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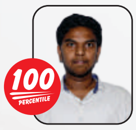

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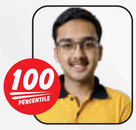

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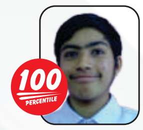

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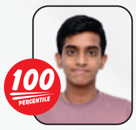

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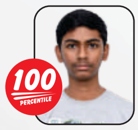

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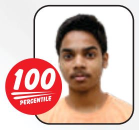

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2025_Jee-Main_03-Apr-2025_Shift-1

MATHEMATICS

Max Marks: 100

(SINGLE CORRECT ANSWER TYPE)

This section contains **20 Multiple Choice Questions.** Each question has 4 options (1), (2), (3) and (4) for its answer, out of which ONLY ONE option can be correct.

Marking scheme: +4 for correct answer, 0 if not attempted and –1 in all other cases.

01. If $y(x)=\begin{vmatrix} \sin x & \cos x & \sin x+\cos x+1 \\ 27 & 28 & 27 \\ 1 & 1 & 1 \end{vmatrix}$, $x\in\mathbb{R}$, then $\dfrac{d^2y}{dx^2}+y$ is equal to

1) -1 2) 27 3) 28 4) 1

Key: 1

Sol: Using $C_2\to C_2-C_1, C_3\to C_3-C_1$

$$y(x)=\begin{vmatrix} \sin x & \cos x-\sin x & \cos x+1 \\ 27 & 1 & 0 \\ 1 & 0 & 0 \end{vmatrix}=-(\cos x+1)$$

$$\frac{dy}{dx}=\sin x, \frac{d^2y}{dx^2}=\cos x, \text{Given expression } =\cos x-\cos x-1=-1$$

02. Let A be a matrix of order 3×3 and $|A|=5$. If $|2\,adj(3A\ adj(2A))|=2^{\alpha}.3^{\beta}.5^{\gamma}$, $\alpha,\beta,\gamma\in N$; then $\alpha+\beta+\gamma$ is equal to

1) 28 2) 27 3) 26 4) 25

Key: 2

Sol: Use $|Adj\,B|=|B|^{n-1}, and\, |KA|=K^n|A|$

$$\text{Given question } =2^3.|3A.adj(2A)|^2=2^3.3^6.|A.Adj(2A)|^2=2^3.3^6.5^2\left(|2A|^2\right)^2$$

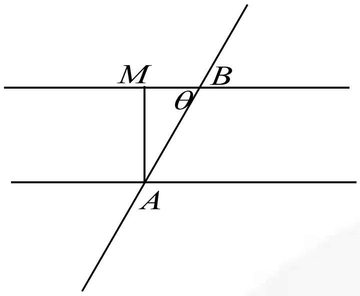
$$=2^3.3^6.5^2.|2A|^4=2^3.3^6.5^2.2^{12}.|A|^4=2^{15}.3^6.5^6\to\alpha+\beta+\gamma=27$$

03. A line passes through the origin and makes equal angle with the positive coordinate axes. It intersects the lines $L_1:2x+y+6=0$ and $L_2:4x+2y-p=0$, $p>0$ at the points A and B respectively. If $AB=\dfrac{9}{\sqrt{2}}$ and the foot of the perpendicular from the point A on the line L_2 is M, then $\dfrac{AM}{BM}$ is equal to

1) 5 2) 3 3) 2 4) 4

Key: 2

Sol: $\tan\theta = \left|\frac{-2-1}{1-2}\right| = 3 = \frac{AM}{BM}$



04. Let $z \in C$ be such that $\frac{z^2+3i}{z-2+i} = 2+3i$. Then the sum of all possible values of z^2 is

1) $19-2i$ 2) $-19-2i$ 3) $-19+2i$ 4) $19+2i$

Key: 2

Sol: $z^2+3i = z(2+3i)+(2+3i)(i-2) = z(2+3i)-7-4i$

$\Rightarrow$ $z^2 - z(2+3i)+7+7i = 0$ has roots α, β

So $\alpha+\beta = 2+3i,\ \alpha\cdot\beta = 7(1+i)$

So sum of all possible values of $z^2 = \alpha^2+\beta^2 = (\alpha+\beta)^2 - 2\alpha\beta$

$= (2+3i)^2 - 14(1+i)$

$= -19-2i$

05. Let g be a differentiable function such that $\int_0^x g(t)\,dt = x - \int_0^x t\ g(t)\,dt,\ x \ge 0$, and let $y = y(x)$ satisfy the differential equation $\frac{dy}{dx} - y\tan x = 2(x+1)\sec x\ g(x),\ x \in \left[0, \frac{\pi}{2}\right)$. If $y(0) = 0$, then $y\left(\frac{\pi}{3}\right)$ is equal to

1) $\frac{4\pi}{3}$ 2) $\frac{2\pi}{3\sqrt{3}}$ 3) $\frac{4\pi}{3\sqrt{3}}$ 4) $\frac{2\pi}{3}$

Key: 1

Sol: $\int_0^x g(t)\,dt = x - \int_0^x t.g(x)\,dt$, differentiate both sides $\Rightarrow g(x) = \frac{1}{1+x}\ \frac{dy}{dx} - y\tan x = 2\sec x$,

I.F $= \cos x$, solutions is $y\cos x = 2x + c$

$y(0) = 0 \Rightarrow C = 0 \rightarrow y = 2x\sec x \Rightarrow y\left(\frac{\pi}{3}\right) = \frac{4\pi}{3}$

06. The radius of the smallest circle which touches the parabolas $y = x^2+2$ and $x = y^2+2$ is

1) $\frac{7\sqrt{2}}{2}$ 2) $\frac{7\sqrt{2}}{16}$ 3) $\frac{7\sqrt{2}}{8}$ 4) $\frac{7\sqrt{2}}{4}$

Key: 3

Sol: $x^2 = y-2$ & $y^2 = x-2$ are Symmetrical and about the line $y = x$

Let $P\left(2+\frac{t^2}{4},\frac{t}{2}\right)$ be any point on $y^2 = x-2$

So tangent at P, is parallel to the line $y = x$

$\Rightarrow \frac{1}{t} = 1 \Rightarrow t = 1, P\left(\frac{9}{4},\frac{1}{2}\right)$

So, $r =$ perpendicular distance from P to the line $x-y=0$ $= \frac{\left|\frac{9}{4}-\frac{1}{2}\right|}{\sqrt{1^2+(-1)^2}} = \frac{7}{4\sqrt{2}} \times \frac{\sqrt{2}}{\sqrt{2}} = \frac{7\sqrt{2}}{8}$

07. A line passing through the point $P\left(\sqrt{5},\sqrt{5}\right)$ intersects the ellipse $\frac{x^2}{36}+\frac{y^2}{25}=1$ at A and B such that $(PA)\cdot(PB)$ is maximum. Then $5\left(PA^2+PB^2\right)$ is equal to

1)218 2) 377 3) 290 4) 338

Key: 4

Sol: Let A, B$=\left(\sqrt{5}+r\cos\theta, \sqrt{5}+r\sin\theta\right)$ lines on the ellipse $\frac{x^2}{36}+\frac{y^2}{25}=1$

$\Rightarrow r^2\left(\frac{\cos^2\theta}{36}+\frac{\sin^2\theta}{25}\right)+r\left(\frac{2\sqrt{5}\cos\theta}{36}+\frac{2\sqrt{5}\sin\theta}{25}\right)+\left(\frac{5}{36}+\frac{5}{25}-1\right)=0$ is a quadratic equation in $'r'$. So $'r'$ has two values $, r_1 = PA, r_2 = PB$

So that $r_1 \cdot r_2$ is maximum

$\Rightarrow r_1 \cdot r_2 = \frac{(-595)}{25\cos^2\theta+36\sin^2\theta}$ is maximum

$\Rightarrow 25\cos^2\theta+36\sin^2\theta$ is minimum

$\Rightarrow 25+11\sin^2\theta$ is minimum for $\theta = 0^0$

Consider $PA^2+PB^2 = r_1^2+r_2^2 = (r_1+r_2)^2 - 2r_1r_2$ for $\theta = 0$

So $5\left(PA^2+PB^2\right) = 338$

08. Let a_1, a_2, a_3....... be a G.P. of increasing positive numbers. If $a_3a_5 = 729$ and $a_2+a_4 = \frac{111}{4}$ then $24(a_1+a_2+a_3)$ is equal to

1) 128 2) 129 3) 130 4) 131

Key: 2

Sol: $ar^2.ar^4 = 729 \Rightarrow a^2r^6 = 729 \Rightarrow ar^3 = 27 \Rightarrow a_4 = 27$

$$a_2 = \frac{111}{4} - 27 = \frac{3}{4} \Rightarrow a = \frac{1}{8}, r = 6, a_1 + a_2 + a_3 = \frac{43}{8} \Rightarrow 24(a_1 + a_2 + a_3) = 129$$

09. Line L_1 passes through the point $(1,2,3)$ and is parallel to z-axis. Line L_2 passes through the point $(\lambda,5,6)$ and is parallel to y-axis. Let for $\lambda = \lambda_1, \lambda_2, \lambda_2 < \lambda_1$, the shortest distance between the two lines be 3. Then the square of the distance of the point $(\lambda_1, \lambda_2, 7)$ from the line L_1 is

1) 40 2) 37 3) 32 4) 25

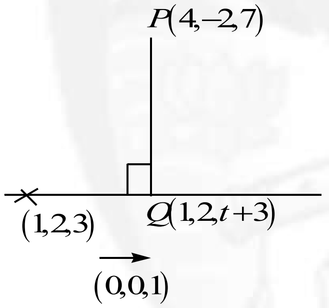
Key: 4

Sol: $L_1 : \frac{x-1}{0} = \frac{y-2}{0} = \frac{z-3}{1}, L_2 : \frac{x-\lambda}{0} = \frac{y-5}{1} = \frac{z-6}{0}$

$$\text{Shortest distance} = \frac{\left[\bar{a}-\bar{c} \quad \bar{b} \quad \bar{d}\right]}{\left|\bar{b}\times\bar{d}\right|} = \frac{\begin{vmatrix} \lambda-1 & 3 & 3 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{vmatrix}}{\begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{vmatrix}} = 3$$

$\Rightarrow |1-\lambda| = 3 \Rightarrow \lambda = -2, 4$

$\Rightarrow \lambda_1 = 4, \lambda_2 = -2$



$\Rightarrow (-3, 4, t-4) \perp^r (0,0,1)$

$\Rightarrow t = 4, \Rightarrow Q(1,2,7)$

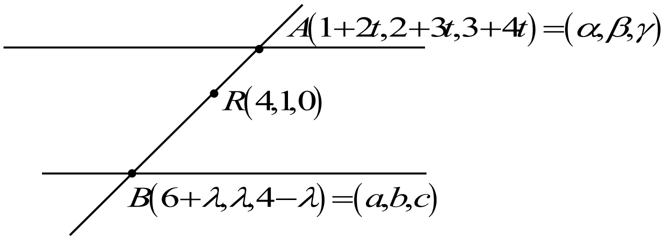
$(PQ)^2 = 9 + 16 = 25$

10. Let a line passing through the point $(4,1,0)$ intersect the line $L_1 : \frac{x-1}{2} = \frac{y-2}{3} = \frac{z-3}{4}$ at the point $A(\alpha,\beta,\gamma)$ and the line $L_2 : x-6 = y = -z+4$ at the point $B(a,b,c)$. Then $\begin{vmatrix} 1 & 0 & 1 \\ \alpha & \beta & \gamma \\ a & b & c \end{vmatrix}$ is equal to

1) 6 2) 16 3) 12 4) 8

Key: 4

Sol:



A, R, B are collinear $\Rightarrow \overline{AR}\ parallel\, \overline{BR}$

$$\Rightarrow \frac{2t-3}{2+\lambda}=\frac{1+3t}{\lambda-1}=\frac{3+4t}{4-\lambda}$$

