(2) 9100

(3) 8925

(4) 8750

Ans. [3]

Sol.



C-I (3G & 2B) & (1G & 2B)

C-II (2G & 3B) & (2G & 1B)

C-III (1G & 4B) & (3G & 0B)

Total = C-I + C-II + C-III

$$= {}^7C_2 \cdot {}^3C_3 + {}^6C_2 \cdot {}^5C_1 + {}^7C_3 \cdot {}^3C_2 + {}^6C_1 \cdot {}^5C_2 + {}^7C_4 \cdot {}^3C_1 + {}^6C_0 \cdot {}^5C_3$$

$$= 8925$$

Q.17 The area of the region enclosed by the curves  $y = e^x$ ,  $y = |e^x - 1|$  and y-axis is :

(1)  $1 + \log_e 2$

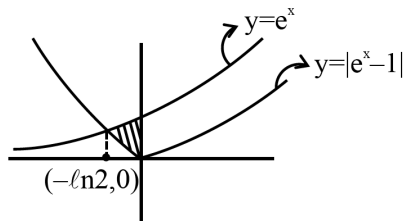
(2)  $\log_e 2$

(3)  $2 \log_e 2 - 1$

(4)  $1 - \log_e 2$

Ans. [4]

Sol.



For Area  $\int_{-\ln 2}^0 [e^x - (1 - e^x)] dx$

$$\int_{-\ln 2}^0 (2e^x - 1) dx = [2e^x - x]_{-\ln 2}^0$$

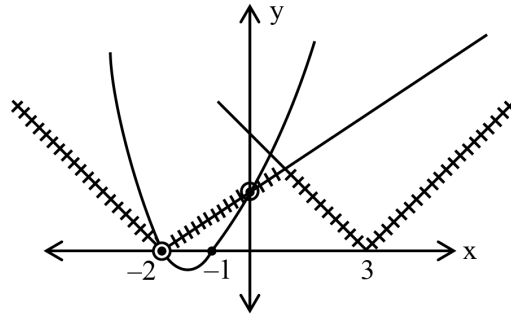
$$= (2 - (1 + \ln 2))$$

$$= 1 - \ln 2$$

**Q.18** The number of real solution(s) of the equation  $x^2 + 3x + 2 = \min\{|x - 3|, |x + 2|\}$  is :

- (1) 2 (2) 0 (3) 3 (4) 1

**Ans.** [1]  
**Sol.**



Only 2 solutions.

**Q.19** Let  $A = [a_{ij}]$  be a square matrix of order 2 with entries either 0 or 1. Let E be the event that A is an invertible matrix. Then the probability P(E) is :

- (1)  $\frac{5}{8}$  (2)  $\frac{3}{16}$  (3)  $\frac{1}{8}$  (4)  $\frac{3}{8}$

**Ans.** [4]

**Sol.** C-I  $\begin{vmatrix} 1 & 1 \\ 0 & 1 \end{vmatrix} \rightarrow 4$  ways

C-II  $\begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix}$  &  $\begin{vmatrix} 0 & 1 \\ 1 & 0 \end{vmatrix} \rightarrow 2$  ways

$$P = \frac{\text{favourable}}{\text{total}} = \frac{6}{16} = \frac{3}{8}$$

**Q.20** If the equation of the parabola with vertex  $V\left(\frac{3}{2}, 3\right)$  and the directrix  $x + 2y = 0$  is  $\alpha x^2 + \beta y^2 - \gamma xy - 30x -$

$60y + 225 = 0$ , then  $\alpha + \beta + \gamma$  is equal to :

- (1) 6 (2) 8 (3) 7 (4) 9

**Ans.** [4]

**Sol.** Equation of axis  $y - 3 = 2 \left( x - \frac{3}{2} \right)$

$$y - 2x = 0$$

foot of directrix

$$y - 2x = 0$$

&

$$2y + x = 0$$

$$\Rightarrow (0, 0)$$



$$\text{Focus} = (3, 6)$$

$$PS^2 = PM^2$$

$$(x-3)^2 + (y-6)^2 = \left(\frac{x+2y}{\sqrt{5}}\right)^2$$

$$4x^2 + y^2 - 4xy - 30x - 60y + 225 = 0$$

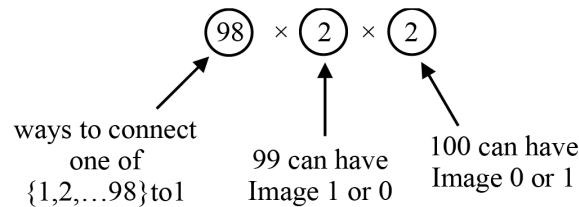
$$\Rightarrow \alpha = 4, \beta = 1, \gamma = 4 \Rightarrow \alpha + \beta + \gamma = 9$$

**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.

**Q.21** Number of functions  $f : \{1, 2, \dots, 100\} \rightarrow \{0, 1\}$ , that assign 1 to exactly one of the positive integers less than or equal to 98, is equal to \_\_\_\_\_.

**Ans.** [392]

**Sol.**



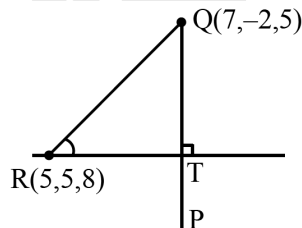
392 Ans.

**Q.22** Let P be the image of the point Q(7, -2, 5) in the line L :  $\frac{x-1}{2} = \frac{y+1}{3} = \frac{z}{4}$  and R(5, p, q) be a point on L.

Then the square of the area of  $\Delta PQR$  is \_\_\_\_\_

**Ans.** [957]

**Sol.**



$$\text{Let } R(2\lambda + 1, 3\lambda - 1, 4\lambda)$$

$$2\lambda + 1 = 5$$

$$\lambda = 2$$

$$R(5, 5, 8)$$

$$\text{let } T(2\lambda + 1, 3\lambda - 1, 4\lambda)$$

$$\vec{QT} = (2\lambda - 6)\hat{i} + (3\lambda + 1)\hat{j} + (4\lambda - 5)\hat{k}$$

$$\vec{b} = 2\hat{i} + 3\hat{j} + 4\hat{k}$$

$$\vec{QT} \cdot \vec{b} = 0$$

$$4\lambda - 12 + 9\lambda + 3 + 16\lambda - 20 = 0$$

$$\lambda = 1$$

$$T(3, 2, 4)$$

$$QT = \sqrt{33} \quad RT = \sqrt{29}$$

$$(\text{area of } \Delta PQR)^2 = \left(\frac{1}{2}\sqrt{29} \cdot 2\sqrt{33}\right)^2 = 957$$

**Q.23** Let  $y = y(x)$  be the solution of the differential equation  $2 \cos x \frac{dy}{dx} = \sin 2x - 4y \sin x$ ,  $x \in \left(0, \frac{\pi}{2}\right)$ . If  $y\left(\frac{\pi}{3}\right) = 0$ , then  $y'\left(\frac{\pi}{4}\right) + y\left(\frac{\pi}{4}\right)$  is equal to \_\_\_\_\_.

