SANTOSH Academia
IIT-JEE | NEET | Foundation

Answers & Solutions

Time : 3 hrs.

for

M.M. : 300

JEE (Main)-2025 Phase-1

[Computer Based Test (CBT) mode]

(Mathematics, Physics and Chemistry)

22/01/2025

Evening

IMPORTANT INSTRUCTIONS:

(1) The test is of **3 hours** duration.

(2) This test paper consists of 75 questions. Each subject (MPC) has 25 questions. The maximum marks are 300.

(3) This question paper contains **Three** Parts. **Part-A** is Physics, **Part-B** is Chemistry and **Part-C** is **Mathematics**. Each part has only two sections: **Section-A** and **Section-B.**

(4) **Section - A :** Attempt all questions.

(5) **Section - B :**Attempt all questions.

(6) **Section - A (01 – 20)** contains 20 multiple choice questions which have **only one correct answer**. Each question carries **+4 marks** for correct answer and **–1 mark** for wrong answer.

(7) **Section - B (21 – 25) contains** 5 **Numerical value** based questions. The answer to each question should be rounded off to the **nearest integer**. Each question carries **+4 marks** for correct answer and **–1 mark** for wrong answer.

MATHEMATICS

SECTION - A

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

Choose the correct answer:

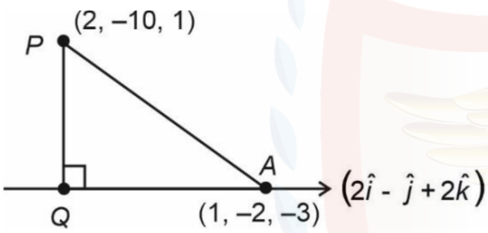
1. The perpendicular distance, of the line $\frac{x-1}{2}=\frac{y+2}{-1}=\frac{z+3}{2}$ from the point $P(2, -10, 1)$, is:

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

(3) $5\sqrt{2}$ (4) 6

Answer (2)

Sol.



PQ (shortest distance)

QA will be projection of PA on line

$PA = (-\hat{i} + 8\hat{j} - 4\hat{k}) \Rightarrow |PA| = \sqrt{81} = 9$

$$\text{Projection} = \frac{|-2-8-8|}{\sqrt{2^2+(-1)^2+2^2}} = \frac{18}{3} = 6$$

$PQ^2 = PA^2 - QA^2 = 81 - 36 = 45$

$\Rightarrow PQ = \sqrt{45} = 3\sqrt{5}$

2. Let $\vec{a}$ and $\vec{b}$ be two unit vectors such that the angle between them is $\frac{\pi}{3}$. If $\lambda\vec{a} + 2\vec{b}$ and $3\vec{a} - \lambda\vec{b}$ are perpendicular to each other, then the number of values of λ in [–1, 3] is:

(1) 1 (2) 2

(3) 3 (4) 0

Answer (4)

Sol. $(\lambda\vec{a} + 2\vec{b})\cdot(3\vec{a} - \lambda\vec{b}) = 0$

$\Rightarrow (3\lambda - 2\lambda) + \vec{a}\cdot\vec{b}\,(-\lambda^2 + 6) = 0$

since $\vec{a}\cdot\vec{b} = (1)(1)\cos\left(\frac{\pi}{3}\right) = \frac{1}{2}$

$\Rightarrow (-\lambda^2 + 6)\frac{1}{2} + \lambda = 0 \Rightarrow \lambda^2 - 2\lambda - 6 = 0$

$(\lambda - 1)^2 = 7$

$\lambda = \pm\sqrt{7} + 1 \notin [-1, 3]$

$\Rightarrow$ no values

3. If $\lim_{x\to\infty}\left(\left(\frac{e}{1-e}\right)\left(\frac{1}{e} - \frac{x}{1+x}\right)\right)^x = \alpha$, then the value of $\frac{\log_e \alpha}{1+\log_e \alpha}$ equals:

(1) e^{-2} (2) e

(3) e^{-1} (4) e^2

Answer (2)

Sol. $\lim_{x\to\infty}\left(\left(\frac{e}{1-e}\right)\left(\frac{1}{e} - \frac{x}{1+x}\right)\right)^x \quad (1^\infty \text{ from})$

$$\lim_{x\to\infty}\left[1 + \left(\left(\frac{e}{1-e}\right)\left(\frac{1}{e} - \frac{x}{1+x}\right) - 1\right)\right]^x$$

$$\Rightarrow \alpha = e^{\lim_{x\to\infty}\left[\left(\frac{e}{1-e}\right)\left(\frac{1}{e} - \frac{x}{1+x}\right) - 1\right]x}$$

$$\Rightarrow e^{\lim_{x\to\infty}\left[\left(\frac{1}{1-e}\right) - 1 + \frac{ex}{(e-1)(1+x)}\right]x}$$

$$\Rightarrow e^{\lim_{x\to\infty}\left[\frac{e}{1-e} + \frac{ex}{(e-1)(1+x)}\right]x}$$

$$\Rightarrow e^{\lim_{x\to\infty}\left(\frac{e}{e-1}\right)x\left[\frac{x}{1+x} - 1\right]} = e^{\lim_{x\to\infty}\frac{-ex}{(e-1)(1+x)}} = e^{\frac{-e}{e-1}}$$

$\Rightarrow \alpha = e^{\frac{e}{1-e}} \Rightarrow \ln\alpha = \frac{e}{1-e}$

$\Rightarrow \frac{\ln\alpha}{1+\ln\alpha} = \frac{\frac{e}{1-e}}{1+\frac{e}{1-e}} = e$

4. Let α, β, γ and δ be the coefficients of x^7, x^5, x^3 and x respectively in the expansion of

$\left(x+\sqrt{x^3-1}\right)^5 + \left(x-\sqrt{x^3-1}\right)^5$, $x > 1$. If u and v satisfy the equations

$\alpha u + \beta v = 18$,

$\gamma u + \delta v = 20$,

then $u + v$ equals:

(1) 3

(2) 4

(3) 5

(4) 8

Answer (3)

Sol. $\left(x+\sqrt{x^3-1}\right)^5 + \left(x-\sqrt{x^3-1}\right)^5$

$= \left[{}^5C_0x^5 + {}^5C_1x^4\left(\sqrt{x^3-1}\right) + ... + {}^5C_5\left(\sqrt{x^3-1}\right)^5\right] +$

$\left[{}^5C_0x^5 - {}^5C_1x^4\left(\sqrt{x^3-1}\right) + ... - {}^5C_5\left(\sqrt{x^3-1}\right)^5\right]$

$= 2\left[x^5 + {}^5C_2x^3(x^3-1) + {}^5C_4x(x^3-1)^2\right]$

$= 10x^7 + 20x^6 + 2x^5 - 20x^4 - 20x^3 + 10x$

Now

$\alpha = 10, \beta = 2, \gamma = -20, \delta = 10$

Also,

$\left.\begin{array}{l}10u + 2v = 18\\ -20u + 10v = 20\end{array}\right\} u = 1, v = 4$

$u + v = 5$

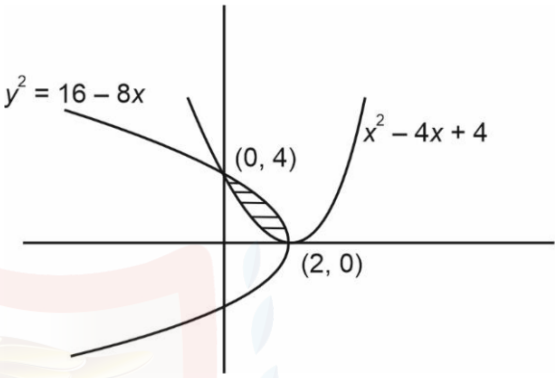
5. The area of the region enclosed by the curves $y = x^2 - 4x + 4$ and $y^2 = 16 - 8x$ is

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

(3) $\frac{4}{3}$ (4) 8

Answer (1)

Sol.