Solving we get $\lambda=-3t \Rightarrow t=-1,\ \lambda=3\ (or)\ t=\frac{-1}{3},\ \lambda=1$

Take $\lambda=3,\ t=-1$

$A(\alpha,\beta,\gamma)=(-1,-1,-1),\ B(a,b,c)=(9,3,1)$

So given determinant $\begin{vmatrix}1 & 0 & 1\\ -1 & -1 & -1\\ 9 & 3 & 1\end{vmatrix}=1(2)+1(6)=8$

11. Let $A=\{-3,-2,-1,0,1,2,3\}$. Let R be a relation on A defined by xRy if and only if $0\le x^2+2y\le 4$. Let l be the number of elements in R and m be the minimum number of elements required to be added in R to make it a reflexive relation. Then $l+m$ is equal to

1) 20 2) 17 3) 18 4) 19

Key: 3

Sol: If $x=0 \to y=0,1,2 \to 3$

$x=\pm1 \to y=0,1 \to 4$

$x=\pm2 \to y=-2,-1,0 \to 6$

$x=\pm3 \to y=-3, \to 2$

$\underline{15}$

So $n(R)=15=l$

minimum number of elements added to R so that R is reflexive is '3'

$\{(-1,-1)(2,2,)(3,3)\} \Rightarrow m=3 \Rightarrow l+m=18$

12. The number of solution of the equation $2x+3\tan x=\pi$, $x\in[-2\pi,2\pi]-\left\{\pm\frac{\pi}{2},\pm\frac{3\pi}{2}\right\}$ is:

1) 6 2) 3 3) 4 4) 5

Key: 4

Sol: $\tan x=\frac{\pi-2x}{3}=\frac{\pi}{3}-\frac{x}{\left(3/2\right)}$

Draw the graphs of $y = \tan x,\ and\ y = \frac{\pi}{3} - \frac{x}{\left(3/2\right)}$, (straight line) we get '5' points of intersection.

13. If $\sum_{r=1}^{9}\left(\frac{r+3}{2^r}\right)\cdot {}^9C_r = \alpha\left(\frac{3}{2}\right)^9 - \beta, \alpha, \beta \in \mathbb{N}$, then $(\alpha+\beta)^2$ is equal to

1) 9 2) 27 3) 81 4) 18

Key: 3

Sol: Given expression $= \sum_{r=1}^{9} r.{}^9C_r.\frac{1}{2}.\frac{1}{2^{r-1}} + 3\sum_{r=1}^{9} 9C_r.\frac{1}{2^r}\left(diff\ (1+x)^9\ wrto\ 'x'\ and\ put\ x = \frac{1}{2}\right)$

$$= \frac{9}{2}\left(\left(1+\frac{1}{2}\right)^8\right) + 3\left(\left(1+\frac{1}{2}\right)^9 - 1\right) = \frac{3^{10}}{2^9} + \frac{3^{10}}{2^9} - 3 = \frac{3^{10}}{2^8} - 3 = 6\left(\frac{3}{2}\right)^9 - 3 \Rightarrow \alpha = 6, \beta = 3$$

So $(\alpha+\beta)^2 = 81$

14. Let $f(x) = \begin{cases} (1+ax)^{1/x} & , x<0 \\ 1+b & ,x=0 \\ \frac{(x+4)^{1/2}-2}{(x+c)^{1/3}-2}, & x>0 \end{cases}$ be continuous at $x=0$. Then $e^a bc$ is equal to:

1) 48 2) 64 3) 72 4) 36

Key: 1

Sol: $f(0) = b+1,\ \ R.H.L = \underset{x\to 0^+}{Lt} \frac{(x+4)^{1/2}-2}{(x+c)^{1/3}-2} = \left(\frac{0}{c^{\frac{1}{3}}-2}\right) \Rightarrow c^{\frac{1}{3}} - 2 = 0 \Rightarrow c = 8$

$$\underset{x\to 0^+}{Lt} \frac{\left(1+\frac{x}{4}\right)^{\frac{1}{2}} - 1}{\left(1+\frac{x}{8}\right)^{\frac{1}{3}} - 1} = \frac{\frac{1}{2}\cdot\frac{1}{4}}{\frac{1}{3}\cdot\frac{1}{8}} = 3 = b+1 \Rightarrow b = 2$$

By $LHL = \underset{x\to 0^-}{Lt}\left(e^{\frac{1}{x}(1+ax-1)}\right) = e^a = b+1$

$so\ e^a.bc = (b+1).b.c = 3.2.8 = 48$

15. Let α and β be the roots of $x^2+\sqrt{3}x-16=0$, and γ and δ be the roots of $x^2+3x-1=0$. If $P_n=\alpha^n+\beta^n$ and $Q_n=\gamma^n+\delta^n$, then $\frac{P_{25}+\sqrt{3}P_{24}}{2P_{23}}+\frac{Q_{25}-Q_{23}}{Q_{24}}$ is equal to

1) 3 2) 7 3) 5 4) 4

Key: 3

Sol: by Newton's theorem $P_{n+2}+\sqrt{3}\,^{P}n_{+1}-16P_n=0 \Rightarrow put\ n=23 \rightarrow P_{25}+\sqrt{3}P_{24}=16P_{23}$

$Q_{n+2}+3Q_{n+1}-1.Q_n=0 \Rightarrow Put\ n=23 \Rightarrow Q_{25}+3Q_{24}=Q_{23}$

So given expression $=\frac{16\cancel{P_{23}}}{2\cancel{P_{23}}}+\frac{\left(-3\cancel{Q_{24}}\right)}{\cancel{Q_{24}}}=8-3=5$

16. The sum of all rational terms in the expansion of $\left(2+\sqrt{3}\right)^8$ is

1) 33845 2) 18817 3) 16923 4) 3763

Key: 2

Sol: $T_{r+1}={}^{8}C_r.2^{8-r}.3^{\frac{r}{2}}$, for rational $r=0,2,4,6,8$

Sum $8C_0.2^8+{}^8C_2.2^6.3+{}^8C_4.2^43^2+{}^8C_6.2^2.3^3+{}^8C_8.2^0.3^4=16\times1171+81=18817$.

17. If the domain of the function $f(x)=\log_e\left(\frac{2x-3}{5+4x}\right)+\sin^{-1}\left(\frac{4+3x}{2-x}\right)$ is $[\alpha,\beta)$, then $\alpha^2+4\beta$ is equal to

1) 3 2) 7 3) 4 4) 5

Key: 3

Sol: $\frac{-3+2x}{5+4x}>0 \Rightarrow x\in\left(-\infty,\frac{-5}{4}\right)\cup\left(\frac{3}{2},\infty\right)$................$\boxed{1}$, $-1\le\frac{4+3x}{2-x}\le1$

$0\le\frac{4+3x}{2-x}+1\ \&\ \frac{4+3x}{2-x}-1\le0$

$0\le\frac{6+2x}{2-x}\ \&\ \frac{2+4x}{2-x}\le0$

$\frac{x+3}{x-2}\le0\ \&\ \frac{2x+1}{x-2}\ge0$

$x\in[-3,2)\ \&\ x\in\left(-\infty,-\frac{1}{2}\right]\cup(2,\infty)$

So $x\in\left[-3,-\frac{1}{2}\right)$ --------(2) & $x\ne2$

From (1) & (2) $x\in\left[-3,-\frac{5}{4}\right)$

So $\alpha=-3,\ \beta=-\frac{5}{4} \Rightarrow \alpha^2+4\beta=9-5=4$

18. Let $f(x)=\int x^3\sqrt{3-x^2}\,dx$. If $5f\left(\sqrt{2}\right)=-4$, then $f(1)$ is equal to

1) $-\frac{8\sqrt{2}}{5}$ 2) $-\frac{4\sqrt{2}}{5}$ 3) $-\frac{6\sqrt{2}}{5}$ 4) $-\frac{2\sqrt{2}}{5}$

Key: 3

Sol: Let $3-x^2=t \Rightarrow f(x)=\int(3-t)\sqrt{t}\left(-\frac{1}{2}\right)dt=\frac{t^{\frac{5}{2}}}{5}-t^{3/2}+C=\frac{\left(3-x^2\right)^{5/2}}{5}-\frac{\left(3-x^2\right)^{3/2}}{1}+C$

$5f\left(\sqrt{2}\right)=-4 \Rightarrow C=0, f(1)=\frac{4\sqrt{2}}{5}-2\sqrt{2}=\frac{-6\sqrt{2}}{5}$

19. Let the domain of the function $f(x)=\log_2\log_4\log_6\left(3+4x-x^2\right)$ be (a,b). If $\int_0^{b-a}\left[x^2\right]dx=p-\sqrt{q}-\sqrt{r},\ p,\ q,\ r\in\mathbb{N}$, $\gcd(p,q,r)=1$, where $[\cdot]$ is the greatest integer function, then $p+q+r$ is equal to

1) 10 2) 9 3) 11 4) 8

Key: 1

Sol: $3+4x-x^2>0 \Rightarrow x^2-4x-3<0 \Rightarrow x\in\left(2-\sqrt{7},2+\sqrt{7}\right)$ ------(1)

$\log_4\left(\log_6\left(3+4x-x^2\right)\right)>0=\log_4 1 \Rightarrow \log_6\left(3+4x-x^2\right)>1=\log_6 6$

$\Rightarrow 3+4x-x^2>6 \Rightarrow x^2-4x+3<0 \Rightarrow (x-1)(x-3)<0 \Rightarrow x\in(1,3)$ -----(2)

From (1) & (2) domain of $f(x)=(1,3)=(a,b) \Rightarrow b-a=2$

So $\int_0^2\left[x^2\right]dx=\int_0^1\left[x^2\right]dx+\int_1^{\sqrt{2}}\left[x^2\right]dx+\int_{\sqrt{2}}^{\sqrt{3}}\left[x^2\right]dx+\int_{\sqrt{3}}^2\left[x^2\right]dx$

$=0+1\left(\sqrt{2}-1\right)+2\left(\sqrt{3}-\sqrt{2}\right)+3\left(2-\sqrt{3}\right)=5-\sqrt{2}-\sqrt{3}$

$p+q+r=10$

20. The sum $1+3+11+25+45+71+.......$ upto 20 terms, is equal to

1) 8124 2) 6982 3) 7130 4) 7240

Key: 4

Sol: Differences of consecutive terms are in AP

$S=1+3+11+25+45+....+T_n$

Let $\underline{S=\quad 1+3+11+25+.............+T_n}$

on substrating we get $0=1+(2+8+14+20+......)-T_n$

$\therefore T_n=1+2(1+4+7+10+...(n-1)terms)(AP)$

$=1+2\left(\frac{n-1}{2}\right)(2.1+(n-2)3)$

$=1+(n-1)(3n-4)=3n^2-7n+5$

$S_n=\Sigma T_n=3\sum_1^{20}n^2-7\sum_1^{20}n+5\sum_1^{20}1=8610-1470+100=7240$

(or) let $T_n = an^2 + bn + C$, use $T_1 = 1, T_2 = 3, T_3 = 11$ solve we get $a = 3, b = -7, c = 5$

SECTION-II (NUMERICAL VALUE TYPE)

This section contains **5 Numerical Value Type Questions.** The Answer should be within **0 to 9999.** If the Answer is in **Decimal** then round off to the **Nearest Integer** value (Example i,e. If answer is above **10** and less than **10.5** round off is **10** and If answer is from **10.5** and less than **11** round off is **11**).

Marking scheme: +4 for correct answer, 0 if not attempt and -1 in all other cases..