**Ans.** [1]

**Sol.**  $\frac{dy}{dx} + 2y \tan x = \sin x$

$$\text{I.F.} = e^{2 \int \tan x \, dx} = \sec^2 x$$

$$y \sec^2 x = \int \frac{\sin x}{\cos^2 x} \, dx = \int \tan x \sec x \, dx = \sec x + C$$

$$C = -2$$

$$y = \cos x - 2 \cos^2 x$$

$$y\left(\frac{\pi}{4}\right) = \frac{1}{\sqrt{2}} - 1$$

$$y' = -\sin x + 4 \cos x \sin x$$

$$y'\left(\frac{\pi}{4}\right) = -\frac{1}{\sqrt{2}} + 2$$

$$y'\left(\frac{\pi}{4}\right) + y\left(\frac{\pi}{4}\right) = 1$$

**Q.24** Let  $H_1 : \frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$  and  $H_2 : \frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$  be two hyperbolas having length of latus rectums  $15\sqrt{2}$  and  $12\sqrt{5}$  respectively. Let their eccentricities be  $e_1 = \sqrt{\frac{5}{2}}$  and  $e_2$  respectively. If the product of the lengths of their transverse axes is  $100\sqrt{10}$ , then  $25e_2^2$  is equal to \_\_\_\_\_

**Ans.** [55]

**Sol.**  $\frac{2b^2}{a} = 15\sqrt{2}$

$$1 + \frac{b^2}{a^2} = \frac{5}{2}$$

$$a = 5\sqrt{2}$$

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

$$\frac{2A^2}{B} = 12\sqrt{5}$$

$$2a \cdot 2B = 100\sqrt{10}$$

$$2.5\sqrt{2} \cdot 2B = 100\sqrt{10}$$

$$B = 5\sqrt{5}$$

$$A = 5\sqrt{6}$$

$$e_2^2 = 1 + \frac{A^2}{B^2} = 1 + \frac{150}{125}$$

$$e_2^2 = 1 + \frac{30}{25}$$

$$25e_2^2 = 55$$

**Q.25** If  $\int \frac{2x^2 + 5x + 9}{\sqrt{x^2 + x + 1}} dx = x\sqrt{x^2 + x + 1} + \alpha\sqrt{x^2 + x + 1} + \beta \log_e \left| x + \frac{1}{2}\sqrt{x^2 + x + 1} \right| + C$ , where C is the constant of integration, then  $\alpha + 2\beta$  is equal to .....

**Ans.** [16]

**Sol.**  $2x^2 + 5x + 9 = A(x^2 + x + 1) + B(2x + 1) + C$

$$A = 2 \quad B = \frac{3}{2} \quad C = \frac{11}{2}$$

$$2 \int \sqrt{x^2 + x + 1} dx + \frac{3}{2} \int \frac{2x+1}{\sqrt{x^2+x+1}} dx + \frac{11}{2} \int \frac{dx}{\sqrt{x^2+x+1}}$$

$$2 \int \sqrt{\left(x + \frac{1}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2} dx + 3 \sqrt{x^2+x+1} + \frac{11}{2} \int \frac{dx}{\sqrt{\left(x + \frac{1}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2}}$$

$$2 \left( \frac{x + \frac{1}{2}}{2} \sqrt{x^2 + x + 1} + \frac{3}{8} \ln \left( x + \frac{1}{2} + \sqrt{x^2 + x + 1} \right) \right) + 3\sqrt{x^2 + x + 1} + \frac{11}{2} \ln \left( x + \frac{1}{2} + \sqrt{x^2 + x + 1} \right) + C$$

$$\alpha = \frac{7}{2} \quad \beta = \frac{25}{4}$$

$$\alpha + 2\beta = 16$$

**PHYSICS**

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

**Q.26** Young's double slit interference apparatus is immersed in a liquid of refractive index 1.44. It has slit separation of 1.5mm. The slits are illuminated by a parallel beam of light whose wavelength in air is 690 nm. The fringe-width on a screen placed behind the plane of slits at a distance of 0.72m, will be :

- (1) 0.23 mm                      (2) 0.33 mm                      (3) 0.63 mm                      (4) 0.46 mm

**Ans.** [1]

**Sol.** 
$$\beta = \left( \frac{\lambda_B}{\mu} \right) \times \frac{D}{d} = \frac{690 \times 10^{-9} \times 0.72}{1.44 \times 1.5 \times 10^{-3}} = 0.23 \text{ mm}$$

**Q.27** Arrange the following in the ascending order of wavelength ( $\lambda$ ) :

- (A) Microwaves ( $\lambda_1$ )                      (B) Ultraviolet rays ( $\lambda_2$ )  
 (C) Infrared rays ( $\lambda_3$ )                      (D) X-rays ( $\lambda_4$ )

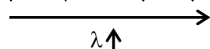
Choose the **most appropriate** answer from the options given below :-

- (1)  $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$                       (2)  $\lambda_3 < \lambda_4 < \lambda_2 < \lambda_1$   
 (3)  $\lambda_4 < \lambda_2 < \lambda_3 < \lambda_1$                       (4)  $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$

**Ans.** [3]

**Sol.**

$\gamma$ -rays	X-rays	U.V rays	Visible rays	IR rays	Micro waves	Radio waves
----------------	--------	----------	--------------	---------	-------------	-------------



**Q.28** Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason(R)**.  
**Assertion (A)** : A electron in a certain region of uniform magnetic field is moving with constant velocity in a straight line path.

**Reason (A)** : The magnetic field in that region is along the direction of velocity of the electron.

In the light of the above statements, choose the correct answer from the options given below :

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

**Ans.** [2]

**Sol.**  $\vec{F} = q(\vec{v} \times \vec{B})$

$$\vec{F} = 0$$

$$\vec{v} \parallel \vec{B}$$

$$\theta = 0 \text{ or } 180$$

**Q.29** A solid sphere is rolling without slipping on a horizontal plane. The ratio of the linear kinetic energy of the centre of mass of the sphere and rotational kinetic energy is :

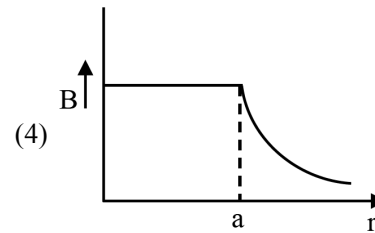
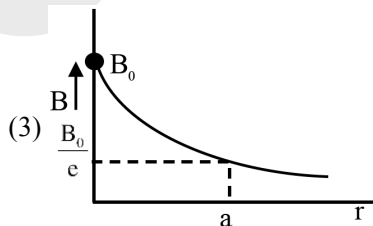
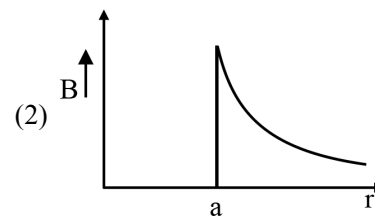
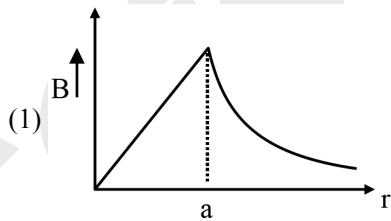
- (1)  $\frac{2}{5}$
- (2)  $\frac{5}{2}$
- (3)  $\frac{3}{4}$
- (4)  $\frac{4}{3}$

**Ans.** [2]

**Sol.** 
$$\frac{\text{Linear KE}}{\text{Rotation K.E.}} = \frac{\frac{1}{2}mv_{cm}^2}{\frac{1}{2}I\omega^2}$$

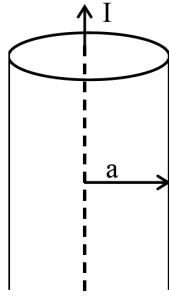
$$\frac{mv_{cm}^2}{2mR^2\omega^2} = \frac{5}{2} \quad (V = \omega R)$$

**Q.30** A long straight wire of a circular cross-section with radius 'a' carries a steady current I. The current I is a uniformly distributed across this cross-section. The plot of magnitude of magnetic field B with distance r from the centre of the wire is given by :



**Ans.** [1]

Sol.



$$B_m = \frac{\mu_0(\vec{J} \times \vec{r})}{2}$$

$$B_{in} \propto r$$

$$B_{out} = \frac{\mu_0 I}{2\pi r}$$

$$B_{net} \propto \frac{1}{r}$$

**Q.31** Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason(R)**.  
**Assertion (A)** : In an insulated container, a gas is adiabatically shrunk to half of its initial volume. The temperature of the gas decreases.