Area $= \int_0^2 \left(\sqrt{16-8x} - \left(x^2 - 4x + 4\right)\right)dx$

$= \left[\frac{-(16-8x)^{3/2}}{12} - \frac{x^3}{3} + 2x^2 - 4x\right]_0^2$

$= \frac{8}{3}$

6. Let $A = \{1, 2, 3, 4\}$ and $B = \{1, 4, 9, 16\}$. Then the number of many-one functions $f: A \to B$ such that $1 \in f(A)$ is equal to

(1) 163 (2) 127

(3) 151 (4) 139

Answer (3)

Sol. $A = \{1, 2, 3, 4\}$

$B = \{1, 4, 9, 16\}$

Total number of functions = 4^4

Total number of one-one functions = $4!$

Total number of many one functions = $4^4 - 4! = 232$

Total number of many-one functions in which $1 \notin f(A) = 3 \times 3 \times 3 \times 3 = 81$

$\therefore$ Total number of many one functions $1 \notin f(A)$

$= 232 - 81$

$= 151$

7. For a 3 × 3 matrix M, let trace (M) denote the sum of all the diagonal elements of M. Let A be a 3 × 3 matrix such that $|A| = \frac{1}{2}$ and trace (A) = 3. If B = adj(adj(2A)), then the value of $|B|$ + trace (B) equals

(1) 174 (2) 132

(3) 56 (4) 280

Answer (4)

Sol. $\text{tr}(A) = 3$ and $|A| = \frac{1}{2}$

Now, $B = \text{adj}(\text{adj}(2A)) = |2A|^{32}\ \cdot(2A)$

$= 2^3\,|A| \cdot 2A = 8A$

$\therefore\ \text{tr}(B) = 8\,\text{tr}(A) = 24$

and $|B| = |8A| = 8^3 \cdot \frac{1}{2} = 256$

$\therefore$ trace (B) + $|B|$ = 24 + 256

= 280

8. Let a line pass through two distinct points $P(-2, -1, 3)$ and Q, and be parallel to the vector $3\hat{i} + 2\hat{j}\ \ 2\hat{k}$. If the distance of the point Q from the point $R(1, 3, 3)$ is 5, then the square of the area of ΔPQR is equal to

(1) 144 (2) 136

(3) 140 (4) 148

Answer (2)

Sol. Equation of line PQ is:

$$\frac{x+2}{3} = \frac{y+1}{2} = \frac{z-3}{2} = r(\text{say})$$

Let coordinate of $Q = (3r - 2, 2r - 1, 2r + 3)$

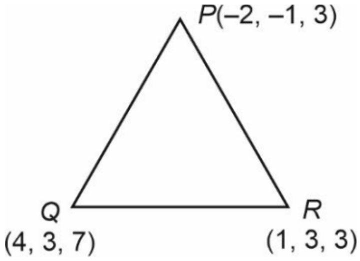
$PR = 5$

Then

$$(3r - 2 - 1)^2 + (2\ \ -1-3)^2 + (2\ \ +3-3)^2 = 25$$

$\therefore$ r = 0 or 2

$\therefore$ Coordinate of Q = (4, 3, 7)



$\therefore$ square of area of $\Delta PQR = \left|\frac{1}{2}(PQ \times PR)\right|^2$

$$= \left|\frac{1}{2}(6\hat{i} + 4\hat{j} + 4\hat{k}) \times (3\hat{i} + 4\hat{j})\right|^2$$

$$= \left|-8\hat{i} + 6\hat{j} + 6\hat{k}\right|^2 = 136$$

9. If the system of linear equations:

$x + y + 2z = 6$,

$2x + 3y + az = a + 1$,

$-x - 3y + bz = 2b$,

where $a, b \in \mathbf{R}$, has infinitely many solutions, then $7a + 3b$ is equal to:

(1) 9 (2) 22

(3) 16 (4) 12

Answer (3)

Sol. The given equations are

$x + y + 2z = 6$,

$2x + 3y + az = a + 1$

$-x - 3y + bz = 2b$, where a, $b, \in \mathbf{R}$.

For infinite many solutions:

$D = D_1 = D_2 = D_3 = 0$

$\therefore\ D = \begin{vmatrix} 1 & 1 & 2 \\ 2 & 3 & a \\ -1 & -3 & b \end{vmatrix} = 2a + b - 6$

$D_1 = \begin{vmatrix} 6 & 1 & 2 \\ a+1 & 3 & a \\ 2b & 3 & b- \end{vmatrix} = 12a + 5b + ab - 6$

$D_2 = \begin{vmatrix} 1 & 6 & 2 \\ 2 & a+1 & a \\ -1 & 2b & b \end{vmatrix} = -4a - 3b - ab + 2$

and $D_3 = \begin{vmatrix} 1 & 1 & 6 \\ 2 & 3 & a+1 \\ -1 & -3 & 2b \end{vmatrix} = 2a + 2b - 16$

from above relations

$a = -2,\ b = 10$

$\therefore\ 7a + 3b = 16$

10. Let the curve $z(1+i) + \bar{z}(1-i) = 4,\ z \in C$, divide the region $|z - 3| \le 1$ into two parts of areas α and β. Then $|\alpha - \beta|$ equals:

(1) $1 + \frac{\pi}{4}$ (2) $1 + \frac{\pi}{3}$

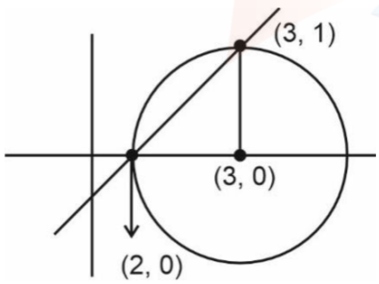
(3) $1 + \frac{\pi}{6}$ (4) $1 + \frac{\pi}{2}$

Answer (4)

Sol. Put $z = x + iy$

$(x + iy)(1 + i) = (x - iy)(1 - i) = 4$

$\Rightarrow x - y = 2$



Area of circle = π

Area of smaller region $= \frac{\pi}{4}\ \frac{1}{2}$

Area of larger region $= \frac{3\pi}{4} + \frac{1}{2}-$

$|\alpha - \beta| = 1 + \frac{\pi}{2}$

11. Let $P(4, 4\sqrt{3})$ be a point on the parabola $y^2 = 4ax$ and PQ be a focal chord of the parabola. If M and N are the foot of perpendiculars drawn from P and Q respectively on the directrix of the parabola, then the area of the quadrilateral $PQMN$ is equal to:

(1) $\frac{263\sqrt{3}}{8}$ (2) $\frac{343\sqrt{3}}{8}$

(3) $\frac{34\sqrt{3}}{3}$ (4) $17\sqrt{3}$

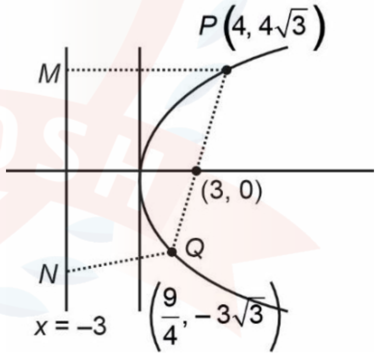
Answer (2)

Sol. $y^2 = 4ax$

$(4, 4\sqrt{3})$ lies on parabola.

$\Rightarrow a = 3$

$y^2 = 12x$ $y = x4\sqrt{3}\ \ -12\sqrt{3}$



$ar(PQNM) = \frac{\left(7 + \frac{21}{4}\right) .7\sqrt{3}}{2}$

$= \frac{343\sqrt{3}}{8}$

12. In a group of 3 girls and 4 boys, there are two boys B_1 and B_2. The number of ways, in which these girls and boys can stand in a queue such that all the girls stand together, all the boys stand together, but B_1 and B_2 are not adjacent to each other, is :

(1) 120 (2) 96

(3) 144 (4) 72

Answer (3)

Sol. $\boxed{G_1}\boxed{G_2}\boxed{G_3}$ _ B_3 _ B_4 _

$2 \times 2 \times 3! \times 2! \times {}^3C_2 = 144$

13. Let $f(x) = \int_0^{x^2} \frac{t^2 - 8t + 15}{e^t} dt, x \in R$. Then the numbers of local maximum and local minimum points of f, respectively, are:

(1) 2 and 3 (2) 1 and 3

(3) 2 and 2 (4) 3 and 2

Answer (1)