21. Let $\vec{a} = \hat{i} + \hat{j} + \hat{k}, \vec{b} = 3\hat{i} + 2\hat{j} - \hat{k}, \vec{c} = \lambda\hat{j} + \mu\hat{k}$ and $\hat{d}$ be a unit vector such that $\vec{a} \times \hat{d} = \vec{b} \times \hat{d}$ and $\vec{c} \cdot \hat{d} = 1$. If $\vec{c}$ is perpendicular to $\vec{a}$, then $\left|3\lambda\hat{d} + \mu\vec{c}\right|^2$ is equal to _____

Key: 5

Sol: $\vec{a} \times \hat{d} = \vec{b} \times \vec{d} \Rightarrow \hat{d} = \alpha\left(\vec{a} - \vec{b}\right) = \alpha\left(-2\hat{i} - \hat{j} + 2\hat{k}\right)$ is unit vector $\Rightarrow \alpha = \frac{1}{3}$

$$\Rightarrow \hat{d} = \pm\frac{\left(2\hat{i} + \hat{j} - 2\hat{k}\right)}{3}$$

$$\Rightarrow \vec{c} \cdot \hat{d} = 1 \Rightarrow \frac{\lambda - 2\mu}{3} = 1 \Rightarrow \lambda - 2\mu = 3$$

$$\vec{c} \cdot \vec{a} = 0 \Rightarrow \lambda + \mu = 0 \Rightarrow \mu = -\lambda \text{ solving } \lambda = 1, \mu = -1$$

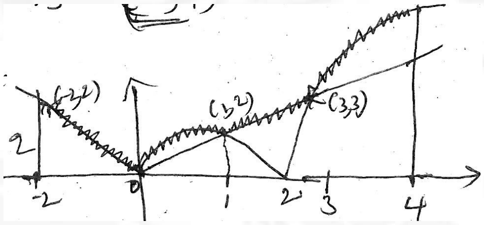
$\left|\vec{c}\right|^2 = 2$, so $\left|3\lambda\hat{d} + \mu\vec{c}\right|^2 = 9\lambda^2 \cdot \left|\hat{d}\right|^2 + \mu^2\left|\vec{c}\right|^2 + 6\lambda\mu\hat{d} \cdot \vec{c}$

$$= 9 + 2 - 6 = 5$$

22. The area of the region bounded by the curve $y = \max\{|x|, x|x-2|\}$, the x-axis and the lines $x = -2$ and $x = 4$ is equal to ____

Key: 12

Sol: Draw the graph of $y = \max\{|x|, x|x-2|\}$ in $(-2, 4)$



Required area

$$= \frac{1}{2}2.2 + \int_0^1\left(2x - x^2\right)dx + \frac{1}{2}.2.(1+3) + \int_3^4\left(x^2 + 2x\right)dx$$

$$= 2 + \frac{2}{3} + 4 + \frac{16}{3} = 12$$

23. Let the product of the focal distance of the point $P\left(4, 2\sqrt{3}\right)$ on the hyperbola $H: \frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ be 32. Let the length of the conjugate axis of H be p and the length of its latus rectum be q. Then $p^2 + q^2$ is equal to _____

Key: 120

Sol: Product of focal distances $=\left|(ex_1+a)(ex_1-a)\right|=e^2{x_1}^2-a^2=32$

$$\Rightarrow 16e^2-a^2=32 \Rightarrow 16\left(1+\frac{b^2}{a^2}\right)=a^2+32 \Rightarrow 16\frac{b^2}{a^2}=a^2+16------(1)$$

$P\left(4,2\sqrt{3}\right)$ Lies on H $\Rightarrow \frac{16}{a^2}-\frac{12}{b^2}=1------(2)$

Solving (1) & (2) we get $a^2=8, b^2=12$

$$p=2b=2\cdot\sqrt{12},\ q=\frac{2b^2}{a}=\frac{24}{2\sqrt{2}}=6\sqrt{2}$$

$$p^2+q^2=48+72=120$$

24. All five letter words are made using all the letters A, B, C, D, E and arranged as in an English dictionary with serial numbers. Let the word at serial number n be denoted by W_n. Let the probability $P(W_n)$ of choosing the word W_n satisfy

$P(W_n)=2P(W_{n-1}),\ n>1$. If $P(CDBEA)=\frac{2^\alpha}{2^\beta-1}, \alpha,\beta\in\mathbb{N}$, then $\alpha+\beta$ is equal to: ____

Key: 183

Sol: Total words formed with letters A, B, C, D, E are 120

"CDBEA" occurs at 64th place.

Let $P(W_1)=k, P(W_2)=2k, P(w_3)=2^2k,.....$

So $P(W_1)+P(W_2)+...+P(W_{120})=1 \Rightarrow k\left(1+2+2^2+...+2^{119}\right)=1 \Rightarrow k=\frac{1}{2^{120}-1}$

So $P(W_{64})=2^{63}K=\frac{2^{63}}{2^{120}-1} \Rightarrow \alpha+\beta=63+120=183$

25. If the number of seven-digit numbers, such that the sum of their digits is even, is $m\cdot n\cdot 10^n;\ m,n\in\{1,2,3,......,9\}$, then $m+n$ is equal to ____

Key: 14

Sol: Total 7 digit numbers $=9\cdot 10^6$

Sum of these 7 digit numbers is even $=\frac{9\cdot 10^6}{2}=9\times5\times10^5 \Rightarrow m=9, n=5$

So $m+n=14$

PHYSICS

SECTION-I (SINGLE CORRECT ANSWER TYPE)

This section contains **20 Multiple Choice Questions.** Each question has 4 options (1), (2), (3) and (4) for its answer, out of which ONLY ONE option can be correct.

Marking scheme: +4 for correct answer, 0 if not attempted and –1 in all other cases.

26. A particle is released from height S above the surface of the earth. At certain height its kinetic energy is three times its potential energy. The height from the surface of the earth and the speed of the particle at that instant are respectively.

1) $\frac{S}{2}, \frac{3gS}{2}$ 2) $\frac{S}{4}, \frac{3gS}{2}$ 3) $\frac{S}{4}, \sqrt{\frac{3gS}{2}}$ 4) $\frac{S}{2}, \sqrt{\frac{3gS}{2}}$

Key: 3

Sol: $KE + P.E = mgS$

$$3P.E + P.E = mgS$$

$$4\cancel{mg}S^1 = \cancel{mg}s$$

$$S^1 = \frac{S}{4}$$

$$K.E = 3mg\frac{S}{4}$$

$$\frac{1}{2}\cancel{m}v^2 = \frac{3}{4}\cancel{m}gs$$

$$v = \sqrt{\frac{3gs}{2}}$$

27. Match the List – I with List – II

LIST – I		LIST - II	
A)	Gravitational constant	I)	$\left[LT^{-2}\right]$
B)	Gravitational potential energy	II)	$\left[L^2T^{-2}\right]$
C)	Gravitational potential	III)	$\left[ML^2T^{-2}\right]$
D)	Acceleration due to gravity	IV)	$\left[M^{-1}L^3T^{-2}\right]$

Choose the correct answer from the options given below:

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

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

Key: 3

Sol: A) Gravitational contact

$$G = \frac{FR^2}{M_1M_2}$$

$$= M^{-1}L^3T^{-2}$$

B) Gravitational potential energy

$$U = \frac{-GM_1M_2}{R}$$

$= M^1L^2T^{-2}$

C) Gravitational potential

$\frac{-GM}{R} = M^0L^2T^{-2}$

D) Acceleration due to gravity

$M^0L^1T^{-2}$

$A-IV, B-III, C-II, D-I$

28. The work function of a metal is $3eV$. The color of the visible light that is required to cause emission of photoelectrons is

1) Yellow 2) Blue 3) Green 4) Red

Key: 2

Sol: $E = \frac{hc}{\lambda}$

$= \frac{1240}{\lambda(nm)}$

$\lambda = \frac{1240}{E}$

$= 413nm$

Among all colours blue colour has the above wavelength

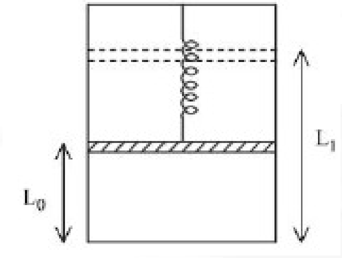
29. During the melting of a slab of ice at 273 K at atmospheric pressure:

1) Positive work is done by the ice-water system on the atmosphere
2) Positive work is done on the ice-water system by the atmosphere
3) Internal energy of the ice-water system decreases.
4) Internal energy of ice-water system remains unchanged

Key: 2

Sol: When a slab of ice at 273K (i,e 0^0C) melts in to water, volume of water formed is less compared to volume of ice , i.e volume decreases hence work done by ice water system is negative. So work done on the ice-water system is positive by atmosphere

30.



A piston of mass M is hung from a massless spring whose restoring force law goes as $F = -kx^3$, where k is the spring constant of appropriate dimension. The piston separates the vertical chamber into two parts, where the bottom part is filled with 'n' moles of an ideal gas. An external work is done on the gas isothermally (at a constant temperature T) with the help of a heating filament (with negligible volume) mounted in lower part of the chamber, so that the piston goes up from a height L_0 to L_1, the total energy delivered by the filament is: (Assume spring to be in its natural length before heating)

1) $nRT\ln\left(\frac{L_1^2}{L_0^2}\right)+\frac{Mg}{2}\left(L_1-L_0\right)+\frac{k}{4}\left(L_1^4-L_0^4\right)$

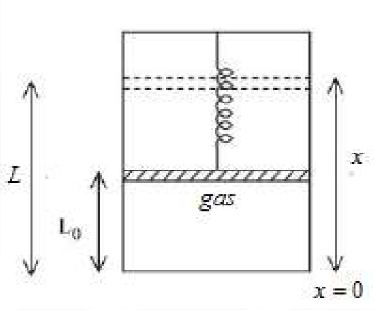
2) $nRT\ln\left(\frac{L_1}{L_0}\right)+Mg\left(L_1-L_0\right)+\frac{k}{4}\left(L_1^4-L_0^4\right)$

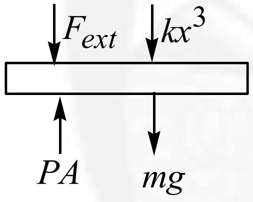
3) $3nRT\ln\left(\frac{L_1}{L_0}\right)+2Mg\left(L_1-L_0\right)+\frac{k}{3}\left(L_1^3-L_0^3\right)$

4) $nRT\ln\left(\frac{L_1}{L_0}\right)+Mg\left(L_1-L_0\right)+\frac{3k}{4}\left(L_1^4-L_0^4\right)$

Key: 2

Sol: At any position of the piston, say at a distance x from the bottom, net force on it is zero





$PA = F_{ext} + mg + kx^3$

$\therefore P = F_{ext} + mg + kx^3$

$\therefore$ External work done by the gas is

$$\Delta w_{gas} = \int PdV = \int \frac{\left(F_{ext} + mg + kx^3\right)}{A} Adx$$

$$= \int_{L_0}^{L_1} F_{ext}dx + mg\int_{L_0}^{L_1} dx + k\int_{L_0}^{L_1} x^3 dx$$

$$= \Delta W_{ext} + mg\left(L_1-L_0\right)+\frac{K}{4}\left(L_1^4-L_0^4\right)$$

$$= nRT\ ln\left(\frac{L_1}{L_0}\right)+mg\left(L_1-L_0\right)+\frac{K}{4}\left(L_1^4-L_0^4\right)$$

According to I law of thermodynamics for the gas

$\Delta Q = \Delta U + \Delta W_{gas} = 0 + \Delta W_{gas} \Rightarrow \Delta Q = \Delta W_{gas}$

$$\Delta Q = nRT\ ln\left(\frac{L_1}{L_0}\right)+mg\left(L_1-L_0\right)+\frac{K}{4}\left(L_1^4-L_0^4\right)$$

31. The radii of curvature for a thin convex lens are $10cm$ and $15cm$ respectively. The focal length of the lens is $12cm$. The refractive index of the lens material is