**Reason (R)** : Free expansion of an ideal gas is an irreversible and an adiabatic process.

In the light of the above statement, 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) (A) is true but (R) is false
- (3) (A) is false but (R) is true
- (4) Both (A) and (R) are true but (R) is **NOT** the correct explanation of (A)

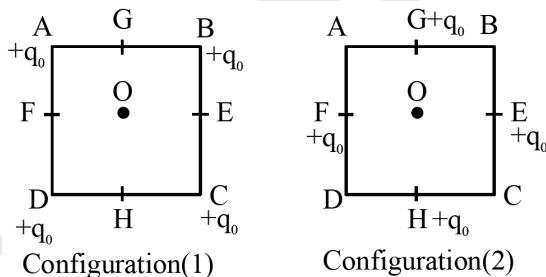
**Ans.** [3]

**Sol.** (A)  $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

Temp increases

R) Free expansion is assumed fast, so Adiabatic

**Q.32**



In the first configuration (1) as shown in the figure, four identical charges ( $q_0$ ) are kept at the corners A,B,C and D of square of side length 'a'. In the second configuration (2), the same charges are shifted to mid points G,E,H and F, of the square, If  $K = \frac{1}{4\pi\epsilon_0}$ , the difference between the potential energies of configuration (2)

and (1) is given by :

and (1) is given by :

- (1)  $\frac{Kq_0^2}{a}(4\sqrt{2} - 2)$
- (2)  $\frac{Kq_0^2}{a}(3 - \sqrt{2})$
- (3)  $\frac{Kq_0^2}{a}(4 - 2\sqrt{2})$
- (4)  $\frac{Kq_0^2}{a}(3\sqrt{2} - 2)$

**Ans.** [4]

**Sol.**  $U_1 = \frac{4Kq_0^2}{a} + \frac{2Kq_0^2}{\sqrt{2}a} = \frac{Kq_0^2}{a} (4 + \sqrt{2})$

$$U_2 = \frac{Kq_0^2}{\left(\frac{a}{\sqrt{2}}\right)} (4 + \sqrt{2}) = \frac{Kq_0^2}{a} (4\sqrt{2} + 2)$$

$$U_2 - U_1 = \frac{Kq_0^2}{a} (3\sqrt{2} - 2)$$

**Q.33** The position vector of a moving body at any instant of time is given as  $\vec{r} = (5t^2\hat{i} - 5t\hat{j})\text{m}$ . The magnitude and direction of velocity at  $t = 2\text{s}$  is,

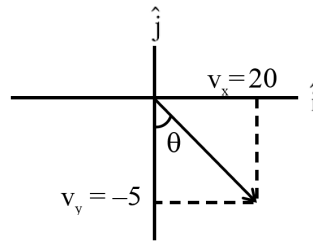
- (1)  $5\sqrt{15}\text{ m/s}$ , making an angle of  $\tan^{-1} 4$  with  $-ve$  Y axis
- (2)  $5\sqrt{15}\text{ m/s}$ , making an angle of  $\tan^{-1} 4$  with  $+ve$  X axis
- (3)  $5\sqrt{17}\text{ m/s}$ , making an angle of  $\tan^{-1} 4$  with  $-ve$  Y axis
- (4)  $5\sqrt{17}\text{ m/s}$ , making an angle of  $\tan^{-1} 4$  with  $+ve$  X axis

**Ans.** [3]

**Sol.**  $\vec{r} = 5t^2\hat{i} - 5t\hat{j}$

$$\vec{v} = 10t\hat{i} - 5\hat{j}$$

$$\vec{v} = 20\hat{i} - 5\hat{j} \quad \text{at } t = 2 \text{ sec}$$



$$\tan \theta = \frac{20}{5} = 4$$

$$\theta = \tan^{-1} 4$$

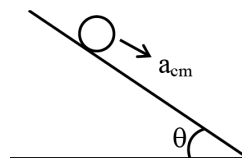
From  $-ve$  Y-axis.

**Q.34** A solid sphere and a hollow sphere of the same mass and of same radius are rolled on an inclined plane. Let the time taken to reach the bottom by the solid sphere and the hollow sphere be  $t_1$  and  $t_2$ , respectively, then

- (1)  $t_1 < t_2$
- (2)  $t_1 = t_2$
- (3)  $t_1 = 2t_2$
- (4)  $t_1 > t_2$

**Ans.** [1]

**Sol.**



$$t = \sqrt{\frac{2\ell}{a_{cm}}}$$

$$a_{cm} = \frac{g \sin \theta}{1 + \frac{I_{cm}}{MR^2}}$$

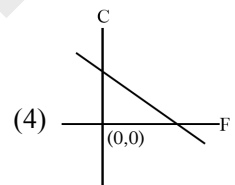
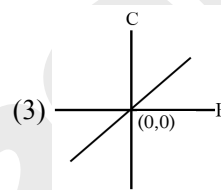
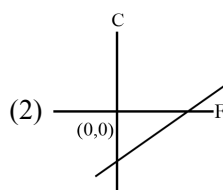
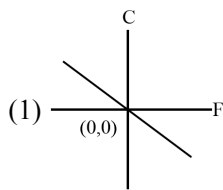
$$a_1 = a_{cm_1} = \frac{5g \sin \theta}{7} \quad \dots \text{Solid}$$

$$a_2 = a_{cm_2} = \frac{3g \sin \theta}{5} \quad \dots \text{Hollow}$$

$$a_1 > a_2$$

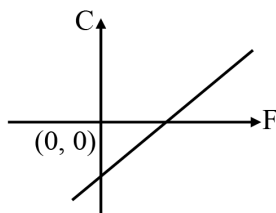
$$t_1 < t_2$$

**Q.35** Which of the following figure represents the relation between Celsius and Fahrenheit temperatures?

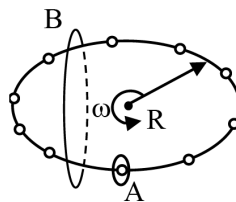


**Ans.** [2]

**Sol.**  $\frac{C}{5} = \frac{F-32}{9} \Rightarrow C = \frac{5F}{9} - \frac{160}{9}$



**Q.36**



$N$  equally spaced charges each of value  $q$ , are placed on a circle of radius  $R$ . The circle rotates about its axis with an angular velocity  $\omega$  as shown in the figure. A bigger Amperian loop  $B$  encloses the whole circle where as a smaller Amperian loop  $A$  encloses a small segment. The difference between enclosed currents,  $I_A - I_B$ , for the given Amperian loops is :

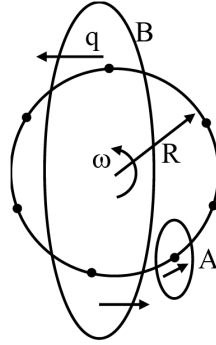
(1)  $\frac{N^2}{2\pi} q\omega$

(2)  $\frac{2\pi}{N} q\omega$

(3)  $\frac{N}{2\pi} q\omega$

(4)  $\frac{N}{\pi} q\omega$

**Ans.** [3]

**Sol.**


$$I_A = \frac{N}{\frac{2\pi}{\omega}}$$

$$I_A = \frac{Nq\omega}{2\pi}, I_B = 0$$

$$I_A - I_B = \frac{Nq\omega}{2\pi}$$

**Q.37** In photoelectric effect, the stopping potential ( $V_0$ ) v/s frequency ( $\nu$ ) curve is plotted. ( $h$  is the Planck's constant and  $\phi_0$  is work function of metal)

(A)  $V_0$  v/s  $\nu$  is linear

(B) The slope of  $V_0$  v/s  $\nu$  curve =  $\frac{\phi_0}{h}$

(C)  $h$  constant is related to the slope of  $V_0$  v/s  $\nu$  line

(D) The value of electric charge of electron is not required to determine  $h$  using the  $V_0$  v/s  $\nu$  curve.

(E) The work function can be estimated without knowing the value of  $h$ .