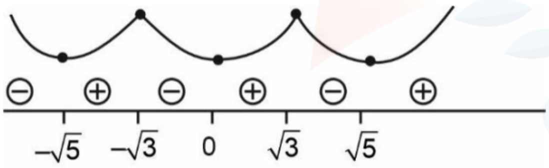
Sol. $f(x) = \int_0^{x^2} \frac{t^2 - 8t + 15}{e^t} dt, x \in R$

$f'(x) = \frac{x^4 - 8x^2 + 15}{e^{x^2}}(2x) = 0$

$\Rightarrow \frac{2x(x^2-5)(x^2-3)}{e^{x^2}} = 0$

$\Rightarrow x(x+\sqrt{5})(x-\sqrt{5})(x+\sqrt{3})(x-\sqrt{3}) = 0$

By using wavy curve method



Number of local maximum = 2

Number of local minimum = 3

$\Rightarrow$ option (1) is correct

14. Suppose that the number of terms in an A.P. is $2k$, $k \in N$. If the sum of all odd terms of the A.P. is 40, the sum of all even terms is 55 and the last term of the A.P. exceeds the first term by 27, then k is equal to :

(1) 8

(2) 4

(3) 5

(4) 6

Answer (3)

Sol. Let the A.P. be

$a, a + 2, a + 2d, \ldots, a + (2k - 1)d$

Now, $a + a + 2d + a + 4d + \ldots + a + (2k - 2)d = 40$

$Ka + 2d + 4d + \ldots + (2k - 2)d = 40$

$\Rightarrow ka + \frac{k-1}{2}[2d + 2kd - 2d] = 40$

$\Rightarrow ka + k(k-1)d = 40$ …(1)

And $a + d + a + 3d + \ldots + a + (2k - 1)d = 55$

$\Rightarrow ka + \frac{k}{2}(d + 2kd - d) = 55$

$\Rightarrow ka + k^2d = 55$ ...(2)

Also, $a + (2k - 1)d - a = 27$

$\Rightarrow (2k-1)d = 27 \Rightarrow d = \frac{27}{2k-1}$ …(3)

From equation (1) and (2)

$k^2d - kd - k^2d = -15$

$\Rightarrow d = \frac{15}{k}$ …(4)

From equation (3) and (4)

$\frac{27}{2k-1} = \frac{15}{k}$

$27k = 30k - 15$

$\Rightarrow 3k = 15$

$\Rightarrow \boxed{k = 5}$

15. If A and B are two events such that $P(A\cap B) = 0.1$, and $P(A|B)$ and $P(B|A)$ are the roots of the equation $12x^2 - 7x + 1 = 0$, then the value of $\frac{P(\bar{A}\cup\bar{B})}{P(\bar{A}\cap\bar{B})}$ is :

(1) $\frac{9}{4}$

(2) $\frac{5}{3}$

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

(4) $\frac{7}{4}$

Answer (1)

Sol. $P(A\cap B) = 0.1$, $P(A \mid B)$ and $P(B \mid A)$ are the roots of the equation $12x^2 - 7x + 1 = 0$

$\Rightarrow P(A \mid B)\ P(B \mid A) = \frac{1}{12}$

$\Rightarrow \frac{P(A\cap B)}{P(B)} \times \frac{P(A\cap B)}{P(A)} = \frac{1}{12}$

$\Rightarrow P(A)\,P(B) = 12(0.1)^2$

$= 0.12$

Also, $P(A \mid B) + P(B \mid A) = \frac{7}{12}$

$\Rightarrow P(A\cap B)\left(\frac{1}{P(B)} + \frac{1}{P(A)}\right) = \frac{7}{12}$

$\Rightarrow P(A) + P(B) = \frac{7}{12} \times \frac{0.12}{0.1}$

$\Rightarrow P(A) + P(B) = 0.7$

$\frac{P(\bar{A}\cup\bar{B})}{P(\bar{A}\cap\bar{B})} = \frac{P(\overline{A\cap B})}{P(\overline{A\cup B})}$

$= \frac{1-P(A\cap B)}{1-P(A\cup B)}$

$= \frac{1-0.1}{1-(0.7-0.1)} = \frac{0.9}{0.4} = \frac{9}{4}$

16. Let $E : \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, $a > b$ and $H : \frac{x^2}{A^2} - \frac{y^2}{B^2} = 1$. Let the distance between the foci of E and the foci of H be $2\sqrt{3}$. If $a - A = 2$, and the ratio of the eccentricities of E and H is $\frac{1}{3}$, then the sum of the lengths of their latus rectums is equal to :

(1) 8

(2) 7

(3) 10

(4) 9

Answer (1)

Sol. $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ foci are $(ae, 0)$ and $(-ae, 0)$

$\frac{x^2}{A^2} - \frac{y^2}{B^2} = 1$ foci are $(Ae', 0)$ and $(-Ae', 0)$

$\Rightarrow 2ae = 2\sqrt{3} \Rightarrow ae = \sqrt{3}$

$\Rightarrow 2Ae' = 2\sqrt{3} \Rightarrow Ae' = \sqrt{3}$

$\Rightarrow ae = Ae' \Rightarrow \frac{e}{e'} = \frac{A}{a}$

$\Rightarrow \frac{1}{3} = \frac{A}{a}$, $a = 3A$

Now, $a - A = 2 \Rightarrow a - \frac{a}{3} - 2 = 2$

$\Rightarrow a = 3$ and $A = 1$

$Ae = \sqrt{3} \Rightarrow e = \frac{1}{\sqrt{3}}$, $e' = \sqrt{3}$

$b^2 = a^2(1 - e^2)$

$b^2 = 6$

and $B^2 = A^2\left((e')^2 - 1\right) = 2$

$\Rightarrow B^2 = 2$

sum of L. R $= \frac{2b^2}{a} + \frac{2B^2}{A} = 8$

17. The sum of all values of $\theta \in [0, 2\pi]$ satisfying $2\sin^2\theta = \cos 2\theta$ and $2\cos^2\theta = 3\sin\theta$ is

(1) π (2) $\frac{5\pi}{6}$

(3) 4π (4) $\frac{\pi}{2}$

Answer (1)

Sol. $2\sin^2\theta = \cos 2\theta$ …(i)

$2\sin^2\theta = 1 - 2\sin^2\theta$

$4\sin^2\theta = 1$

$\sin\theta = \pm\frac{1}{2}$

$2\cos^2\theta = 3\sin\theta$ …(ii)

$2(1 - \sin^2\theta) = 3\sin\theta$

$2\sin^2\theta + 3\sin\theta - 2 = 0$

$\sin\theta = \frac{1}{2} \Rightarrow \theta = \frac{\pi}{6}, \frac{5\pi}{6}$

$\sin\theta = -2$ (Not possible)

$\theta = \frac{\pi}{6}, \frac{5\pi}{6}$

18. Let α_θ and β_θ be the distinct roots of $2x^2 + (\cos\theta)x - 1 = 0$, $\theta \in (0, 2\pi)$. If m and M are the minimum and the maximum values of $\alpha_\theta^4 + \beta_\theta^4$, then $16(M + m)$ equals:

(1) 17 (2) 24

(3) 27 (4) 25

Answer (4)

Sol. $2x^2 + (\cos\theta)x - 1 = 0$

$\alpha_\theta + \beta_\theta = \frac{-\cos\theta}{2}$

$\alpha_\theta \cdot \beta_\theta = \frac{-1}{2}$

$\alpha_\theta^2 + \beta_\theta^2 = (\alpha_\theta + \beta_\theta)^2 - 2\alpha_\theta\beta_\theta = \frac{\cos^2\theta}{4} + 1$

$\alpha_\theta^4 + \beta_\theta^4 = (\alpha_\theta^2 + \beta_\theta^2)^2 - 2\alpha_\theta^2\beta_\theta^2 = \left(\frac{\cos^2\theta}{4} + 1\right)^2 - \frac{2}{4}$

$= \left(\frac{\cos^2\theta}{4} + 1\right)^2 - \frac{1}{2}$

Maximum when $\cos\theta = 1$

$M = \left(\frac{1}{4} + 1\right)^2 - \frac{1}{2}$

$M = \frac{17}{16}$

Minimum when $\cos\theta = 0$

$m = 1 - \frac{1}{2} = \frac{1}{2}$

$16(M + m) = 16\left(\frac{17}{16} + \frac{1}{2}\right) = 25$

19. If $x = f(y)$ is the solution of the differential equation $\left(1 + y^2\right) + \left(x - 2e^{\tan^{-1}y}\right)\frac{dy}{dx} = 0, y \in \left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$ with $f(0) = 1$, then $f\left(\frac{1}{\sqrt{3}}\right)$ is equal to:

(1) $e^{\pi/12}$ (2) $e^{\pi/6}$

(3) $e^{\pi/3}$ (4) $e^{\pi/4}$

Answer (2)

Sol. $\left(1 + y^2\right)\frac{dx}{dy} + x = 2e^{\tan^{-1}y}$

$\Rightarrow \frac{dx}{dy} + \frac{1}{1 + y^2}x = \frac{2e^{\tan^{-1}y}}{1 + y^2}$

I.F $= e^{\int \frac{1}{1+y^2}dy} = e^{\tan^{-1}y}$

Solution of $DE \Rightarrow x.e^{\tan^{-1}y} = \int \frac{2\left(e^{\tan^{-1}y}\right)^2}{1 + y^2}dy$

$\Rightarrow x.e^{\tan^{-1}y} = e^{2\tan^{-1}y} + c$

$f(0) = 1 \Rightarrow c = 0$

$\Rightarrow x = e^{\tan^{-1}y}$

$f\left(\frac{1}{\sqrt{3}}\right) = e^{\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)} = e^{\pi/6}$

20. If $\int e^x\left(\left(\frac{x\sin^{-1}x}{\sqrt{1-x^2}}\right) + \frac{\sin^{-1}x}{\left(1-x^2\right)^{3/2}} + \frac{x}{1-x^2}\right)dx = g(x) + C$,

where C is the constant of integration, then $g\left(\frac{1}{2}\right)$ equals:

(1) $\frac{\pi}{4}\sqrt{\frac{e}{2}}$ (2) $\frac{\pi}{6}\sqrt{\frac{e}{2}}$

(3) $\frac{\pi}{4}\sqrt{\frac{e}{3}}$ (4) $\frac{\pi}{6}\sqrt{\frac{e}{3}}$

Answer (4)

Sol. $\frac{d}{dx}\left(\frac{x.\sin^{-1}x}{\sqrt{1-x^2}}\right) = \sin^{-1}x\cdot\left(\frac{1.\sqrt{1-x^2} + \frac{x\cdot 2x}{2\sqrt{1-x^2}}}{1-x^2}\right) + \frac{x}{\sqrt{1-x^2}}\cdot\frac{1}{\sqrt{1-x^2}}$

$= \frac{\sin^{-1}x}{\left(1-x^2\right)^{3/2}} + \frac{x}{1-x^2}$

Hence, $I = \int e^x(f(x) + f'(x))dx$

$= e^x.f(x) + C$

$I = e^x\cdot\frac{x.\sin^{-1}x}{\sqrt{1-x^2}} + C = g(x) + C$

$\Rightarrow g(x) = \frac{xe^x\sin^{-1}x}{\sqrt{1-x^2}}$ and $g\left(\frac{1}{2}\right) = \frac{\pi}{6}\sqrt{\frac{e}{3}}$

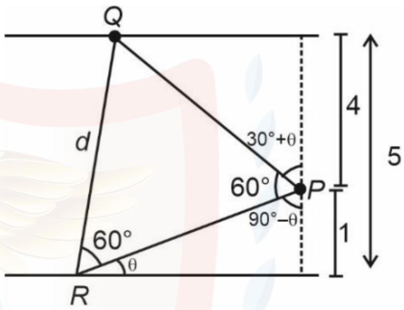
SECTION - B

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

21. Let the distance between two parallel lines by 5 units and a point *P* lie between the lines at a unit distance from one of them. An equilateral triangle *PQR* is formed such that *Q* lies on one of the parallel lines, while *R* lies on the other. then $(QR)^2$ is equal to ______.

Answer (28)

Sol.



$PR = \frac{1}{\sin\theta} = PQ = \frac{4}{\cos(30° + \theta)}$

∴ *PQR* is equilateral.

$\Rightarrow \frac{1}{\sin\theta} = \frac{4}{\cos(30° + \theta)}$

$\frac{\sqrt{3}}{2}\cos\theta - \frac{1}{2}\sin\theta = 4\sin\theta$

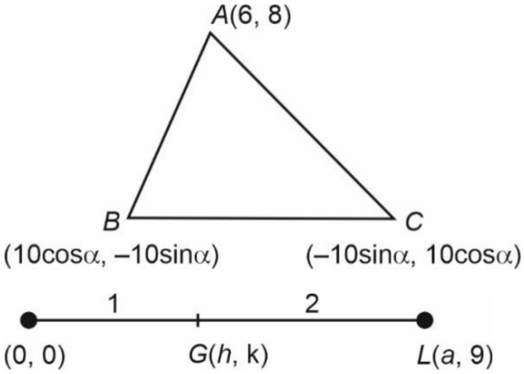
$\Rightarrow \tan\theta = \frac{1}{3\sqrt{3}}$

$QR^2 = d = \text{cosec}^2\theta = 28$

22. Let $A(6, 8)$ $B(10\cos\alpha, -10\sin\alpha)$ and $C(-10\sin\alpha, 10\cos\alpha)$, be the vertices of a triangle. If $L(a, 9)$ and $G(h, k)$ be its ortho center and centroid respectively, then $(5a - 3h + 6k + 100\sin 2\alpha)$ is equal to ______.

Answer (145)

Sol.



$\frac{a+0}{3} = h \Rightarrow a = 3h$

$\frac{9+0}{3} = k \Rightarrow k = 3$

$(h, k) = \left(\frac{6+10\cos\alpha - 10\sin\alpha}{3}, \frac{8-10\sin\alpha - 10\cos\alpha}{3}\right)$

$6 + 10\cos\alpha - 10\sin\alpha = 3h$

$10\cos\alpha - 10\sin\alpha = 3h - 6$ …(1)

$10(\cos\alpha - \sin\alpha) = 1$ …(2)

$\frac{8 - 10\sin\alpha + 10\cos\alpha}{3} = k$

$\Rightarrow$ $100\sin 2\alpha = 99$

$h = \frac{7}{3}$

$\Rightarrow$ $a = 7$

Now, $5a - 3h + 6k + 100\sin 2\alpha = 35 - 7 + 18 + 99$

$= 145$

23. Let $A = \{1, 2, 3\}$. The number of relations on A, containing (1, 2) and (2, 3), which are reflexive and transitive but not symmetric, is _______.

Answer (3)

Sol. R is reflexive $\Rightarrow R$ have (1, 1), (2, 2), (3, 3)

R is transitive

$(1, 2), (2, 3) \in R \therefore (1, 3) \in R$

$\therefore$ $R_1 = \{(1, 1), (2, 2), (3, 3), (1, 2), (2, 3), (1, 3)\}$

Clearly R_1 is reflexive and transitive but not symmetric.

Similarly,

$R_2 = \{(1, 1), (2, 2), (3, 3), (1, 2), (2, 3), (1, 3), (3, 2)\}$

$R_3 = \{(1, 1), (2, 2), (3, 3), (1, 2), (2, 3), (1, 3), (2, 1)\}$

Therefore, 3 relations are possible

24. If $\sum_{r=1}^{30} \frac{r^2\left({}^{30}C_r\right)^2}{{}^{30}C_{r-1}} = \alpha \times 2^{29}$, then α is equal to _____.

Answer (465)

Sol. $\sum_{r=1}^{30} \frac{r^2\left({}^{30}C_r\right)^2}{{}^{30}C_{r-1}}$

$\frac{r^2 \cdot 30!}{(30-r)!r!} \cdot \frac{30!}{(30-r)!r!} \times \frac{(r-1)!(31-r)!}{30!}$

$= \frac{30!(31-r)}{(r-1)!(30-r)!}$

$\Rightarrow \sum_{r=0}^{30} \frac{r^2\left({}^{30}C_r\right)^2}{{}^{30}C_{r-1}} = 30\sum_{r=0}^{30} (31-r)\,{}^{29}C_{r-1}$

$= 30\sum_{r=0}^{30} (31-r)\,{}^{29}C_{30-r}$

$= 30\sum_{r=0}^{30} [(30-r)+1]\,{}^{29}C_{30-r}$

$= 30\sum_{r=0}^{30} \frac{29}{(30-r)}(30-r)\,{}^{28}C_{29-r} + 30\sum_{r=0}^{30} {}^{29}C_{30-r}$

$= 30.29.2^{28} + 30.2^{29}$

$= 30.2^{28}(29 + 2) = (31 \times 15) \cdot 2^{29}$

$= 465.2^{29}$

$\therefore \quad \alpha = 465$

25. Let $y = f(x)$ be the solution of the differential equation $\frac{dy}{dx} + \frac{xy}{x^2-1} = \frac{x^6+4x}{\sqrt{1-x^2}}, -1 < x < 1$ such that $f(0) = 0$. If $6\int_{-1/2}^{1/2} f(x)dx = 2\pi - \alpha$, then α^2 is equal to______.