1) 1.4 2) 1.5 3) 1.2 4) 1.8

Key: 2

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

Convex lens

$R_1=+Ve, R_2=-Ve$

$$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$$

$$\frac{1}{12}=(\mu-1)\left(\frac{1}{10}+\frac{1}{15}\right)$$

$$\frac{1}{\underset{6}{\cancel{12}}}=(\mu-1)\left(\frac{\cancel{25}}{\underset{6}{\cancel{150}}}\right)$$

$$(\mu)=\frac{1}{2}$$

$$\mu=1+\frac{1}{2}=\frac{3}{2}$$

$$\mu=1.5$$

32. A gas is kept in a container having walls which are thermally non-conducting. Initially the gas has a volume of $800\,cm^3$ and temperature 27^0C. The change in temperature when the gas is adiabatically compressed to $200\ cm^3$ is:

(Take $\gamma=1.5$; γ is the ratio of specific heats at constant pressure and at constant volume)

1) 327 K 2) 300 K 3) 600 K 4) 522 K

Key: 2

Sol: $TV^{\gamma-1}=cont$

$$T_1V_1^{\gamma-1}=T_2V_2^{\gamma-1}$$

$$\frac{T_2}{T_1}=\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$=\left(\frac{800}{200}\right)^{1.5-1}$$

$$=(4)^{1/2}$$

$$\frac{T_2}{T_1}=2$$

$$T_2=2T_1$$

$$=2\times300$$

$$=600K$$

$\Delta T = T_2 - T_1$

$= 600 - 300$

$= 300K$

33. A wire of length $25\ m$ and cross-sectional area $5\ mm^2$ having resistivity of $2\times10^{-6}\ \Omega m$ is bent into a complete circle. The resistance between diametrically opposite points will be

1) $12.5\,\Omega$ 2) $50\,\Omega$ 3) $100\,\Omega$ 4) $25\,\Omega$

Key: **No key** (correct answer 2.5Ω)

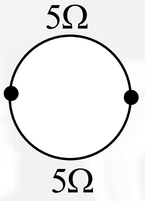
Sol: Resistance

$$R = \frac{\rho l}{A}$$

$$= \frac{2\times\cancel{10^{-6}}\times 25}{5\times\cancel{10^{-6}}}$$

$= 10\Omega$

Diametrically opposite points



$$R_{eff} = \frac{5\times5}{5+5}$$

$$= \frac{25}{10}$$

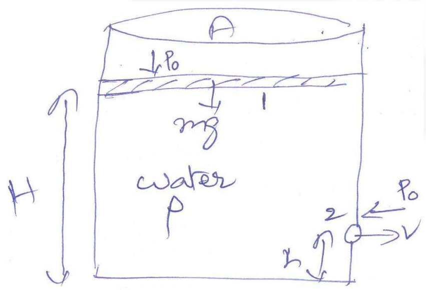
$= 2.5\Omega$

34. Consider a completely full cylindrical water tank of height $1.6m$ and of cross-sectional area $0.5m^2$. It has a small hole in its side at a height $90cm$ from the bottom. Assume the cross-sectional area of the hole to be negligibly small as compared to that of the water tank. If a load $50kg$ is applied at the top surface of the water in the tank then the velocity of the water coming out at the instant when the hole is opened is: $\left(g = 10\ m/s^2\right)$

1) $5\ m/s$ 2) $4\ m/s$ 3) $3\ m/s$ 4) $2\ m/s$

Key: 2

Sol:



Acc to Bernoulli's principle

$P + \frac{1}{2}\rho v^2 + \rho gh =$ const at points 1 and 2

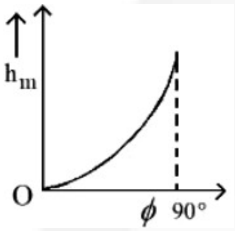
$$P_0+\frac{mg}{A}+0+\rho gH=P_0+\frac{1}{2}\rho V^2+\rho gh$$

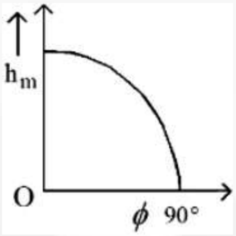
$$\frac{mg}{A}=\frac{1}{2}\rho V^2-\rho g\left(H-h\right)$$

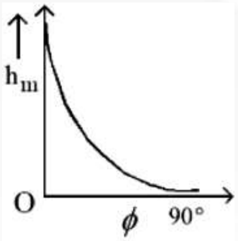
$$\frac{50\times10}{0.5}=\frac{1}{2}\times10^3V^2-10^3\times10\left(1.6-0.9\right)$$

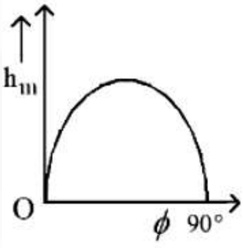
Solving $V=4m/s$

35. The angle of projection of a particle is measured from the vertical axis as ϕ and the maximum height reached by the particle is h_m. Here h_m as function of ϕ can be presented as

1) 

2) 

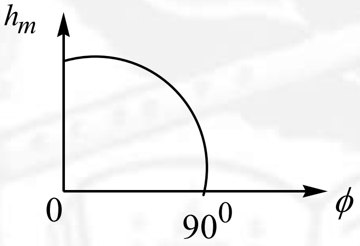
3) 

4) 

Key: 2

Sol:

$$h_m=\frac{u^2\cos^2\phi}{2g}=\frac{u^2}{2g}\left[\frac{1+\cos2\phi}{2}\right]$$



36. The radiation pressure exerted by a 450 W light source on a perfectly reflecting surface placed at $2m$ away from it, is

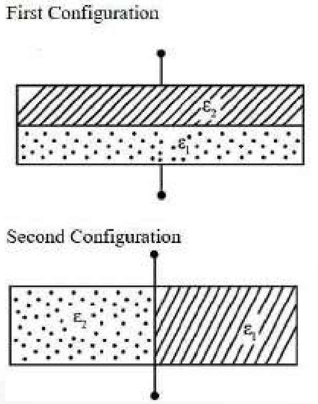
1) 1.5×10^{-8}pascal
2) 6×10^{-8} pascal
3) 0
4) 3×10^{-8} pascal

Key: 2

Sol: Radiation pressure$=\frac{2I}{C}=\frac{2P}{4\pi r^2C}=\frac{2\times450}{4\times\frac{22}{7}\times2^2\times3\times10^8}$

$$=6\times10^{-8}\,pascal$$

37. A parallel plate capacitor is filled equally (half) with two dielectrics of dielectric constants ε_1 and ε_2, as shown in figures. The distance between the plates is d and area of each plate is A. If capacitance in first configuration and second configuration are $C_1$and C_2 respectively, then $\frac{C_1}{C_2}$is:



1) $\frac{4\varepsilon_1\varepsilon_2}{(\varepsilon_1+\varepsilon_2)^2}$ 2) $\frac{\varepsilon_0(\varepsilon_1+\varepsilon_2)}{2}$ 3) $\frac{\varepsilon_1\varepsilon_2^2}{(\varepsilon_1+\varepsilon_2)^2}$ 4) $\frac{\varepsilon_1\varepsilon_2}{\varepsilon_1+\varepsilon_2}$

Key: 1

Sol: In case I, two di-electric slabs are inserted such that plates separation is halved, hence effective di-electric constant is $\frac{2\varepsilon_1\varepsilon_2}{\varepsilon_1+\varepsilon_2}$

$$\therefore C_1=\left(\frac{2\varepsilon_1\varepsilon_2}{\varepsilon_1+\varepsilon_2}\right)\frac{\varepsilon_0 A}{d}$$

In case II, two di-electric slabs are inserted such that plates area is halved, hence effective di-electric constant is $\frac{\varepsilon_1+\varepsilon_2}{2}$

$$\therefore C_2=\left(\frac{\varepsilon_1+\varepsilon_2}{2}\right)\frac{\varepsilon_0 A}{d}$$

$$\therefore \frac{C_1}{C_2}=\frac{4\varepsilon_1\varepsilon_2}{(\varepsilon_1+\varepsilon_2)^2}$$

38. A person measure mass of 3 different particles as 435.42g, 226.3g and 0.125g.According the rules for arithmetic operation with significant figures, the addition of the masses of 3 particles will be

1) 661.845 g 2) 661.84 g 3) 661.8 g 4) 662 g

Key: 3

Sol: $435.42+226.3+0.125$

` $=661.845$

In addition and subtraction, the final result should have least number of decimal places as they are in the given individual values

$=661.8$

39. Consider following statements for refraction of light through prism, when angle of deviation is minimum.

A) The refracted ray inside prism becomes parallel to the base

B) Large angle prisms provide smaller angle of minimum deviation

C) Angle of incidence and angle of emergence becomes equal

D) There are always two sets of incidence for which deviation will be same except at minimum deviation setting.

E) Angle of refraction becomes double of prism angle.

Choose the correct answer from the options given below:

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

Key: 3

Sol: When the angle of prism (A) increases the minimum deviation may or may not decrease.

And hence B is wrong. According to $\mu = \dfrac{\sin\left(\dfrac{A+d_m}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$

40. The electrostatic potential on the surface of uniformly charged spherical shell of radius R=10cm is 120V. The potential at the centre of shell, at a distance r=5 cm from, centre, and at a distance r=15cm from the centre of the shell respectively, are

1) $0V, 0V, 80V$ 2) $120V, 120V, 80V$ 3) $0V, 120V, 40V$ 4) $40V, 40V, 80V$

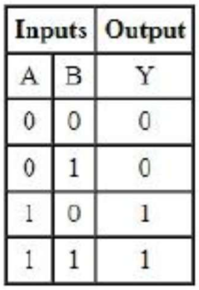
Key: 2

Sol: In case of uniformly charged spherical shell, potential at any point inside is constant and equal to potential on the surface

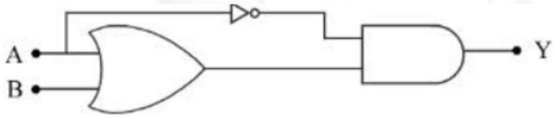
On the surface of shell $\dfrac{KQ}{R} = 120$ at outside $\dfrac{KQ}{r} = ?$

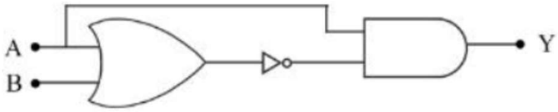
$\dfrac{KQ}{r} = \dfrac{120 \times 10}{15} = 80$

41. Choose the correct logic circuit for the given with table having inputs A and B.



Inputs		Output
A	B	Y
0	0	0
0	1	0
1	0	1
1	1	1

1.


2.


3.

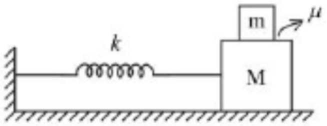

4.


Key: 4

Sol: On verifying the truth tables

42. Two blocks of masses m and M,(M>m), are placed on a friction less table as shown in figure. A massless spring with spring constant k is attached with the lower block. If the system is slightly displaced and released, then

($\mu =$ Coefficient of friction between the two blocks)



A. The time period of small oscillation of the two blocks is $T = 2\pi\sqrt{\frac{(m+M)}{K}}$

B. The acceleration of the blocks is $a = -\frac{kx}{M+m}$

(x-displacement of the blocks from the mean position)

C. The magnitude of frictional force on the upper block is $\frac{m\mu|x|}{M+m}$

D. The maximum amplitude of the upper block, if it does not slip, is $\frac{\mu(M+m)g}{k}$

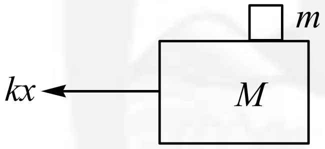
E. Maximum frictional force can be $\mu(M+m)g$

Choose the correct answer from the options given below:

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

Key: 3

Sol:



$a = \frac{kx}{M+m}$

Force on upper block is $F = ma$

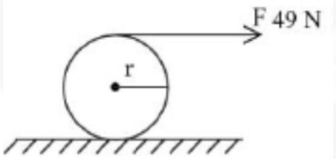
$= \frac{kxm}{M+m}$

Option C is wrong →

→ Maximum frictional force is $F = \mu mg$

So option E is wrong

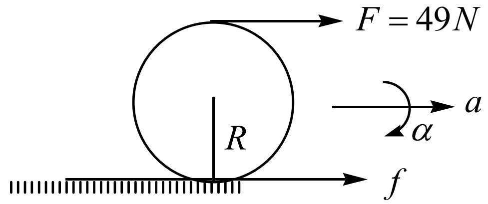
43. A force of 49N acts tangentially at the highest point of a sphere (solid) of mass 20kg, kept on a rough horizontal plane. If the sphere rolls without slipping then the acceleration of the center of the sphere is



1) $0.25m/s^2$ 2) $2.5m/s^2$ 3) $0.35m/s^2$ 4) $3.5m/s^2$

Key: 4

Sol:



$\rightarrow$The net force acting on the sphere is the applied force F and the friction force

$F + f = ma$ …….(1)

$\rightarrow$ The torque is due to the applied force and the frictional force.