Choose the correct answer from the options given below :

(1) (A),(B) and (C) only

(2) (C) and (D) only

(3) (A),(C) and (E) only

(4) (D) and (E) only

**Ans.** [3]

**Sol.**  $h\nu = \phi + KE_{\max}$

$$KE_{\max} = eV_0$$

$$V_0 = \frac{h\nu - \phi}{e}$$

(A)  $V_0$  v/s  $\nu$  is linear correct

(B) Slope

$$V_0 = \left(\frac{h}{e}\right)\nu - \frac{\phi}{e} \text{ Wrong}$$

$$\text{Slope } \frac{h}{e}$$

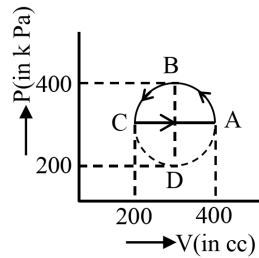
(C) Correct

(D) Incorrect

(E) Correct



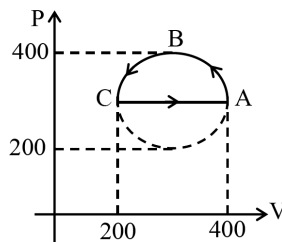
**Q.38** The magnitude of heat exchanged by a system for the given cyclic process ABCA (as shown in figure) is (in SI unit)



- (1)  $10\pi$                                       (2)  $5\pi$                                       (3) zero                                      (4)  $40\pi$

**Ans.** [2]

**Sol.**



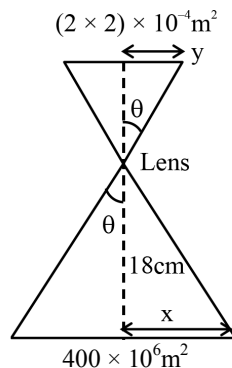
$$\begin{aligned}
 W &= \frac{1}{2} \pi R^2 \\
 &= \frac{1}{2} \times \pi \times \left( \frac{200}{2} \times 10^3 \right) \times \frac{200}{2} \times 10^{-6} \\
 &= \frac{10\pi}{2} = 5\pi \text{ J}
 \end{aligned}$$

**Q.39** A photograph of a landscape is captured by a drone camera at a height of 18 cm. The size of the camera film is  $2 \text{ cm} \times 2 \text{ cm}$  and the area of the landscape photographed is  $400 \text{ km}^2$ . The focal length of the lens in the drone camera is :

- (1) 1.8 cm                                      (2) 2.8 cm                                      (3) 2.5 cm                                      (4) 0.9 cm

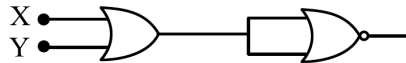
**Ans.** [1]

**Sol.**



$$\begin{aligned}
 H &= 18 \text{ km} \\
 \text{Size of camera film} &= 2\text{cm} \times 2\text{cm} \\
 A_{\text{image}} &= 400 \text{ km}^2 \\
 x &= 20 \times 10^3 \text{ m} = 2 \times 10^4 \text{ m} \\
 y &= 2 \times 10^{-2} \text{ m} \\
 \frac{x}{y} &= 10^6 = \frac{18\text{Km}}{f} \\
 f &= 18 \times 10^{-3} \text{ m} = 18 \text{ mm} \\
 f &= 1.8 \text{ cm}
 \end{aligned}$$

**Q.40** The output of the circuit is low (zero) for :

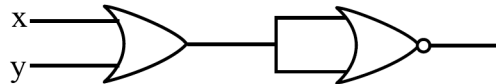


- (A)  $X = 0, Y = 0$                       (B)  $X = 0, Y = 1$                       (C)  $X = 1, Y = 0$                       (D)  $X = 1, Y = 1$

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

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

**Ans.** [3]  
**Sol.**



x	y	
0	0	1
0	1	0
1	0	0
1	1	0

**Q.41** The temperature of a body in air falls from  $40^\circ\text{C}$  to  $24^\circ\text{C}$  in 4 minutes. The temperature of the air is  $16^\circ\text{C}$ . The temperature of the body in the next 4 minutes will be :

- (1)  $\frac{14}{3}^\circ\text{C}$                       (2)  $\frac{28}{3}^\circ\text{C}$                       (3)  $\frac{56}{3}^\circ\text{C}$                       (4)  $\frac{42}{3}^\circ\text{C}$

**Ans.** [3]

**Sol.** 
$$\frac{T_2 - T_1}{t} = K [T_{\text{avg}} - T_s]$$

$T_1 = 24^\circ\text{C}; T_2 = 40^\circ\text{C}, t = 4, T_s = 16^\circ\text{C}$

$$\frac{40 - 24}{4} = K [32 - 16]$$

$$K = \frac{4}{16} = \frac{1}{4}$$

Now 
$$\frac{24 - T}{4} = K \left[ \frac{T + 24}{2} - 16 \right]$$

$$24 - T = \frac{T - 16}{2} + 16$$

$$\frac{3T}{2} = 28$$

$$T = \frac{56}{3}^\circ\text{C}$$

**Q.42** The energy  $E$  and momentum  $p$  of a moving body of mass  $m$  are related by some equation. Given that  $c$  represents the speed of light, identify the correct equation.

(1)  $E^2 = pc^2 + m^2c^4$   
 (3)  $E^2 = p^2c^2 + m^2c^2$

(2)  $E^2 = pc^2 + m^2c^2$   
 (4)  $E^2 = p^2c^2 + m^2c^4$

**Ans.** [4]

**Sol.**  $[E] = M^1L^2T^{-2}$   
 $[Pc] = M^1L^1T^{-1} \cdot L^1T^{-1} = M^1L^2T^{-2}$   
 $[mc^2] = M^1L^2T^{-2}$   
 $E^2 = M^1L^2T^{-2}$   
 $E^2 = P^2c^2 + m^2c^4$

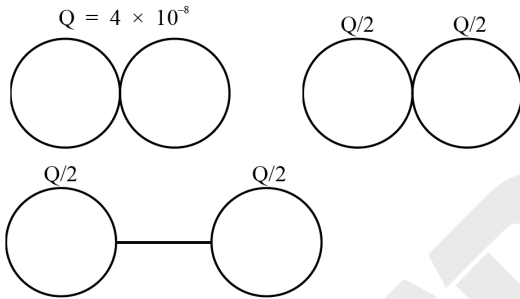
**Q.43** A small uncharged conducting sphere is placed in contact with an identical sphere but having  $4 \times 10^{-8}$  C charge and then removed to a distance such that the force of repulsion between them is  $9 \times 10^{-3}$  N.

The distance between them is (Take  $\frac{1}{4\pi\epsilon_0}$  as  $9 \times 10^9$  in SI units)

- (1) 2 cm                                      (2) 3 cm                                      (3) 4 cm                                      (4) 1 cm

**Ans.** [1]

**Sol.**



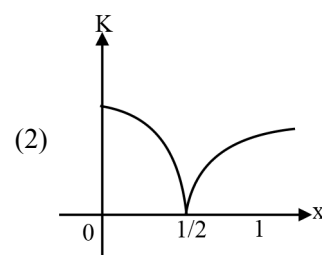
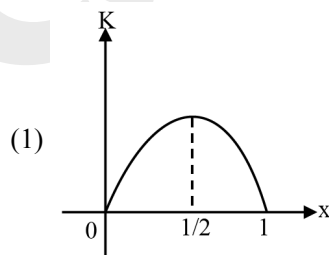
$$F = \frac{k \left(\frac{Q}{2}\right) \left(\frac{Q}{2}\right)}{r^2}$$

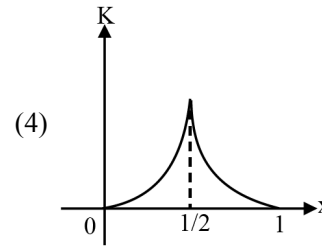
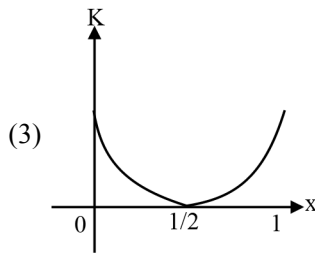
$$9 \times 10^{-3} = \frac{9 \times 10^9 \times (4 \times 10^{-8}) \times 4 \times 10^{-8}}{4 \times r^2}$$

$$r^2 = \frac{9 \times 10^9 \times 16 \times 10^{-16}}{4 \times 9 \times 10^{-3}} = 4 \times 10^{-4}$$

$$r = 2 \times 10^{-2} \text{ m} \Rightarrow 2 \text{ cm}$$

**Q.44** A particle oscillates along the  $x$ -axis according to the law,  $x(t) = x_0 \sin^2 \left( \frac{t}{2} \right)$  where  $x_0 = 1$  m. The kinetic energy ( $K$ ) of the particle as a function of  $x$  is correctly represented by the graph.