Answer (27)

Sol. $\frac{dy}{dx} + \frac{xy}{x^2-1} = \frac{x^6+4x}{\sqrt{1-x^2}}, -1 < x < 1$

I.F $= e^{-\frac{1}{2}\int \frac{2x}{1-x^2}dx}$

I.F $= e^{\frac{1}{2}\ln(1-x^2)}$

I.F $= \sqrt{1-x^2}$

As $-1 < x < 1$, $\Rightarrow$ I.F $= \sqrt{1-x^2}$

$\therefore \; y\cdot\sqrt{1-x^2} = \int \frac{x^6+4x}{\sqrt{1-x^2}} \sqrt{1-x^2}\, dx$

$y\cdot\sqrt{1-x^2} = \int (x^6 + 4x)dx$

$y\cdot\sqrt{1-x^2} = \frac{x^7}{7} + 2x^2 + C$

Given $f(0) = 0$

$C = 0$

$\therefore \; y = \frac{x^7}{7\sqrt{1-x^2}} + \frac{2x^2}{\sqrt{1-x^2}}$

$\int_{-1/2}^{1/2} f(x)dx = \frac{1}{7}\int_{-1/2}^{1/2} \frac{x^7}{\sqrt{1-x^2}}dx + 2\int_{-1/2}^{1/2} \frac{x^2}{\sqrt{1-x^2}}dx$

$\int_{-1/2}^{1/2} f(x)dx = 0 + \int_{-1/2}^{1/2} \frac{2x^2}{\sqrt{1-x^2}}dx$

Put $x = \sin\theta$

$dx = \cos\theta d\theta$

When $x = \frac{1}{2}, \theta = \frac{\pi}{6}$

$x = \frac{-1}{2}, \theta = \frac{-\pi}{6}$

$\int_{-\pi/6}^{\pi/6} \frac{2\sin^2\theta.\cos\theta d\theta}{\cos\theta}$

$= 2\int_{-\pi/6}^{\pi/6} \frac{(1-\cos 2\theta)}{2} d\theta$

$\int_{-1/2}^{1/2} f(x)dx = \frac{\pi}{3} - \frac{\sqrt{3}}{2}$

$6\int_{-1/2}^{1/2} f(x)dx = 2\pi - 3\sqrt{3}$

$\therefore \alpha = 3\sqrt{3}$

$\alpha^2 = 27$

PHYSICS

SECTION - A

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

Choose the correct answer :

26. Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A) : A simple pendulum is taken to a planet of mass and radius, 4 times and 2 times, respectively, than the Earth. The time period of the pendulum remains same on earth and the planet.

Reason (R) : The mass of the pendulum remains unchanged at Earth and the other planet. 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) **(A)** is true but **(R)** is false

(4) Both **(A)** and **(R)** are true but **(R)** is **NOT** the correct explanation of **(A)**

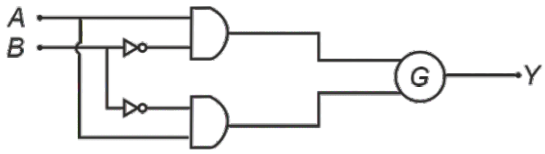
Answer (4)

Sol. $T = 2\pi\sqrt{\frac{l}{g}}$

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

$g' = \frac{G4M}{(2R)^2} = g$

Reason is true but not correct explanation.

27. 

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

To obtain the given truth table, following logic gate should be placed at G

(1) NOR Gate (2) NAND Gate

(3) OR Gate (4) AND Gate

Answer (Bonus)

Sol. As per the figure output is not matching with any of the options given.

Output for NOR gate is $\left(\overline{A}+B\right)$

Output for NAND gate is $\left(\overline{A}+B\right)$

Output for OR gate and AND gate is $A\overline{B}$

None of the option is matching

28. The torque due to the force $\left(2\hat{i}+2\hat{j}+\hat{k}\right)$ about the origin, acting on a particle whose position vector is $\left(\hat{i}+\hat{j}+\hat{k}\right)$, would be

(1) $\hat{i}+\hat{k}$ (2) $\hat{i}-\hat{j}+\hat{k}$

(3) $\hat{j}+\hat{k}$ (4) $\hat{i}-\hat{k}$

Answer (4)

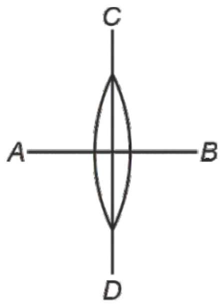
Sol. $\tau = r \times F$

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

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

$$= \hat{i}-\hat{k}$$

29. A symmetric thin biconvex lens is cut into four equal parts by two planes *AB* and *CD* as shown in figure. If the power of original lens is 4D then the power of a part of the divided lens is



(1) 4D (2) 2D
(3) 8D (4) D

Answer (2)

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

$4\text{D}=(\mu-1)\frac{2}{R}$

For each part

$P=(\mu-1)\left(\frac{1}{R}\right)=2\text{D}$

30. A series LCR circuit is connected to an alternating source of emf *E*. The current amplitude at resonant frequency is I_0. If the value of resistance *R* becomes twice of its initial value then amplitude of current at resonance will be

(1) $2I_0$ (2) $\frac{I_0}{2}$
(3) $\frac{I_0}{\sqrt{2}}$ (4) I_0

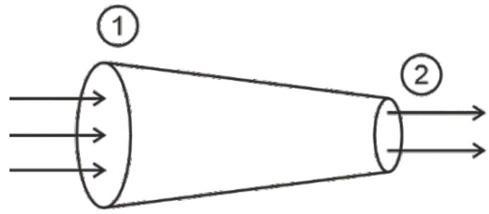
Answer (2)

Sol. At resonance, $Z = R$

$I_0=\frac{E}{R}$

$I'=\frac{E}{2R}=\frac{I_0}{2}$

31.



A tube of length L is shown in the figure. The radius of cross section at the point (1) is 2 cm and at the point (2) is 1 cm, respectively. If the velocity of water entering at point (1) is 2 m/s, then velocity of water leaving the point (2) will be

(1) 2 m/s (2) 4 m/s
(3) 6 m/s (4) 8 m/s

Answer (4)

Sol. $A_1V_1 = A_2V_2$

$V_2=V_1\left(\frac{A_1}{A_2}\right)=(4)2$

= 8 m/s

32. The maximum percentage error in the measurement of density of a wire is

[Given, mass of wire = (0.60 ± 0.003) g

radius of wire = (0.50 ± 0.01) cm

length of wire = (10.00 ± 0.05) cm]

(1) 5 (2) 8
(3) 4 (4) 7

Answer (1)

Sol. $\rho=\frac{m}{v}=\frac{m}{\pi r^2 l}$

$\frac{\Delta\rho}{\rho}=\frac{\Delta m}{m}+\frac{\Delta l}{l}+\frac{2\Delta r}{r}$

$=\frac{1}{2}\%+\frac{1}{2}\%+2\times 2\%$

= 5%

33. Given below are two statements. One is labelled as **Assertion (A)** and the other is labelled as **Reason (R).**

Assertion (A) : In Young's double slit experiment, the fringes produced by red light are closer as compared to those produced by blue light.

Reason (R) : The fringe width is directly proportional to the wavelength of light.