$\tau = FR - fR \qquad (\tau = I\alpha)$

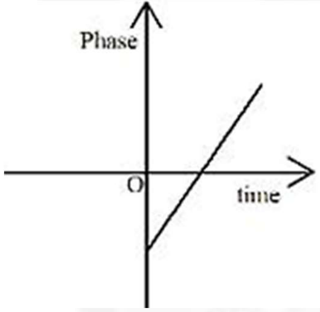
$FR - fR = I\alpha$

$$FR - fR = \frac{2}{5}mR^2\left(\frac{a}{R}\right)$$

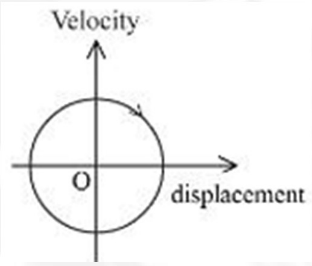
$$F - f = \frac{2}{5}ma.........(2)$$

$from\ 1 \& 2 \qquad a = 3.5m/s^2$

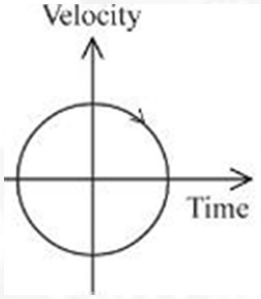
44. Which of the following curves possibly represent one-dimensional motion of a particle?



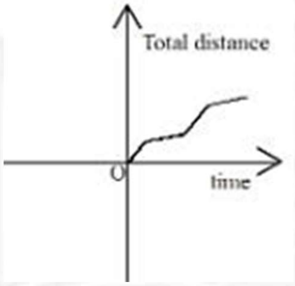
1)



2)



3)



4)

Choose the correct answer from the option given below.

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

Key: 2

Sol: A, B belong to linear SHM, time is always positive and increases hence C is wrong
In case of body moving in a straight line in forward motion with non- uniform speed.
Distance increases with time, hence D is correct.

45. Match the List-I with List-II

LIST-I		LIST-II	
A.	${}_0^1n + {}_{92}^{235}U \rightarrow {}_{54}^{140}Xe + {}_{38}^{94}Sr + 2\,{}_0^1n$	I	chemical reaction
B.	$2H_2 + O_2 \rightarrow 2H_2O$	II	fusion with +ve Q value

C.	${}_{1}^{2}H+{}_{1}^{2}H\rightarrow{}_{2}^{3}He+{}_{0}^{1}n$	III.	fission
D.	${}_{1}^{1}H+{}_{1}^{3}H\rightarrow{}_{1}^{2}H+{}_{1}^{2}H$	IV	fusion with –ve Q value

Choose the correct answer from the option given below.

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

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

Key: 3

Sol: $A-III,B-I,C-II,D-IV$

SECTION-II (NUMERICAL VALUE TYPE)

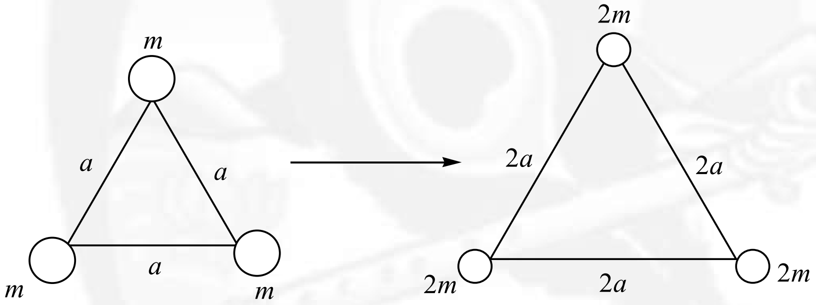
This section contains **5 Numerical Value Type Questions.** The Answer should be within **0 to 9999.** If the Answer is in **Decimal** then round off to the **Nearest Integer** value (Example i,e. If answer is above **10** and less than **10.5** round off is **10** and If answer is from **10.5** and less than **11** round off is **11).**

Marking scheme: +4 for correct answer, 0 if not attempt and -1 in all other cases.

46. Three identical spheres of mass m, are placed at the vertices of an equilateral triangle of length a, when released, they interact only through gravitational force and collide after a time T=4 seconds. If the sides of the triangle are increased to length 2a also the masses of the spheres are made 2m, then will collide after ____ seconds.

Key: 8sec

Sol:



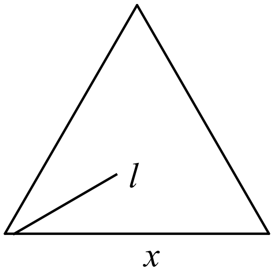
According to the conservation of energy

$$-3\frac{Gm^2}{a}+0=3.\frac{1}{2}mV^2-3\frac{Gm^2}{x}$$, (x= side length of triangle at any time t)

$$\frac{mV^2}{2}=Gm^2\left(\frac{1}{x}-\frac{1}{a}\right)$$

$$V=\sqrt{2Gm\left(\frac{1}{x}-\frac{1}{a}\right)}$$

$$-\frac{dl}{dt}=\sqrt{2Gm\left(\frac{1}{x}-\frac{1}{a}\right)}$$



$$l=\frac{x}{\sqrt{3}}$$

$$-\frac{1}{\sqrt{3}}\frac{dx}{dt}=\sqrt{2Gm\left(\frac{1}{x}-\frac{1}{a}\right)} \qquad =\frac{-dx}{\sqrt{6Gm\left(\frac{1}{x}-\frac{1}{a}\right)}}=dt$$

$$\int_0^t dt=-\int_a^0\frac{dx}{\sqrt{6Gm\left(\frac{1}{x}-\frac{1}{a}\right)}}$$

On the calculation the above integration using method of substitution

Put $x=a\ \cos^2\theta$, we will get

$$t\alpha\sqrt{\frac{a^3}{m}}$$

$$\frac{t_2}{t_1}=\sqrt{\left(\frac{a_2}{a_1}\right)^3\times\frac{m_1}{m_2}}$$

$$\frac{t_2}{4}=\sqrt{\left(\frac{2a}{a}\right)^3\times\frac{m}{2m}}$$

$$t_2=8\sec$$

47. A 4.0cm long straight wire carrying a current of 8A is placed perpendicular to a uniform magnetic field of strength 0.15 T. The magnetic force on the wire is ______ mN.

Key: 48mN

Sol: Given $l=4cm\Rightarrow l=4\times10^{-2}m$

$i=8A\ \ B=0.15T$

Magnetic force on the wire is $F=Bil\sin\theta$

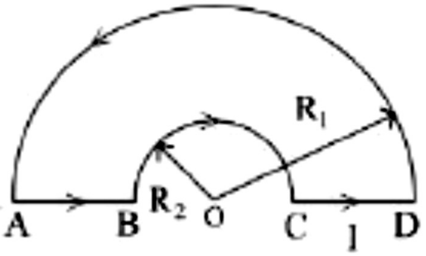
$\left(\theta=90^0\right)$

$F=0.15\times8\times4\times10^{-2}\sin90^0$

$F=48mN$

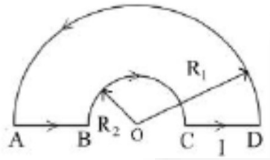
48. A loop ABCDA, carrying current I=12 A, is placed in a plane consists of two semi-circular segments of radius $R_1=6\pi\,m\ and\ R_2=4\pi m.$ The magnitude of the resultant magnetic field at center O is $k\times10^{-7}T$. The value of k is _______

(Given $\mu_0=4\pi\times10^{-7}TmA^{-1}$)



Key: 1

Sol:



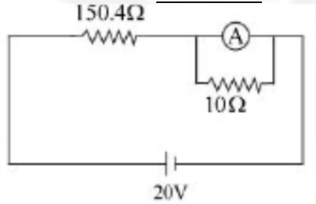
$$B_1 = \frac{\mu_0}{4\pi}\frac{i}{r_1}[\pi] \qquad = 10^{-7} \times \frac{12}{6\pi} \times \pi$$

$$B_1 = 2 \times 10^{-7} T$$

$$B_2 = \frac{\mu_0}{4\pi}\frac{i}{r_2}[\pi] \qquad = \frac{10^{-7} \times 12}{4\pi} \times \pi \qquad = 3 \times 10^{-7}$$

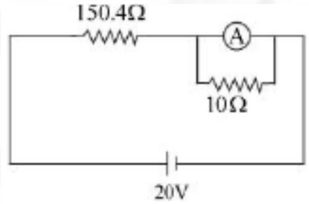
$$B_{net} = B_2 - B_1 \qquad = [3-2] \times 10^{-7} \qquad = 1 \times 10^{-7} T$$

49. In the figure shown below, a resistance of 150.4Ω is connected in series to an ammeter A of resistance 240Ω. A shunt resistance of 10Ω is connected in parallel with the ammeter. The reading of the ammeter is ______ mA.



Key: 5

Sol:



$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{240 \times 10}{250}$$

$$= 9.6\Omega$$

$$R_{tot} = 9.6 + 150.4 = 160\Omega$$

$$I = \frac{V}{R} = \frac{20}{160} = \frac{1}{8} A$$

$$V_1 = V_2$$

$$I_1 R_1 = I_2 R_2$$

$$\frac{I_1}{I_2}=\frac{10}{240}=\frac{1}{24}$$

$I_1 = x$

$I_2 = 24x$

$$\frac{1}{8}=25x$$

$$x=\frac{1}{200}$$

$I_1 = x$

$$=\frac{1}{200}\times\frac{1000}{1000}$$

$= 5mA$

50. Two coherent monochromatic light beams of intensities 4I and 9I are superimposed. The difference between the maximum and minimum intensities in the interference pattern is xI. The value of x is ______

Key: 24

Sol: $I_{\max}=\left(\sqrt{I_1}+\sqrt{I_2}\right)^2=\left(\sqrt{4I}+\sqrt{9I}\right)^2=25I$

$I_{\min}=\left(\sqrt{I_1}-\sqrt{I_2}\right)^2=\left(\sqrt{4I}-\sqrt{9I}\right)^2=1I$

Difference between $I_{\max} and\, I_{\min}=?$

$I_{\max}-I_{\min}=25I-1I=24I$

CHEMISTRY

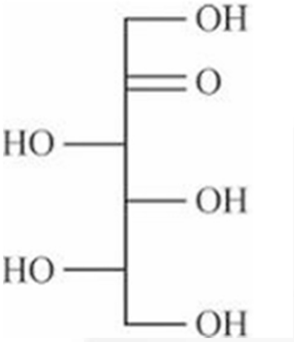
Max Marks: 100

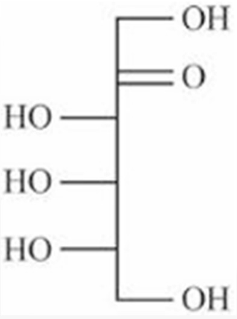
SECTION-I (SINGLE CORRECT ANSWER TYPE)

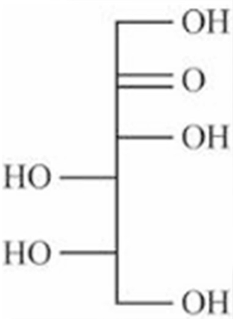
This section contains **20 Multiple Choice Questions.** Each question has 4 options (1), (2), (3) and (4) for its answer, out of which ONLY ONE option can be correct.