**Ans.** [1]

**Sol.**  $x = x_0 \sin^2 \frac{t}{2} = x_0 \left( \frac{1 - \cos t}{2} \right)$

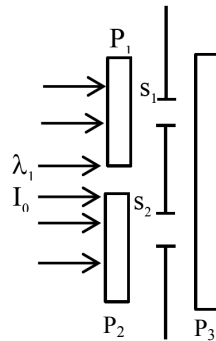
$$x - \frac{x_0}{2} = \frac{-\cos t}{2}$$

where  $x_0 = 1$

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

Particle is oscillating between  $x = 0$  to  $x = 1$ .

**Q.45** In a Young's double slit experiment, three polarizers are kept as shown in the figure. The transmission axes of  $P_1$  and  $P_2$  are orthogonal to each other. The polarizer  $P_3$  covers both the slits with its transmission axis at  $45^\circ$  to those of  $P_1$  and  $P_2$ . An unpolarized light of wavelength  $\lambda$  and intensity  $I_0$  is incident on  $P_1$  and  $P_2$ . The intensity at a point after  $P_3$  where the path difference between the light waves from  $s_1$  and  $s_2$  is  $\frac{\lambda}{3}$ , is :



(1)  $\frac{I_0}{2}$

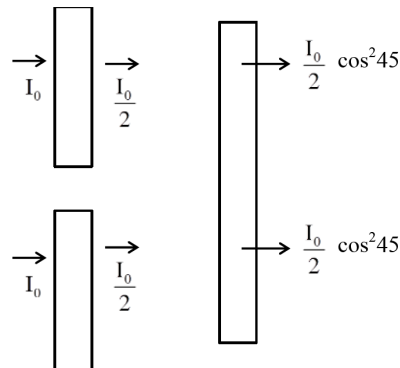
(2)  $\frac{I_0}{4}$

(3)  $I_0$

(4)  $\frac{I_0}{3}$

**Ans.** [2]

**Sol.**



(Unpolarised light)

(Polarised light)

after passing through third polariser, Intensity of both the waves must be  $\frac{I_0}{4}$

now, at a point where path diff is  $\frac{\lambda}{3}$ , phase difference

$$\Delta f = 2K \left( \frac{\Delta x}{\lambda} \right) = \frac{2\pi}{3}$$

$$\begin{aligned} \therefore I_{\text{res}} &= \sqrt{\left(\frac{I_0}{4}\right)^2 + \left(\frac{I_0}{4}\right)^2 + 2\left(\frac{I_0}{4}\right)^2 \cos \frac{2\pi}{3}} \\ &= \frac{I_0}{4} \end{aligned}$$

**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.

**Q.46** A tightly wound long solenoid carries a current of 1.5 A. An electron is executing uniform circular motion inside the solenoid with a time period of 75ns. The number of turns per metre in the solenoid is \_\_\_\_\_.

[Take mass of electron  $m_e = 9 \times 10^{-31}$  kg, charge of electron  $|q_e| = 1.6 \times 10^{-19}$  C,

$$\mu_0 = 4\pi \times 10^{-7} \frac{\text{N}}{\text{A}^2}, 1 \text{ ns} = 10^{-9} \text{ s}]$$

**Ans.** [250]

**Sol.** Since time period of a revolving charge is  $\frac{2\pi m}{qB}$

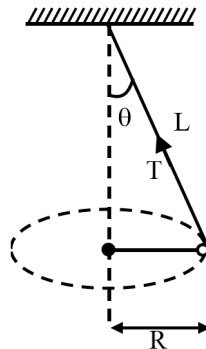
Where B = magnetic field  
due to a solenoid =  $\mu_0 n I$

$$\therefore T = \frac{2\pi m}{q(\mu_0 n I)}$$

$$75 \times 10^{-9} = \frac{(2\pi)(9 \times 10^{-31})}{1.6 \times 10^{-19} \times 4\pi \times 10^{-7} \times n \times 1.5}$$

$$N = 250$$

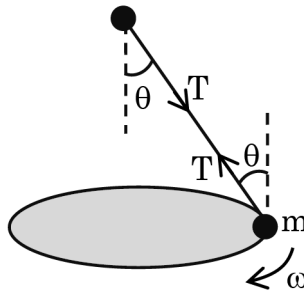
**Q.47**



A string of length L is fixed at one end and carries a mass of M at the other end. The mass makes  $\left(\frac{3}{\pi}\right)$  rotations per second about the vertical axis passing through end of the string as shown. The tension in the string is \_\_\_\_\_ ML.

Ans. [36]

Sol.



$$T \cos \theta = mg \quad \dots(1)$$

$$T \sin \theta = M\omega^2 R \quad \dots(2)$$

Using equation (2)

$$T \sin \theta = M\omega^2 (L \sin \theta)$$

$$T = M\omega^2 L = M \left( \frac{3}{\pi} \times 2\pi \right)^2 L$$

$$T = 36 ML$$

**Q.48** The ratio of the power of a light source  $S_1$  to that of the light source  $S_2$  is 2.  $S_1$  is emitting  $2 \times 10^{15}$  photons per second at 600 nm. If the wavelength of the source  $S_2$  is 300 nm, then the number of photons per second emitted by  $S_2$  is  $\underline{\hspace{2cm}} \times 10^{14}$ .

Ans. [5]

Sol. Since power emitted by a source is given as

$$= \frac{\text{Total energy emitted}}{\text{time}}$$

$$= \frac{(E_1 \text{ photon}) \times \text{Number of photons (N)}}{t}$$

$$P_1 = (E_1)n$$

$$\frac{P_1}{P_2} = \frac{(E_1)n_1}{(E_2)n_2} = \frac{\left(\frac{hc}{\lambda_1}\right)n_1}{\left(\frac{hc}{\lambda_2}\right)n_2}$$

$$\frac{P_1}{P_2} = \left(\frac{\lambda_2}{\lambda_1}\right) \frac{n_1}{n_2}$$

Substituting the given values

$$2 = \left(\frac{300}{600}\right) \times \frac{2 \times 10^{15}}{n_2}$$

$$n_2 = \frac{1}{2} \times 10^{15} = 5 \times 10^{14} \text{ Photon/sec}$$

**Q.49** The increase in pressure required to decrease the volume of a water sample by 0.2% is  $P \times 10^5 \text{ Nm}^{-2}$ . Bulk modulus of water is  $2.15 \times 10^9 \text{ Nm}^{-2}$ . The value of  $P$  is  $\underline{\hspace{2cm}}$ .

Ans. [43]

**Sol.** Since bulk modulus is given as

$$B = \frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

$$2.15 \times 10^9 = \frac{-\Delta P}{-\left(\frac{0.2}{100}\right)}$$

$$\Delta P = 2.15 \times 10^9 \times 2 \times 10^{-3} \\ = 4.3 \times 10^6 = 43 \times 10^5 \text{ N/m}^2$$

**Q.50** Acceleration due to gravity on the surface of earth is 'g'. If the diameter of earth is reduced to one third of its original value and mass remains unchanged, then the acceleration due to gravity on the surface of the earth is

\_\_\_\_\_g.

**Ans.** [9]

**Sol.** ∴ acceleration due to gravity on surface is given by

$$g = \frac{GM}{R_e^2}$$

Now since diameter is reduced to  $1/3^{\text{rd}}$ , radius also reduces to  $1/3^{\text{rd}}$ , keeping mass constant

New value of acceleration due to gravity on Earth's surface is

$$g' = \frac{GM}{\left(\frac{R_e}{3}\right)^2} = 9 \frac{GM}{R_e^2} = 9g$$

## CHEMISTRY

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

**Q.51** Based on the data given below :

$$E^0_{\text{Cr}_2\text{O}_7^{2-}/\text{Cr}^{3+}} = 1.33\text{V} \quad E^0_{\text{Cl}_2/\text{Cl}^{(-)}} = 1.36\text{V}$$

$$E^0_{\text{MnO}_4^-/\text{Mn}^{2+}} = 1.51\text{V} \quad E^0_{\text{Cr}^{3+}/\text{Cr}} = -0.74\text{V}$$

the strongest reducing agent is :

- (1)  $\text{Mn}^{2+}$                       (2) Cr                                      (3)  $\text{MnO}_4^-$                       (4)  $\text{Cl}^-$

**Ans.** [2]

**Sol.** For strongest reducing agent

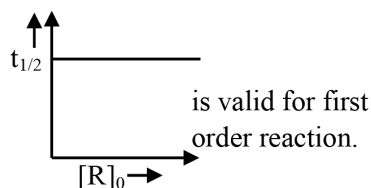
Reduction potential should be lowest

Hence Cr is the strongest reducing agent.