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) (A) is true but (R) is false

(4) Both (A) and (R) are true but (R) is NOT the correct explanation of (A)

Answer (1)

Sol. $\beta = \frac{\lambda D}{d}$

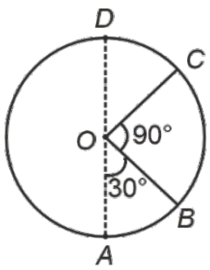
$\lambda_{red}\ \lambda < {}_{blue}$

Assertion is false

Reason is true

34. A body of mass 100 g is moving in circular path of radius 2 m on vertical plane as shown in figure.

The velocity of the body at point *A* is 10 m/s. The ratio of its kinetic energies at point *B* and *C* is



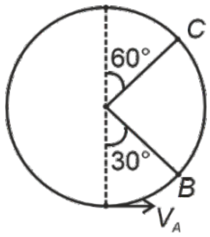
(Take acceleration due to gravity as 10 m/s^2)

(1) $\frac{3+\sqrt{3}}{2}$ (2) $\frac{2+\sqrt{2}}{3}$

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

Answer (1)

Sol.



$V_B = \sqrt{V_A^2 - 2gl\left(1 - \frac{\sqrt{3}}{2}\right)}$

$= \sqrt{60\ \ 20\sqrt{3}}$

$V_C = \sqrt{V_A^2\ \ 2g\left(\frac{3l}{2}\right)}$

$= \sqrt{100\ \ 60}$

$= \sqrt{40}$

$\frac{K_B}{K_C} = \left(\frac{V_B}{V_C}\right)^2 = \frac{3+\sqrt{3}}{2}$

35. A small rigid spherical ball of mass *M* is dropped in a long vertical tube containing glycerine. The velocity of the ball becomes constant after some time. If the density of glycerine is half of the density of the ball, then the viscous force acting on the ball will be (consider *g* as acceleration due to gravity)

(1) 2 *Mg*

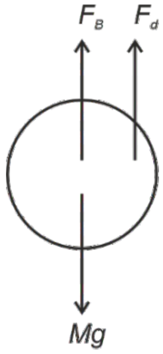
(2) $\frac{3}{2}$ *Mg*

(3) $\frac{Mg}{2}$

(4) *Mg*

Answer (3)

Sol. At terminal velocity $a = 0$



$$F_B = \frac{v\rho g}{2} = \frac{Mg}{2}$$

$$\therefore \quad F_d = Mg - \frac{Mg}{2} = \frac{Mg}{2}$$

36. A ball of mass 100 g is projected with velocity 20 m/s at 60° with horizontal. The decrease in kinetic energy of the ball during the motion from point of projection to highest point is

(1) 20 J (2) Zero
(3) 15 J (4) 5 J

Answer (3)

Sol. At highest point $v = u\cos\theta = 10$ m/s

$$k_1 = \frac{1}{2}mu^2,\ k_2 = \frac{1}{2}mv^2$$

$$k_1 - k_2 = \frac{1}{2}m(u^2 - v^2)$$

$$= \frac{1}{2} \times \frac{1}{10} \times 300 = 15 \text{ J}$$

37 A transparent film of refractive index, 20 is coated on a glass slab of refractive index, 1.45. What is the minimum thickness of transparent film to be coated for the maximum transmission of Green light of wavelength 550 nm. [Assume that the light is incident nearly perpendicular to the glass surface.]

(1) 68.7 nm (2) 94.8 nm
(3) 275 nm (4) 137.5 nm

Answer (4)

Sol. For maximum transmission, reflection is zero.

$\therefore$ For green light there should be minima for interference of two reflected lights.

$2\mu t = n\lambda$

$$t_{min} = \frac{\lambda}{2\mu} = \frac{550}{2 \times 2} = 137.5 \text{ nm}$$

38. Which one of the following is the correct dimensional formula for the capacitance in F? M, L, T and C stand for unit of mass, length, time and charge,

(1) $[F] = [CM^{-2} L^{-2} T^{-2}]$ (2) $[F] = [C^2M^{-1} L^{-2} T^2]$
(3) $[F] = [CM^{-1} L^{-2} T^2]$ (4) $[F] = [C^2 M^{-2} L^2 T^2]$

Answer (2)

Sol. $\text{Energy} = \frac{Q^2}{2C}$

$$\therefore \quad [F] = \frac{[C^2]}{[ML^2T^{-2}]}$$

$$= [C^2M^{-1}L^{-2}T^{+2}]$$

39. An electron projected perpendicular to a uniform magnetic field B moves in a circle. If Bohr's quantization is applicable, then the radius of the electronic orbit in the first excited state is :

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

Answer (3)

Sol. $mvr = \frac{nh}{2\pi}$ …(i)

$r = \frac{vm}{Bq}$ …(ii)

$n = 2$

$$mr\left(\frac{rBq}{m}\right) = \frac{2h}{2\pi}$$

$$r = \sqrt{\frac{h}{\pi Bq}}$$

$q = e$

$$r = \sqrt{\frac{h}{\pi Be}}$$

40. A light source of wavelength λ illuminates a metal surface and electrons are ejected with maximum kinetic energy of 2 eV. If the same surface is illuminated by a light source of wavelength $\frac{\lambda}{2}$, then the maximum kinetic energy of ejected electrons will be (The work function of metal is 1 eV)

(1) 5 eV (2) 3 eV

(3) 2 eV (4) 6 eV

Answer (1)

Sol. Einstein's photoelectric equation

$$\text{KE} = \frac{hc}{\lambda} = \phi_0$$

$$2\text{ eV} = \frac{hc}{\lambda} - 1\text{ eV}$$

$$\frac{hc}{\lambda} = 3\text{ eV}$$

$$\text{KE}' = \frac{hc}{(\lambda/2)} - \phi_0 = 6\text{ eV} - 1\text{ eV}$$

$$= 5\text{ eV}$$

41. Given are statements for certain thermodynamic variables,

(A) Internal energy, volume (V) and mass (M) are extensive variables.

(B) Pressure (P), temperature (T) and density (ρ) are intensive variables.

(C) Volume (V), temperature (T) and density (ρ) are intensive variables.

(D) Mass (M), temperature (T) and internal energy are extensive variables.

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

(1) (C) and (D) only (2) (A) and (D) only

(3) (B) and (C) only (4) (A) and (B) only

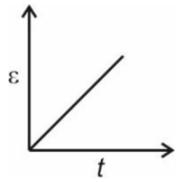
Answer (4)

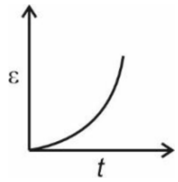
Sol. Extensive variables depend on size and amount of system.

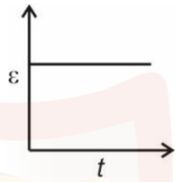
Extensive : Volume, mass, internal energy

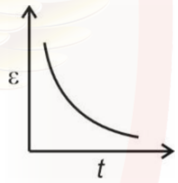
Intensive : Pressure, temperature, density

42. A rectangular metallic loop is moving out of a uniform magnetic field region to a field free region with a constant speed. When the loop is partially inside the magnate field, the plot of magnitude of induced emf (ε) with time (t) is given by

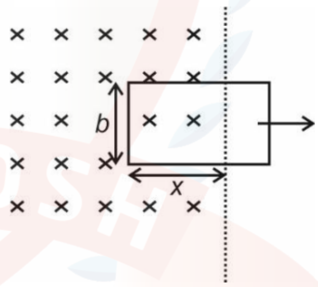
(1)


(2)


(3)


(4)


Answer (3)

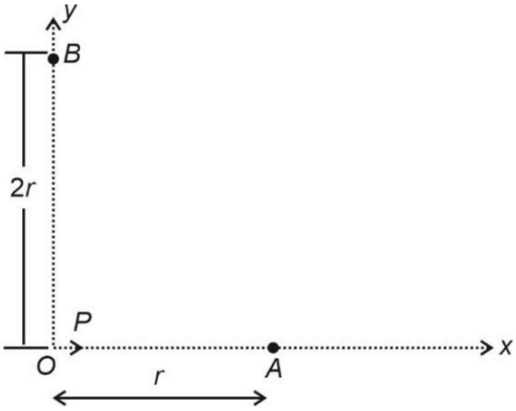
Sol.


$$E = -\frac{d\phi}{dt}$$

$\phi = Bbx$

$|E| = Bbv$

43. For a short dipole placed at origin O, the dipole moment P is along x-axis, as shown in the figure. If the electric potential and electric field at A are V_0 and E_0, respectively, then the correct combination of the electric potential and electric field, respectively, at point B on the y-axis is given by



(1) zero and $\frac{E_0}{16}$ (2) zero and $\frac{E_0}{8}$

(3) $\frac{V_0}{2}$ and $\frac{E_0}{16}$ (4) V_0 and $\frac{E_0}{4}$

Answer (1)

Sol. At point *A* (axial)

$$|E_0| = \frac{2k_p}{r^3}, V_0 = \frac{k_p}{r^2}$$

At point *B* (equatorial)

$$|E| = \frac{k_p}{(2r)^3} = \frac{E_0}{16}$$

$V = 0$

44. A force $F = 2\hat{i} + b\hat{j} + \hat{k}$ is applied on a particle and it undergoes a displacement $\hat{i} - 2\hat{j} - \hat{k}$. What will be the value of *b*, if work done on the particle is zero?