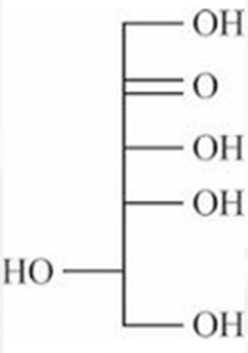
Marking scheme: +4 for correct answer, 0 if not attempted and –1 in all other cases.

51. Which of the following is the correct structure of L – Fructose?

1) 

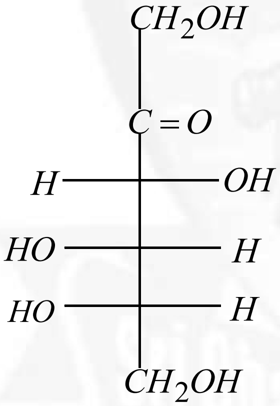
2) 

3) 

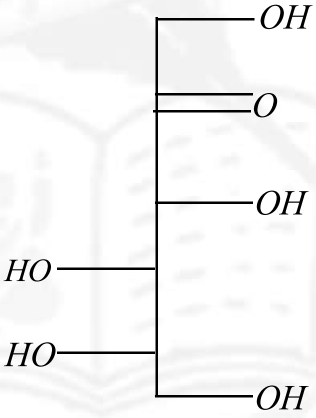
4) 

Key: 3

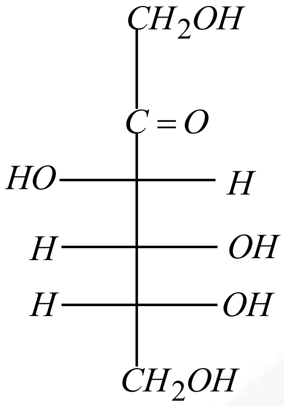
Sol: The structure of L- fructose



(or)



The structure of D- fructose



52. The correct order of the complexes $\left[Co\left(NH_3\right)_5\left(H_2O\right)\right]^{3+}(A)$, $\left[Co\left(NH_3\right)_6\right]^{3+}(B)$, $\left[Co\left(CN\right)_6\right]^{3-}(C)$ and $\left[CoCl\left(NH_3\right)_5\right]^{2+}(D)$ in terms of wavelength of light absorbed is

1) $C > B > A > D$ 2) $D > A > B > C$ 3) $D > C > B > A$ 4) $C > B > D > A$

Key: 2

Sol: Crystal field splitting energy $(\Delta)\,\alpha\,\frac{1}{\lambda_{(abs)}}$

$\Delta\,\alpha$ Strength of ligand.

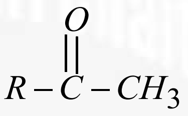
If the strength of ligand is more, the wave length of light absorbed by the corresponding complex is less.

$$\lambda_{(abs)}:\left[CoCl\left(NH_3\right)_5\right]^{2+} > \left[Co\left(NH_3\right)_5\left(H_2O\right)\right]^{3+} > \left[Co\left(NH_3\right)_6\right]^{3+} > \left[Co\left(CN\right)_6\right]^{3-}$$

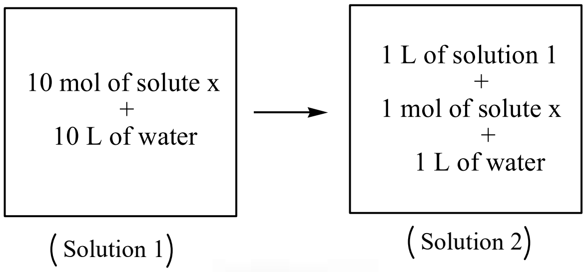
53. Number of molecules from below which cannot give iodoform reaction is:
Ethanol, Isopropyl alcohol, Bromoacetone, 2-Butanol, 2-Butanone, Butanal, 2-Pentanone, 3-Pentanone, Pentanal and 3-Pentanol.

1) 3 2) 5 3) 2 4) 4

Key: 4

Sol: Molecules which can give iodoform reaction are ethanol, isopropyl alcohol, 2-Butanol, 2-Butanone, 2-Pentanone, Bromo acetone. Molecules which cannot give iodoform reaction are butanal, 3-pentanone, pentanal and 3-ethanol. Molecules containing either a methyl ketone ( $R-\overset{\overset{O}{||}}{C}-CH_3$) (or) a secondary alcohol that can be positive for the test.

54. Which of the following properties will change when system containing solution 1 will become solution 2?



1) Density 2) Gibbs free energy 3) Molar heat capacity 4) Concentration

Key: 2

Sol: Solution – 1 which contain 10 mole x.

$$M_1 = \frac{n_{(x)}}{V_{(L)}} = \frac{10}{10} = 1 molar$$

Solution –2 contain 1 L of solution–1 + 1 mole of solute x +1 L of water

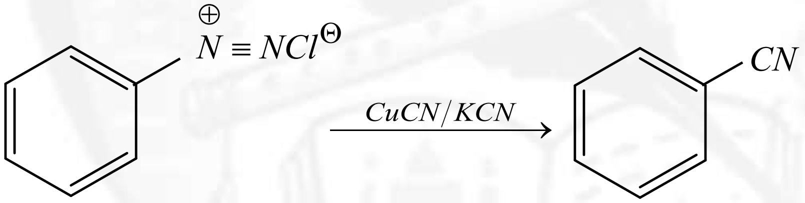
Total volume of solution – 2 = 2L

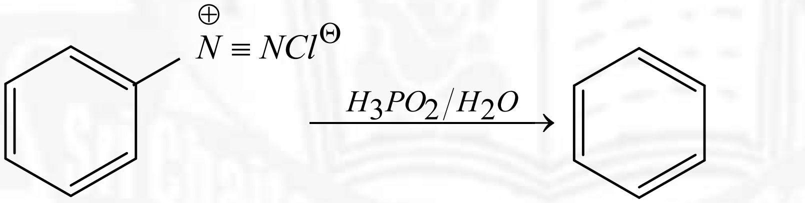
Total moles of x in solution – 2 = 2 mole

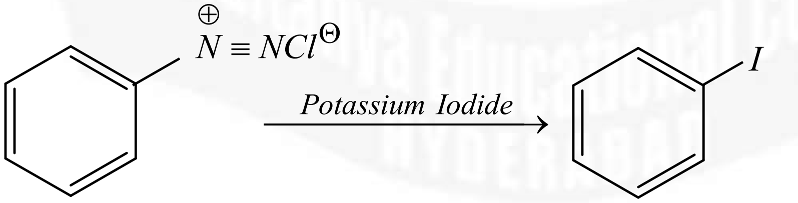
$$M_2 = \frac{2 mole}{2L} = 1 molar$$

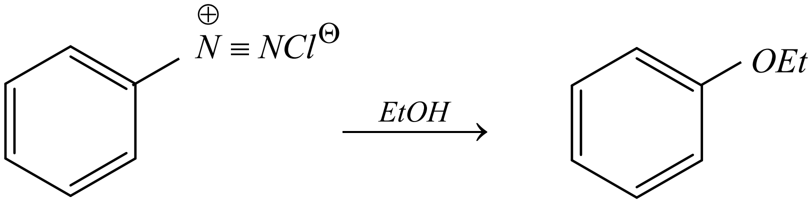
Solution – 1 and solution – 2 are equimolar. Hence density molar heat capacity and concentration of solution – 1 and solution – 2 are same. But the (ΔG) Gibbs free energy change of the process of preparation of solution- 2 is negative because the formation of solution is positive entropy driven process whose ΔG is negative (spontaneous process).

55. In the following reactions, which one is **NOT** correct?

1)


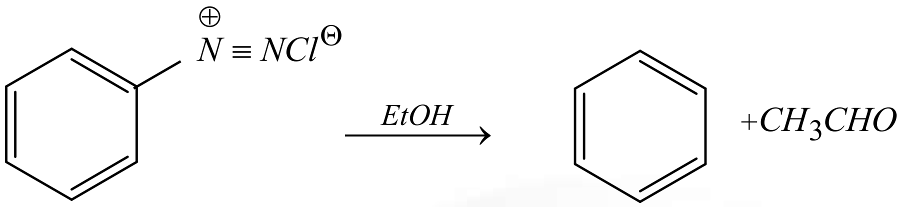
2)


3)


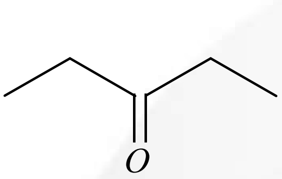
4)


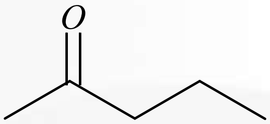
Key: 4

Sol:

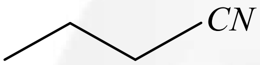


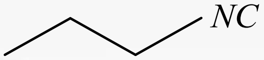
56. Identify the correct statements from the following

A) 

and 

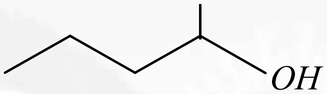
are metamers

B) 

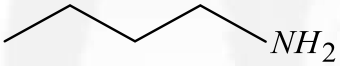
and 

are functional isomers

C) 

and 

are position isomers

D) 

and 

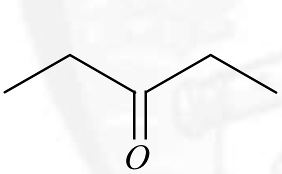
are homologous

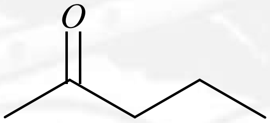
Choose the correct answer from the options given below:

1) A, B & C only 2) A & B Only 3) B & C only 4) C & D only

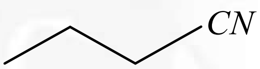
Key: 2

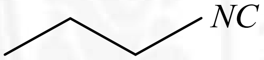
Sol:

A) 

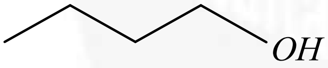
and 

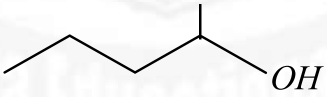
are metamers

B) 

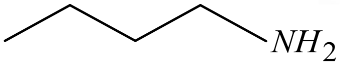
and 

are functional isomers

C) 

and 

have different molecular formula. Hence they are not a pair of isomers.

D) 

and 

They are not homologues, they differ in functional group.

57. The metal ions that have the calculated spin-only magnetic moment value of 4.9 B.M. are:

A) Cr^{2+} B) Fe^{2+} C) Fe^{3+} D) Co^{2+} E) Mn^{3+}

Choose the correct answer from the options given below:

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

Key: 3

Sol: The spin-only magnetic moment formula is = $\mu_{BM} = \sqrt{n(n+2)}$

Where n = number of unpaired electrons in d –orbital.