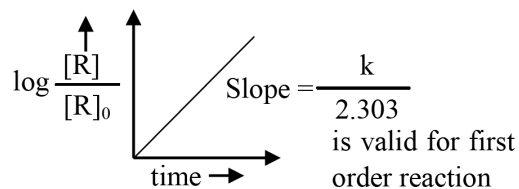
Options (2)

**Q.52** Given below are two statements :

**Statement(I) :**



Statement(II) :

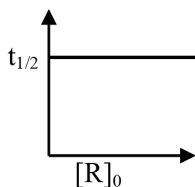


In the light of the above statements, choose the **correct** answer from the options given below :

- (1) Both **Statement I** and **Statement II** are false
- (2) **Statement I** is false but **Statement II** is true
- (3) Both **Statement I** and **Statement II** are true
- (4) **Statement I** is true but **Statement II** is false

Ans. [4]

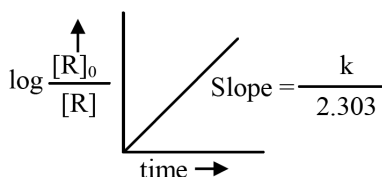
Sol. For first order reaction  $t_{1/2} = \frac{\ln 2}{k}$



For first order reaction

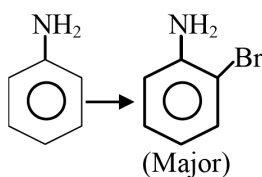
$$\log \frac{[R]_0}{[R]} = \frac{1}{2.303} kt$$

$$\log \frac{[R]_0}{[R]} = \left( \frac{k}{2.303} \right) \times t$$



Options (4)

Q.53 For reaction



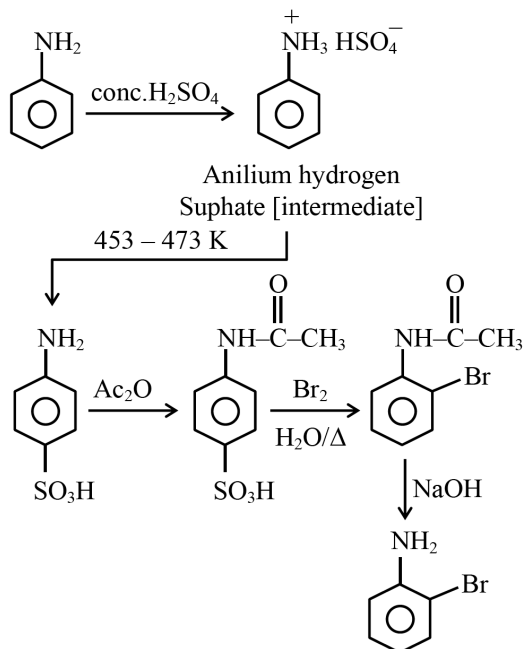
The correct order of set of reagents for the above conversion is :

- (1)  $\text{Br}_2 \mid \text{FeBr}_3, \text{H}_2\text{O}(\Delta), \text{NaOH}$
- (2)  $\text{H}_2\text{SO}_4, \text{Ac}_2\text{O}, \text{Br}_2, \text{H}_2\text{O}(\Delta), \text{NaOH}$
- (3)  $\text{Ac}_2\text{O}, \text{Br}_2, \text{H}_2\text{O}(\Delta), \text{NaOH}$
- (4)  $\text{Ac}_2\text{O}, \text{H}_2\text{SO}_4, \text{Br}_2, \text{NaOH}$

Ans. [2]



Sol.



- Q.54** For hydrogen atom, the orbital/s with lowest energy is/are :  
 (A) 4s (B) 3p<sub>x</sub> (C) 3d<sub>x<sup>2</sup>-y<sup>2</sup></sub> (D) 3d<sub>z<sup>2</sup></sub>

 (E) 4p<sub>z</sub>

Choose the correct answer from the options given below :

(1) (A) and (E) only

(2) (B) only

(3) (A) only

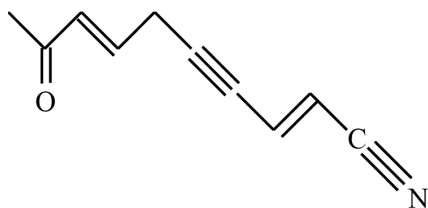
(4) (B), (C) and (D) only

**Ans.** [4]

**Sol.** In hydrogen atom the orbitals in a shell are degenerate means energy depends only on 'n'

$$\therefore E_{3p_x} = E_{3d_{x^2-y^2}} = E_{3d_{z^2}}$$

- Q.55** In the given structure, number of sp and sp<sup>2</sup> hybridized carbon atoms present respectively are :



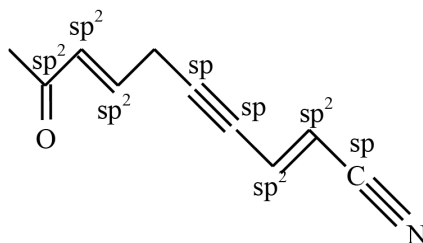
(1) 3 and 6

(2) 3 and 5

(3) 4 and 6

(4) 4 and 5

**Ans.** [2]

**Sol.**

 Number of sp and sp<sup>2</sup> hybridised carbon atom are 3 and 5.

- Q.56** Which of the following mixing of 1M base and 1M acid leads to the largest increase in temperature?  
 (1) 30 mL HCl and 30 mL NaOH (2) 30 mL CH<sub>3</sub>COOH and 30 mL NaOH  
 (3) 50 mL HCl and 20 mL NaOH (4) 45 mL CH<sub>3</sub>COOH and 25 mL NaOH

**Ans.** [1]

**Sol.** Higher the number of milli moles of acid or base reacted higher will be temperature rise.

Option (4)  $n_{\text{acid}}$  or  $n_{\text{base}}$  reacted = 30 m mol

Option (2)  $n_{\text{acid}}$  or  $n_{\text{base}}$  reacted = 30 m mol

but less energy will be released by neutralisation reaction of weak acid hence option (2) can not be correct.

Option (3)  $\Rightarrow$  20 m mol

Option (4)  $\Rightarrow$  25 m mol

Hence Correct Option (1)

- Q.57** Given below are two statements :

**Statement(I)** : Experimentally determined oxygen-oxygen bond lengths in the O<sub>3</sub> are found to be same and the bond length is greater than that of a O = O (double bond) but less than that of a single (O – O) bond.

**Statement (II)** : The strong lone pair-lone pair repulsion between oxygen atoms is solely responsible for the fact that the bond length in ozone is smaller than that of a double bond (O=O) but more than that of a single bond (O – O).

In the light of the above statements, choose the **correct** answer from the options given below:

(1) **Statement I** is true but **Statement II** is false

(2) Both **Statement I** and **Statement II** are true

(3) Both **Statement I** and **Statement II** are false

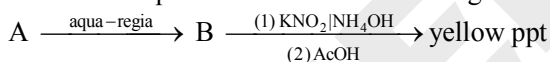
(4) **Statement I** is false but **Statement II** is true

**Ans.** [1]

**Sol.** Due to resonance bond length is identical in ozone.

Therefore statement I is true and statement II is false

- Q.58** Find the compound 'A' from the following reaction sequences.