(1) 0 (2) $\frac{1}{3}$

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

Answer (3)

Sol. $w = 0$

$\therefore \quad F \cdot S = 0$

$$(2\hat{i} + b\hat{j} + \hat{k}) \cdot (\hat{i} - 2\hat{j} - \hat{k}) = 0$$

$2 - 2b - 1 = 0$

$$b = \frac{1}{2}$$

45. For a diatomic gas, if $\gamma_1 = \left(\frac{C_p}{C_v}\right)$ for rigid molecules and $\gamma_2 = \left(\frac{C_p}{C_v}\right)$ for another diatomic molecules, but also having vibrational modes. Then, which one of the following options is correct? (C_p and C_v are specific heats of the gas at constant pressure and volume)

(1) $\gamma_2 > \gamma_1$ (2) $2\gamma_2 = \gamma_1$

(3) $\gamma_2 < \gamma_1$ (4) $\gamma_2 = \gamma_1$

Answer (3)

Sol. For rigid diatomic molecules

$f = 5$

$$\therefore \quad \gamma_1 = \frac{7}{5} = 1.4$$

For non-rigid diatomic molecules

$f = 5 + 2 = 7$

$$\gamma_2 = \frac{9}{7} = 1.28$$

$\therefore \quad \gamma_1 > \gamma_2$

SECTION - B

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

46. A tube of length 1 m is filled completely with an ideal liquid of mass 2 *M*, and closed at both ends. The tube is rotated uniformly in horizontal plane about one of its ends. If the force exerted by the liquid at the other end is *F* then angular velocity of the tube is $\sqrt{\frac{F}{\alpha M}}$ in SI unit. The value of α is _______.

Answer (1)

Sol. $F = m\omega^2 r_{cm}$

$$r_{cm} = \frac{1}{2} \text{ m}$$

$$\omega = \sqrt{\frac{2F}{m}}$$

$m = 2M$

$$\omega = \sqrt{\frac{F}{M}}$$

$\alpha = 1$

47. A proton is moving undeflected in a region of crossed electric and magnetic fields at a constant speed of 2×10^5 ms^{-1}. When the electric field is switched off, the proton moves along a circular path of radius 2 cm. The magnitude of electric field is $x \times 10^4$ N/C. The value of x is _______. Take the mass of proton = 1.6×10^{-27} kg.

Answer (2)

Sol. $Bvq = Eq$

$E = Bv$

$$r = \frac{vm}{Bq}$$

$$B = \frac{mv}{rq}$$

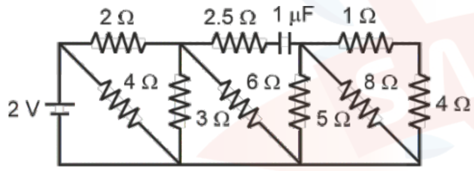
$$E = v\left(\frac{mv}{rq}\right) = \frac{mv^2}{rq}$$

$$= \frac{1.6\times10^{-27}\times4\times10^{10}}{2\times10^{-2}\times1.6\times10^{-19}}$$

$= 2 \times 10^4$ N/C

$x = 2$

48. The net current flowing in the given circuit is _______ A.



Answer (1)

Sol. $I = \frac{V}{R_{eq}}$

C behaves as open circuit

$R_{eq} = 2\ \Omega$

$$i = \frac{2}{2} = 1\text{ A}$$

49. A parallel plate capacitor of area A = 16 cm^2 and separation between the plates 10 cm, is charged by a DC current, Consider a hypothetical plane surface of area A_0 = 3.2 cm^2 inside the capacitor and parallel to the plates. At an instant, the current through the circuit is 6 A. At the same instant the displacement current through A_0 is _______ mA.

Answer (1200)

Sol. $i_d = i_c$

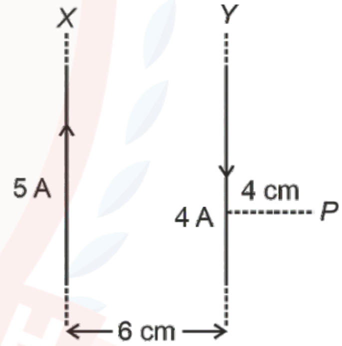
∴ Total displacement current = 6 A

Through A_0

$$i = \left(\frac{A_0}{A}\right)6$$

$$= \frac{3.2}{16}\times 6 = 1.2\text{ A} = 1200\text{ mA}$$

50. Two long parallel wires X and Y, separated by a distance of 6 cm, carry currents of 5 A and 4 A, respectively, in opposite directions as shown in the figure. Magnitude of the resultant magnetic field at point P at a distance of 4 cm from wire Y is $x \times 10^{-5}$ T. The value of x is _______. Take permeability of free space as $\mu_0 = 4\pi \times 10^{-7}$ SI units.



Answer (1)

Sol. At P

$$\vec{B} = \vec{B}_1 + \vec{B}_2$$

$$= \frac{\mu_0 i_2}{2\pi r_2}\hat{k} - \frac{\mu_0 i_1}{2\pi r_1}\hat{k}$$

$$= \frac{\mu_0}{2\pi}\left(\frac{4}{4}\times10^{2} - \frac{5}{10}\times10^{2}\right)\hat{k}$$

$$= \frac{2\times10^{-7}\times10^{2}}{2} = 10^{-5}$$

$x = 1$

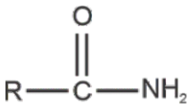
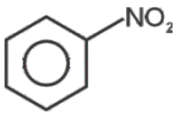
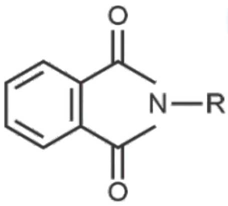
CHEMISTRY

SECTION - A

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

Choose the correct answer :

51. Match the compounds (List-I) with the appropriate Catalyst/Reagents (List-II) for their reduction into corresponding amines.

List-I	List-II
(A) 	(I) NaOH (aqueous)
(B) 	(II) H_2/Ni
(C) R–C≡N	(III) $LiAlH_4$, H_2O
(D) 	(IV) Sn, HCl

Choose the correct answer from the options given below:

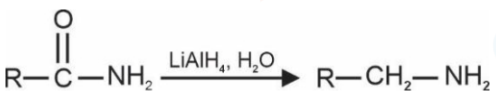
(1) (A)-(III), (B)-(IV), (C)-(II), (D)-(I)

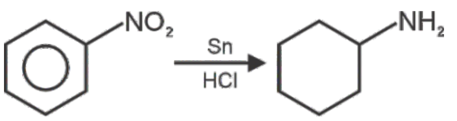
(2) (A)-(II), (B)-(I), (C)-(III), (D)-(IV)

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

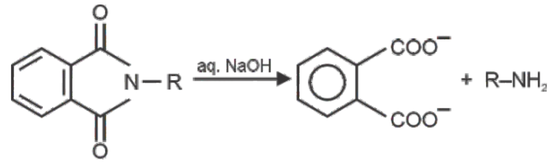
(4) (A)-(III), (B)-(II), (C)-(IV), (D)-(I)

Answer (1)

Sol. (A) 

(B) 

(C) R–C≡N $\xrightarrow{H_2,Ni}$ R–CH_2–NH_2

(D) 