A) Cr – (24): $(Ar)3d^5 4s^1$

$Cr^{2+}: (Ar)\,3d^4$

$d^4, n = 4$

$\mu_{BM} = \sqrt{4(4+2)} = \sqrt{24} = 4.89$

B) Fe-(26) : $(Ar)3d^6 4s^2$

$Fe^{2+}:(Ar)\,3d^6$

$d^6 = d^4, n = 4$

$\mu_{BM} = \sqrt{4(4+2)} = \sqrt{24} = 4.89$

C) Fe-(26): $(Ar)3d^6 4s^2$

$Fe^{3+}:(Ar)\,3d^5$

$n = 5$

$\mu_{BM} = \sqrt{5(5+2)} = \sqrt{35} = 5.91$

D) Co- (27):$(Ar)3d^7 4s^2$

$Co^{2+}:(Ar)\,3d^7$

$d^7 = d^3$

$n = 3$

$\mu_{BM} = \sqrt{3(3+2)} = \sqrt{15} = 3.87$

E) Mn - (25):$(Ar)3d^5 4s^2$

$Mn^{3+}:(Ar)\,3d^4$

d^4

$n = 4$

$\mu_{BM} = \sqrt{4(4+2)} = \sqrt{24} = 4.89$

58. In a reaction $A + B \rightarrow C$, initial concentrations of A and B are related as $[A]_0 = 8[B]_0$. The half lives of A and B are 10 min and 40 min, respectively. If they start to disappear at the same time. Both following first order kinetics, after how much time will the concentration of both the reactants be same?

1) 40 min 2) 60 min 3) 80 min 4) 20 min

Key: 1

Sol: $[A]_0 = 8[B]_0$

Half life of A = 10 min

Half life of B = 40 min

Order with respect to A = 1

Order with respect to B = 1

Let Initial concentration of A be 8 molar then initial concentration of B is 1 molar.

At 40 min (four half life of A)

$$[A]=\frac{[A]_0}{2^4}=\frac{8}{16}=\frac{1}{2}molar$$

At 40 min (one half life of B)

$$[B]=\frac{[B]_0}{2}=\frac{1}{2}molar$$

At 40 min, the concentration of A and B are equal.

59. Among $10^{-9}g$ (each) of the following elements, which one will have the highest number of atoms? Element: $Pb, Po,$ Pr and Pt

1) Pb 2) Pt 3) Po 4) Pr

Key: 4

Sol: Number of atoms α number of moles

Number of atoms $\alpha \frac{weight}{G.A\,wt}$

Given that weight of given elements are equal.

Number of atoms $\alpha \frac{1}{G.A\,wt}$

Among the give list of elements, Pr has the minimum gram atomic weight. Hence Pr contain maximum number of atoms.

60. Match the List – I with List – II

List –I (Molecules/ion)		List –II (Hybridization of central atom)	
A	PF_5	I	dsp^2
B	SF_6	II	sp^3d
C	$Ni(CO)_4$	III	sp^3d^2
D	$[PtCl_4]^{2-}$	IV	sp^3

Choose the correct answer from the options given below:

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

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

Key: 4

Sol:

Molecule/ion → Hybridisation

A) $PF_5 \rightarrow sp^3d$

B) $SF_6 \to sp^3d^2$

C) $Ni(CO)_4 \to sp^3$

D) $[PtCl_4]^{2-} \to dsp^2$

61. Given below are two statements:

Statement – I: A catalyst cannot alter the equilibrium constant (K_c) of the reaction, temperature remaining constant.

Statement – II: A homogenous catalyst can change the equilibrium composition of a system, temperature remaining constant.

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) Statement – I is true but statement – II is false
4) Both Statement – I and statement – II are true

Key: 4

Sol: A catalyst cannot alter the equilibrium constant (K_c) of the reaction, (at constant temperature). A homogeneous catalyst can change the equilibrium composition of a system.

62. Which of the following postulate of Bohr's model of hydrogen atom is not in agreement with quantum mechanical model of an atom?

1) The electron in a H atom's stationary state moves in a circle around the nucleus.
2) An atom in a stationary state does not emit electromagnetic radiation as long as it stays in the same state.
3) An atom can take only certain distinct energies E_1, E_2, E_3, etc. These allowed states of constant energy are called the stationary states of atom.
4) When an electron makes a transition from a higher energy stationary state to a lower energy stationary state, then it emits a photon of light.

Key: 1

Sol: According to the Bhor's postulate, the electron in H – atoms stationary state moves in a circle around the nucleus, but according to quantum mechanical model of an atom, it is impossible to locate the accurate position and velocity of the electron and the existence of circular orbits at a accurate distance is over ruled.

63. Given below are two statements:

Statement – I: The $N-N$ single bond is weaker and longer than that of $P-P$ single bond.

Statement – II: Compounds of group 15 elements in + 3 oxidation states readily undergo disproportionation reactions.

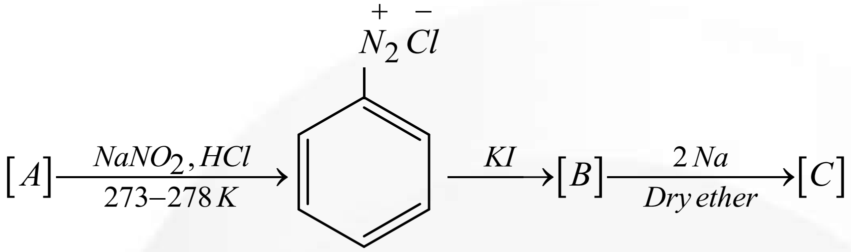
In the light of the above statements, choose the correct answer from the options given below

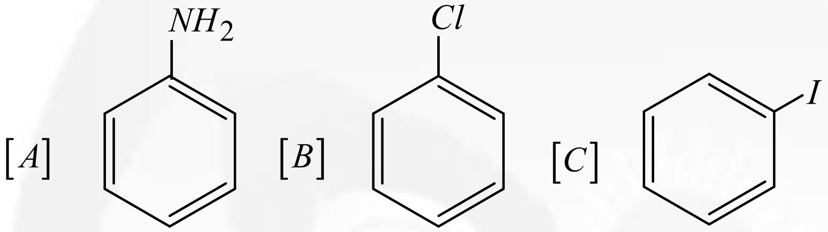
1) Both statement – I and statement – II are false
2) Statement – I is false but Statement – II is true
3) Statement – I is true but statement – II is false
4) Both Statement – I and statement – II are true

Key: 1

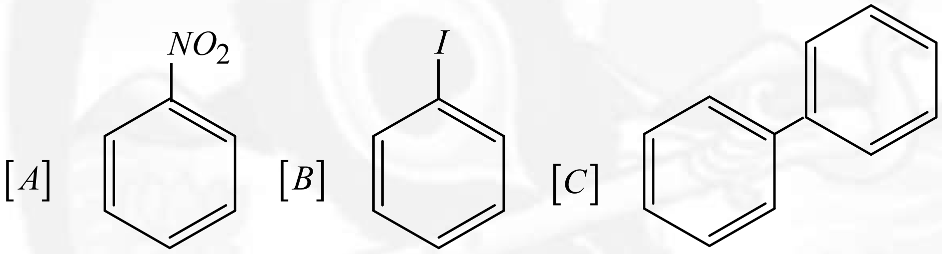
Sol: Because of inter electronic repulsion of non bonding electrons, N – N single bond is weaker that P – P single bond. But N – N single bond is shorter than P – P single bond. In case of group – 15 elements, +3 is one of the common oxidation state. Elements in their common oxidation state does not participate in disproportionation reaction rapidly.

64 Identify $[A],[B]$and $[C]$, respectively in the following reaction sequence:

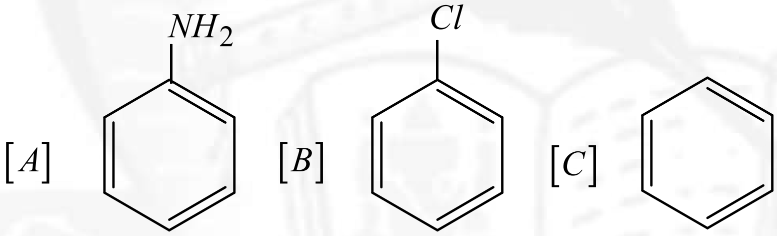




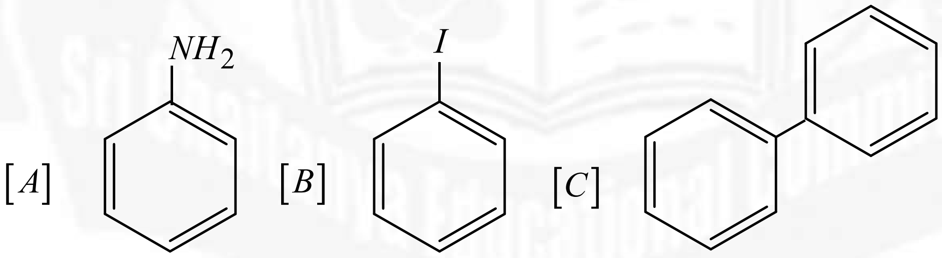
1)



2)



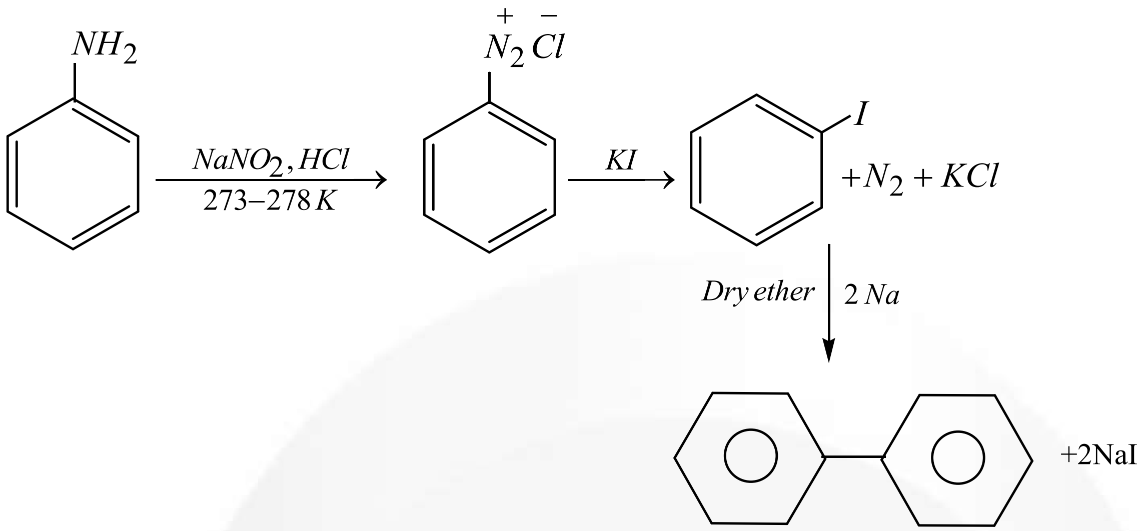
3)



4)

Key: 4

Sol:



65. In the following system, $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ at equilibrium, upon addition of xenon gas at constant T & p, the concentration of

1) PCl_5, PCl_3 & Cl_2 remain constant 2) PCl_3 will increase

3) PCl_5 will increase 4) Cl_2 will decrease

Key: 2

Sol: $PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$

Since the products side $\left(PCl_3\ and\ Cl_2\right)$ has more moles of gas (2 moles) than the reactant side $\left(PCl_5, 1 mole\right)$ the equilibrium will shift to the right.

$\therefore$ Addition an inert gas at constant pressure increases the total volume of the system.

$\therefore$ The concentration of PCl_3 and Cl_2 will increase and the concentrate of will PCl_5 decrease.

66. Which of the following statements are correct?

A) The process of adding an electron to a neutral gaseous atom is always exothermic.

B) The process of removing an electron from an isolated gaseous atom is always endothermic.

C) The 1st ionization energy of boron is less than that of beryllium.

D) The electronegativity of C is 2.5 in CH_4 and CCl_4

E) Li is the most electropositive among elements of group I.

Choose the correct answer from the options given below:

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

Key: 3

Sol: A) The process of adding an electron to a neutral gaseous atom is generally exothermic because energy is released when an electron is added. But it's not always exothermic. For example adding an electron to a uni-negative ion is endothermic.

B) The process removing an electron from an isolated gaseous atom is always endothermic as it required energy to overcome the attraction between the electron and the nucleus.