(1) ZnS

(2) CoS

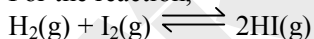
(3) MnS

(4) NiS

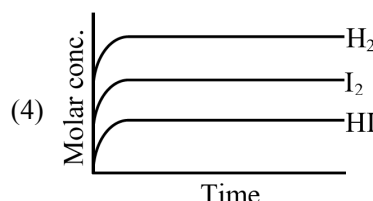
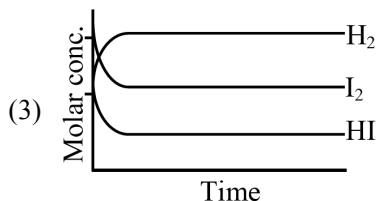
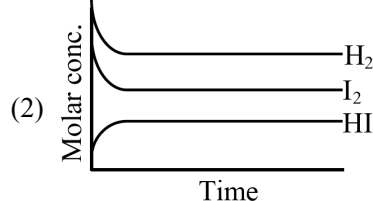
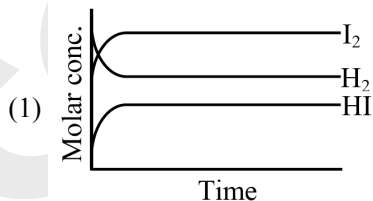
**Ans.** [2]

**Sol.**  $\text{CoS} \xrightarrow{\text{Aquaregia}} \text{CoCl}_2 \xrightarrow[\text{2. AcOH}]{\text{1. KNO}_2/\text{NH}_4\text{OH}} \text{K}_3[\text{Co}(\text{NO}_2)_6] \downarrow \text{yellow}$

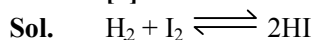
- Q.59** For the reaction,



Attainment of equilibrium is predicted correctly by:



Ans. [2]



Concentration of  $\text{H}_2$  and  $\text{I}_2$  decreases until equilibrium condition and concentration of  $\text{HI}$  increases till equilibrium condition and after equilibrium concentration of all the reactant and products remain constant.

Correct option (2)

Q.60 Match List-I with List-II.

List-I (Transition metal ion)		List-II (Spin only magnetic moment (B.M.))	
(A)	$\text{Ti}^{3+}$	(I)	3.87
(B)	$\text{V}^{2+}$	(II)	0.00
(C)	$\text{Ni}^{2+}$	(III)	1.73
(D)	$\text{Sc}^{3+}$	(IV)	2.84

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

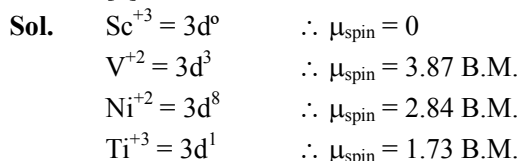
(1) (A)-(III), (B)-(I), (C)-(II), (D)-(IV)

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

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

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

Ans. [2]



Q.61 The elemental composition of a compound is 54.2% C, 9.2% H and 36.6% O. If the molar mass of the compound is  $132 \text{ g mol}^{-1}$ , the molecular formula of the compound is :

[Given : The relative atomic mass of C : H : O = 12 : 1 : 16]

(1)  $\text{C}_4\text{H}_9\text{O}_3$

(2)  $\text{C}_6\text{H}_{12}\text{O}_6$

(3)  $\text{C}_6\text{H}_{12}\text{O}_3$

(4)  $\text{C}_4\text{H}_8\text{O}_2$

Ans. [3]

Sol.

$$\begin{array}{ccc} \text{C} & : & \text{H} & : & \text{O} \\ \frac{54.2}{12} & : & 9.2 & : & \frac{36.6}{16} \\ 4.516 & : & 9.2 & : & 2.287 \\ \frac{4.516}{2.287} & : & \frac{9.2}{2.287} & : & \frac{2.287}{2.287} \\ 1.97 & : & 4.02 & : & 1 \end{array}$$

$\text{C}_2\text{H}_4\text{O} \Rightarrow$  Empirical formula

E.F. mass =  $24 + 4 + 16 = 44$

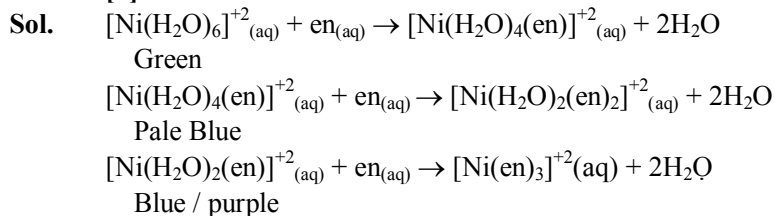
and molar mass = 132

Hence molecular formula =  $(\text{C}_2\text{H}_4\text{O})_3$   
 =  $\text{C}_6\text{H}_{12}\text{O}_3$

Correct Option (3)

- Q.62** When Ethane-1,2-diamine is added progressively to an aqueous solution of Nickel (II) chloride, the sequence of colour change observed will be :
- (1) Pale Blue → Blue → Green → Violet
  - (2) Pale Blue → Blue → Violet → Green
  - (3) Green → Pale Blue → Blue → Violet
  - (4) Violet → Blue → Pale Blue → Green

**Ans.** [3]



- Q.63** The conditions and consequence that favours the  $t_{2g}^3, e_g^1$  configuration in a metal complex are :

- (1) weak field ligand, high spin complex
- (2) strong field ligand, high spin complex
- (3) strong field ligand, low spin complex
- (4) weak field ligand, low spin complex

**Ans.** [1]

**Sol.** For  $3d^4$

If ligand is SFL :  $t_{2g}^4 e_g^0$  (Low spin)

If ligand is WFL :  $t_{2g}^3 e_g^1$  (High spin)

- Q.64** Identify correct statement/s :

- (A)  $-\text{OCH}_3$  and  $-\text{NHCOCH}_3$  are activating group
- (B)  $-\text{CN}$  and  $-\text{OH}$  are meta directing group
- (C)  $-\text{CN}$  and  $-\text{SO}_3\text{H}$  are meta directing group
- (D) Activating groups act as ortho – and para directing groups
- (E) Halides are activating groups

Choose the correct answer from the options given below :

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

**Ans.** [1]

**Sol.** (B)  $-\text{CN}$  is meta directing But  $-\text{OH}$  is ortho / para directing.

(E) Halides are deactivating groups.

- Q.65** Given below are two statements :

**Statement (I)** : The first ionization energy of Pb is greater than that of Sn

**Statement(II)** : The first ionization energy of Ge is greater than that of Si.

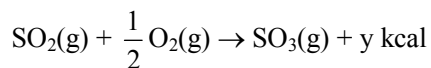
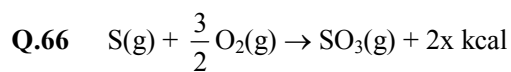
In the light of the above statements, choose the **correct** answer from the options given below :

- (1) **Statement I** is true but **Statement II** is false
- (2) Both **Statement I** and **Statement II** are false
- (3) **Statement I** is false but **Statement II** is true
- (4) Both **Statement I** and **Statement II** are true

**Ans.** [1]

**Sol.** Order of I.E. (in KJ/mol) :

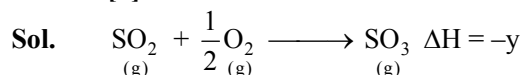
C > Si > Ge > Sn < Pb  
 1086 786 761 708 715



The heat of formation of  $SO_2(g)$  is given by :

- (1)  $\frac{2x}{y} \text{ kcal}$                       (2)  $y - 2x \text{ kcal}$                       (3)  $2x + y \text{ kcal}$                       (4)  $x + y \text{ kcal}$

**Ans.** [2]



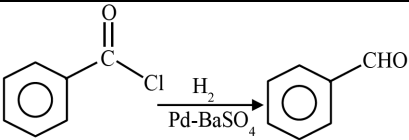
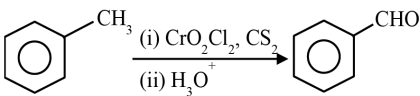
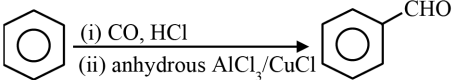
$$\Delta H_r = (\Delta H_f)_{SO_3} - (\Delta H_f)_{SO_2}$$

$$-y = -2x - (\Delta H_f)_{SO_2}$$

$$(\Delta H_f)_{SO_2} = y - 2x$$

Option (2)