C) $B_5 - 1s^2 2s^2 2p^1, Be_4 - 1s^2 2s^2$

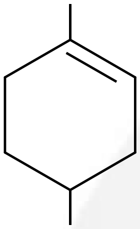
The 1st ionization energy of Boron is less than that of Beryllium. This is because the added electron in Boron occupies a 2p orbital which is further from the nucleus and shielded by the 2s electrons. $\therefore IE : B < Be$

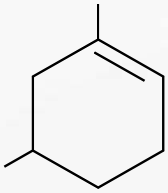
D) The electro negativity of carbon is approximately 2.5 electro negativity is an intrinsic property of an atom and is not affected by the type of molecule it is in$\left(CH_4\, or\, CCl_4\right)$.

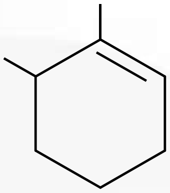
E) Electro positivity of Li is lesser than that group I order of electro positivity:

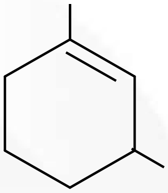
$Li^{\oplus} < Na^{\oplus} < Ic^{\oplus} < Rb^{\oplus} < Cs^{\oplus}$

67. Which compound would give 3-methyl-6-oxoheptanal upon ozonolysis?

1) 

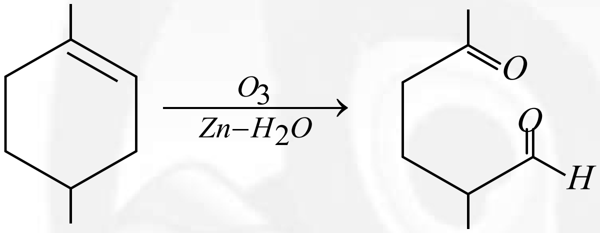
2) 

3) 

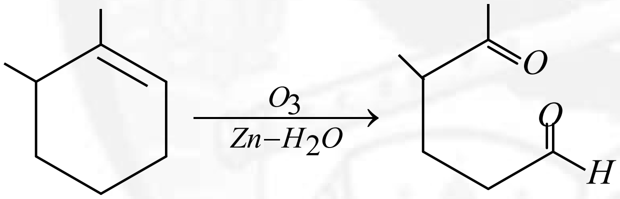
4) 

Key: 1

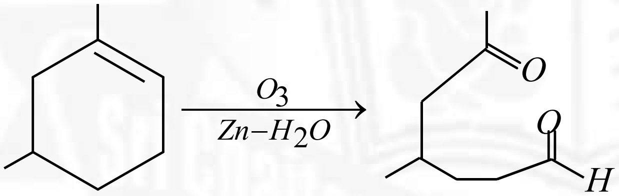
Sol:



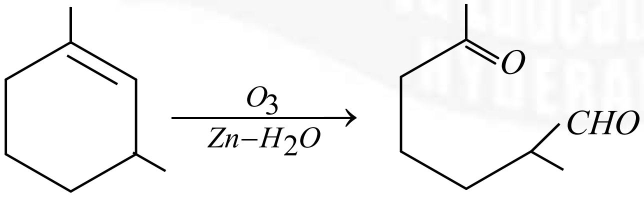
3-methyl-6-oxoheptanal



5-methyl-6-oxoheptanal



4-methyl-6-oxoheptanal



2-methyl-6-oxoheptanal

68. 2 moles each of ethylene glycol and glucose are dissolved in $500\, g$ of water. The boiling point of the resulting solution is:

(Given: Ebullioscopic constant of water $= 0.52 K\ kg\ mol^{-1}$)

1) 379.2 K 2) 277.3 K 3) 375.3 K 4) 377.3 K

Key: 4

Sol: 2 moles of ethylene glycol (A) in 500 g water

$$\therefore m_{(A)} = \frac{2}{500} \times 1000 = 4 molal$$

2 moles of glucose (B) in 500 g water

$$\therefore m_{(B)} = \frac{2}{500} \times 1000 = 4 molal$$

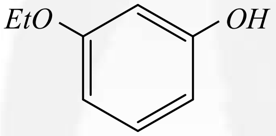
$$\therefore m_{Total} = 8 molal$$

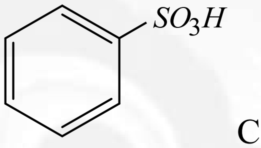
$$\Delta T_b = iK_b m = 1 \times 0.52 \times 8 = 4.16$$

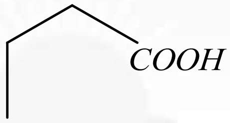
$$\Delta T_b = T_b - T_b^0$$

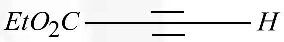
$$T_b = \Delta T_b + T_b^0 = 373.15 + 4.16 = 377.3K$$

69. The least acidic compound, among the following is:

A) 

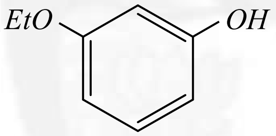
B) 

C) 

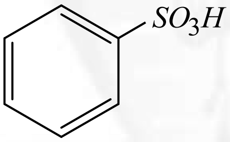
D) 

1) A 2) B 3) C 4) D

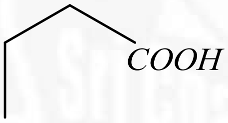
Key: 4

Sol: A) 

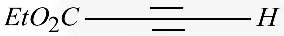
More acidic due to the resonance stabilization of the phenoxide ion after deprotonation.

B) 

More acidic due to a sulphonic acid group $(-SO_3H)$.

C) 

More acidic due to carboxylic acidic group $(-COOH)$.

D) 

As ester group and terminal alkyne. The hydrogen on the terminal is weakly acidic.

70. Correct order of limiting molar conductivity for cations in water at 298 K is:

1) $H^+ > Ca^{2+} > Mg^{2+} > K^+ > Na^+$ 2) $H^+ > Na^+ > K^+ > Ca^{2+} > Mg^{2+}$

3) $Mg^{2+} > H^+ > Ca^{2+} > K^+ > Na^+$ 4) $H^+ > Na^+ > Ca^{2+} > Mg^{2+} > K^+$

Key: 1

Sol: Limiting molar conductivity order $H^+ > Ca^{2+} > Mg^{2+} > K^+ > Na^+$

Ion	Limiting molar conductivity

	$\left(S\,cm^2\,mol^{-1}\right)$
H^+	349.6
Na^+	50.1
K^+	73.5
Ca^{+2}	119.0
Mg^{+2}	106.0

SECTION-II (NUMERICAL VALUE TYPE)

This section contains **5 Numerical Value Type Questions.** The Answer should be within **0 to 9999.** If the Answer is in **Decimal** then round off to the **Nearest Integer** value (Example i,e. If answer is above **10** and less than **10.5** round off is **10** and If answer is from **10.5** and less than **11** round off is **11).**

Marking scheme: +4 for correct answer, 0 if not attempt and -1 in all other cases.

71. Given:

$$\Delta H^{\Theta}{}_{sub}\left[C\left(graphite\right)\right]=710\ kJ\ mol^{-1}$$

$$\Delta_{C-H}H^{\Theta}=414\ kJ\ mol^{-1}$$

$$\Delta_{H-H}H^{\Theta}=436\ kJ\ mol^{-1}$$

$$\Delta_{C=C}H^{\Theta}=611\ kJ\ mol^{-1}$$

The ΔH_f^{Θ} for $CH_2=CH_2$ is______$kJ\ mol^{-1}$ (nearest integer value)

Key: 25

Sol: $$\underset{\substack{(graphite)\\(solid)}}{2C}+2H_{2(g)}\longrightarrow CH_2=CH_{2(g)}:\Delta H_f^O----1$$

$$2C_{graphite}+\underset{(gas)}{2H_2}\longrightarrow CH_2=CH_{2(g)}:\Delta H_r-----2$$

$$\Delta H_r=2\left|BE_{(H-H)}\right|-4\left|BE_{(C-H)}\right|-\left|BE_{(C=C)}\right|=2(436)-4(414)-611=-1395kJ$$

Given that

$$C_{(solid)}\longrightarrow C_{gas};+710kJ$$

$$\underset{(2mol)}{2C_{(solid)}}\longrightarrow 2C_{gas};+1420kJ----3$$

Eq-2 +eq-3

$$\Rightarrow \underset{(gas)}{2C}+2H_2\longrightarrow CH_2=CH_2;\ \Delta H_r=-1395kJ$$

$$\underset{(solid)}{2C}\longrightarrow 2C_{(gas)};\Delta H=1420kJ$$

$$\underset{(solid)}{2C}+\underset{(gas)}{2H_2}\longrightarrow CH_2=CH_{2\ (gas)};\Delta H=25kJ$$

72. The number of optical isomers exhibited by the iron complex (A) obtained from the

following reaction is _______.

$FeCl_3 + KOH + H_2C_2O_4 \to A$

Key: 2

Sol: Step – I: $H_2C_2O_4 + 2KOH \longrightarrow K_2C_2O_4 + 2H_2O$

Step – II: $FeCl_3 + 3KOH \longrightarrow Fe(OH)_3 + 3KCl$

Step – III: $Fe(OH)_3 + 3K_2C_2O_4 + 3KOH \longrightarrow K_3\left[Fe(C_2O_4)_3\right] + 3H_2O$

A is $K_3\left[Fe(C_2O_4)_3\right] \to$ 2 optical isomers are possible.

73. Consider the following reactions

$$A + \underset{\substack{Little \\ amount}}{NaCl} + H_2SO_4 \to CrO_2Cl_2 + Side\ \mathrm{Pr}oducts$$

$$CrO_2Cl_2(Vapour) + NaOH \to B + NaCl + H_2O$$

$$B + H^+ \to C + H_2O$$

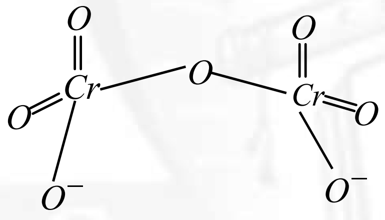
The number of terminal $'O'$ present in the compound $'C'$ is _____.

Key: 6

Sol: $$\underset{A}{K_2Cr_2O_7} + 4NaCl + 6H_2SO_4 \longrightarrow 2CrO_2Cl_2 + 2KHSO_4 + 4NaHSO_4 + 3H_2O$$

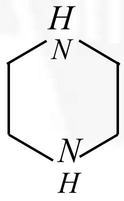
$$CrO_2Cl_2 + 4NaOH \longrightarrow \underset{B}{Na_2CrO_4} + 2NaCl + 2H_2O$$

$$2Na_2CrO_4 + H_2SO_4 \longrightarrow \underset{C}{Na_2Cr_2O_7} + Na_2SO_4 + H_2O$$



Terminal "O" atom are 6.

74. During estimation of nitrogen by Duma's method of compound $X(0.42\ g)$



X

______ mL of N_2 gas will be liberated at STP. (Nearest integer)

(Given molar mass in $g\ mol^{-1} : C:12, H:1, N:14$)

Key: 109

Sol: mass of x = 0.4 g

moles of $n = x = \frac{w}{gm} = \frac{0.42}{86}$ $\because N_2$ gas at STP

moles of n $= \frac{0.42}{80} \times 22.400 = 109.3$

75. $0.5\ g$ of an organic compound on combustion gave $1.46\ g$ of CO_2 and $0.9\,g$ of H_2O. The percentage of carbon in the compound is ______. (nearest integer)
[Given: Molar mass (in $g\ mol^{-1}$) $C:12,\ H:1,\ O:16$]

Key: 80

Sol: $C_xH_y + \left[x + \frac{y}{4}\right]O_2 \longrightarrow xCO_2 + \frac{y}{2}H_2O$

$$\%C = \frac{12}{44} \times \frac{wt\,CO_2}{wt\,of\ organic\ compound} \times 100$$

$$\%C = \frac{12}{44} \times \frac{1.46}{0.5} \times 100 = 79.63 = 80\%$$