**Q.67** Match **List-I** with **List-II**

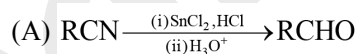
List-I		List-II	
(A)	$RCN \xrightarrow[\text{(ii) } H_3O^+]{\text{(i) } SnCl_2, HCl} RCHO$	(I)	Etard reaction
(B)		(II)	Gatterman –Koch reaction
(C)		(III)	Rosenmund reduction
(D)		(IV)	Stephen reaction

Choose the correct answer from the options given below :

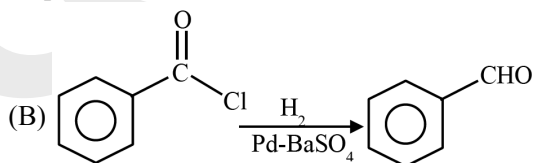
- (1) (A)-(IV), (B)-(III), (C)-(I), (D)-(II)  
 (2) (A)-(III), (B)-(IV), (C)-(II), (D)-(I)  
 (3) (A)-(I), (B)-(III), (C)-(II), (D)-(IV)  
 (4) (A)-(III), (B)-(IV), (C)-(I), (D)-(II)

**Ans.** [1]

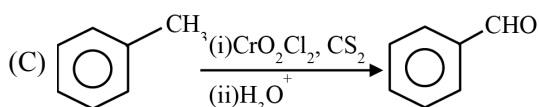
**Sol.** **List-I**



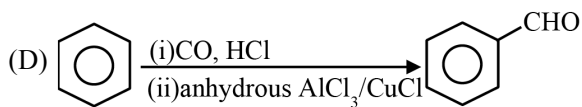
Stephen reaction



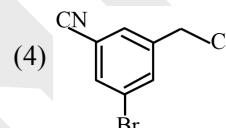
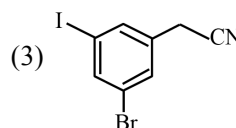
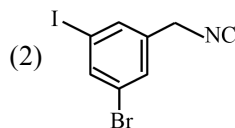
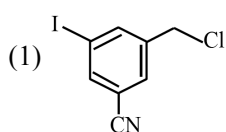
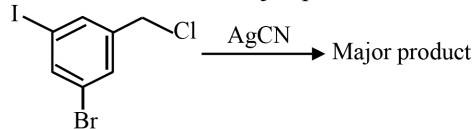
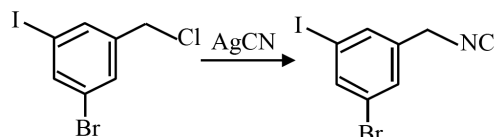
Rosenmund reduction



Etard reaction



Gatterman-Koch reaction

**Q.68** The structure of the major product formed in the following reaction is :

**Ans.** [2]  
**Sol.**

**Q.69** Match List-I with List-II.

List-I		List-I	
(A)	Adenine	(I)	
(B)	Cytosine	(II)	
(C)	Thymine	(III)	
(D)	Uracil	(IV)	

Choose the correct answer from the options given below :

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

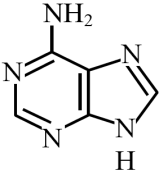
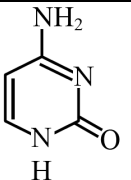
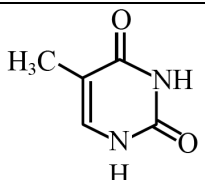
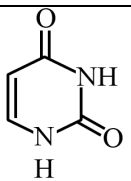
(2) (A)-(III), (B)-(I), (C)-(IV), (D)-(II)

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

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

**Ans.** [1]

Sol.

(A)	Adenine	(III)	
(B)	Cytosine	(IV)	
(C)	Thymine	(II)	
(D)	Uracil	(I)	

**Q.70** The successive 5 ionisation energies of an element are 800, 2427, 3658, 25024 and 32824 kJ/mol, respectively. By using the above values predict the group in which the above element is present :

- (1) Group 2                      (2) Group 13                      (3) Group 4                      (4) Group 14

**Ans.** [2]

**Sol.** The  $IE_4$  is suddenly very high therefore element must have 3 valence  $e^-$ (s) and it belong to group 13

**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.

**Q.71** The observed and normal masses of compound  $MX_2$  are 65.6 and 164 respectively. The percent degree of ionisation of  $MX_2$  is \_\_\_\_\_%. (Nearest integer)

**Ans.** [75]

**Sol.**  $MX_2 \rightarrow M^{+2} + 2X^-$

$$i = \frac{\text{normal molar mass}}{\text{observed molar mass}}$$

$$i = \frac{164}{65.6}$$

$$1 + (3 - 1) \alpha = \frac{164}{65.6}$$

$$2\alpha = \frac{98.4}{65.6}$$

$$\alpha = 0.75$$

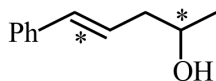
percent dissociation = 75%

**Ans.** 75

**Q.72** The possible number of stereoisomers for 5-phenylpent-4-en-2-ol is \_\_\_\_\_.

**Ans.** [4]

**Sol.**



$n$  (stereogenic unit) = 2,  $2^2 = 4$  stereoisomers are possible.

**Q.73** Consider a complex reaction taking place in three steps with rate constants  $k_1$ ,  $k_2$  and  $k_3$  respectively.

The overall rate constant  $k$  is given by the expression  $k = \sqrt{\frac{k_1 k_3}{k_2}}$ . If the activation energies of the three steps are 60, 30 and 10  $\text{kJ mol}^{-1}$  respectively, then the overall energy of activation in  $\text{kJ mol}^{-1}$  is \_\_\_\_\_.  
(Nearest integer)

**Ans.** [20]

**Sol.**  $K = \sqrt{\frac{k_1 k_3}{k_2}}$

$$A \cdot e^{-E_a/RT} = \sqrt{\frac{A_1 e^{-E_{a1}/RT} \times A_3 e^{-E_{a3}/RT}}{A_2 e^{-E_{a2}/RT}}}$$

By comparing exponential term

$$\frac{E_a}{RT} = \frac{1}{2} \times \left( \frac{E_{a1}}{RT} + \frac{E_{a3}}{RT} - \frac{E_{a2}}{RT} \right)$$

$$E = (E_{a1} + E_{a3} + E_{a2}) / 2$$

$$E_a = (60 + 10 - 30) / 2 = 20 \text{ kJ mol}^{-1}$$

**Ans.** 20

**Q.74** The hydrocarbon (X) with molar mass 80  $\text{g mol}^{-1}$  and 90% carbon has \_\_\_\_\_ degree of unsaturation.

**Ans.** [3]

**Sol.** Mass of carbon =  $\frac{80 \times 90}{100} = 72 \text{ gm}$

$$\text{Mole of C} = \frac{72}{12} = 6$$

$$\text{Mass of hydrogen} = \frac{80 \times 10}{800} = 8 \text{ gm}$$

$$\text{Mole of H} = \frac{8}{1} = 8$$

So molecular formula  $\text{C}_6\text{H}_8$

$$\text{D.U.} = 6 + 1 - 8/2 = 7 - 4 = 3$$

**Q.75** In Carius method of estimation of halogen, 0.25 g of an organic compound gave 0.15 g of silver bromide (AgBr). The percentage of Bromine in the organic compound is \_\_\_\_\_  $\times 10^{-1}\%$  (Nearest integer).  
(Given : Molar mass of Ag is 108 and Br is 80  $\text{g mol}^{-1}$ )

**Ans.** [255]

**Sol.** % Bromine =  $\frac{\text{Molar Mass of Bromine}}{\text{Molar Mass of Silver bromide}} \times \frac{\text{Weight of AgBr}}{\text{Weight of sample}} \times 100$

$$= \frac{80}{188} \times \frac{0.165}{0.25} \times 100 = \frac{4800}{188} = 25.53 = 255 \times 10^{-1}$$