52. Match **List-I** with **List-II**

List-I (Partial Derivatives)	List-II (Thermodynamic Quantity)
(A) $\left(\frac{\partial G}{\partial T}\right)_P$	(I) C_P
(B) $\left(\frac{\partial H}{\partial T}\right)_P$	(II) –S
(C) $\left(\frac{\partial G}{\partial P}\right)_T$	(III) C_V
(D) $\left(\frac{\partial U}{\partial T}\right)_V$	(IV) V

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

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

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

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

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

Answer (4)

Sol. dH = dq (at P = constant)

$dH = C_P dT$

$\left(\frac{dH}{dT}\right)_P = C_P$

dU = dq (at V = constant)

$dU = C_V dT$

$\left(\frac{dU}{dT}\right)_V = C_V$

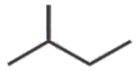
dG = VdP – SdT

at P = constant, dP = 0

$$\left(\frac{dG}{dT}\right)_P = -S$$

at T = constant

$$\left(\frac{dG}{dP}\right)_T = V$$

53. $RBr \xrightarrow[\text{(ii) } H_2O]{\text{(i) Mg, dry ether}}$ 
2-Methylbutane

The maximum number of RBr producing 2-methylbutane by above sequence of reactions is _______. (Consider the structural isomers only)

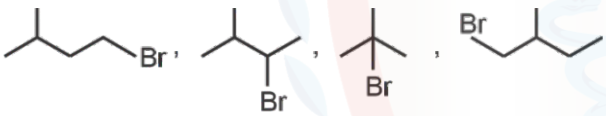
(1) 3　　(2) 4

(3) 1　　(4) 5

Answer (2)

Sol. $RBr \xrightarrow[\text{dry Ether}]{Mg} RMgBr \xrightarrow{H_2O} R-H$

Hence, RBr Can be



Total 4 Structural isomers.

54. The species which does not undergo disproportionation reaction is:

(1) ClO^-

(2) ClO_3^-

(3) ClO_2^-

(4) ClO_4^-

Answer (4)

Sol. The species having Cl-atom in its maximum oxidation state of (+7) or minimum oxidation state of (–1) will not undergo disproportionation reaction.

ClO_4^- has Cl in (+7) oxidation state.

55. Given below are two statements:

Statement (I): Corrosion is an electrochemical phenomenon in which pure metal acts as an anode and impure metal as a cathode.

Statement (II): The rate of corrosion is more in alkaline medium than in acidic medium.

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

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

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

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

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

Answer (2)

Sol. During corrosion metal oxidises, and acts as anode in acidic medium and impure metal as cathode.

Hence, acidic medium increases the rate of corrosion.

56. Density of 3 M NaCl solution is 1.25 g/mL. The molality of solution is

(1) 2 m　　(2) 3 m

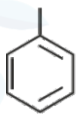
(3) 1.79 m　　(4) 2.79 m

Answer (4)

Sol. Molality $= \frac{1000 \times M}{1000 \times d - M.M_w}$

Molality $= \frac{1000 \times 3}{1000 \times 1.25 - 3 \times 58.5} = \frac{3000}{1074.5}$

= 2.79 molal

57. 
Toluene (excess)

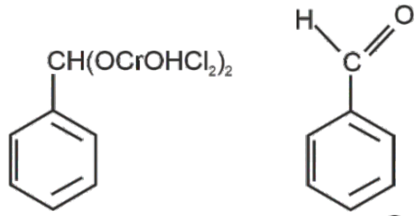
$\xrightarrow[\text{(ii) } H_3O^+ \text{ (iii) } NaHSO_3]{\text{(i) } CrO_2Cl_2, CS_2} \text{Filter} \longrightarrow \text{Residue (A)}$

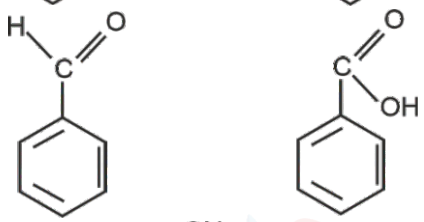
Residue (A) + HCl (dil.) → Compound (B)

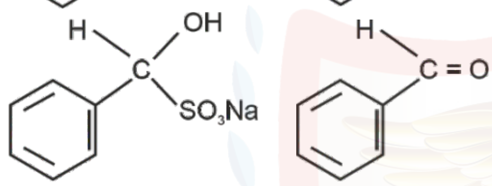
Structure of residue (A) and compound (B) formed respectively is

(A)　　**(B)**

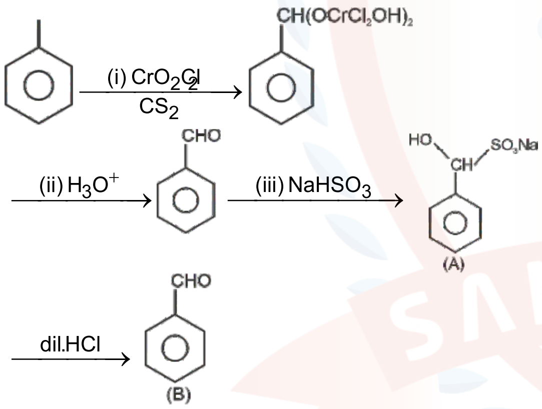
(1) 

(2) 

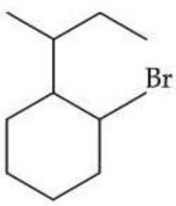
(3) 

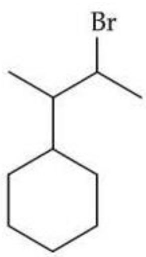
(4) 

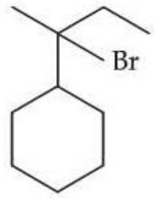
Answer (4)

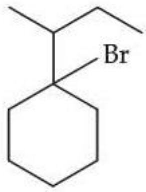
Sol. 

58. When sec-butylcyclohexane reacts with bromine in the presence of sunlight, the major product is:

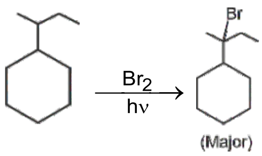
(1) 

(2) 

(3) 

(4) 

Answer (3)

Sol. 

59. Given below are two statements:

Statement (I): A spectral line will be observed for a $2p_x \rightarrow 2p_y$, transition.

Statement (II): $2p_x$ and $2p_y$ are degenerate orbitals.

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

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

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

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

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

Answer (4)

Sol. $2p_x$ and $2p_y$ are degenerated orbitals hence having equal energy and therefore no spectral line will be observed for $2p_x \rightarrow 2p_y$ transition.

60. Identify the homoleptic complex(es) that is/are low spin.

(A) $[Fe(CN)_5NO]^{2-}$ (B) $[CoF_6]^{3-}$

(C) $[Fe(CN)_6]^{4-}$ (D) $[Co(NH_3)_6]^{3+}$

(E) $[Cr(H_2O)_6]^{2+}$

Choose the correct answer from the options given below:

(1) (C) and (D) only (2) (C) only

(3) (B) and (E) only (2) (A) and (C) only

Answer (1)

Sol. Except $[Fe(CN)_5NO]^{2-}$ all are homoleptic as have only one type of ligand.

High spin complexes are $[CoF_6]^{3-}$, $[Cr(H_2O)_6]^{2+}$

Low spin complexes are $[Fe(CN)_6]^{4-}$, $[Co(NH_3)_6]^{3+}$

Hence (C) and (D) are homoleptic and low spin complexes.

61. The molar solubility(s) of zirconium phosphate with molecular formula $(Zr^{4+})_3(PO_4^{3-})_4$, is given by relation:

(1) $\left(\frac{K_{sp}}{8435}\right)^{\frac{1}{7}}$ (2) $\left(\frac{K_{sp}}{6912}\right)^{\frac{1}{7}}$

(3) $\left(\frac{K_{sp}}{5348}\right)^{\frac{1}{6}}$ (4) $\left(\frac{K_{sp}}{9612}\right)^{\frac{1}{3}}$

Answer (2)

Sol. $Zr_3(PO_4)_4(s) \rightleftharpoons \underset{3s}{3Zr^{4+}(aq)} + \underset{4s}{4PO_4^{3-}(aq)}$

$K_{sp} = (3s)^3.(4s)^4$

$K_{sp} = 6912\ s^7$

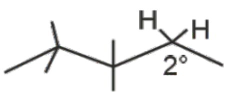
$s = \left(\frac{K_{sp}}{6912}\right)^{\frac{1}{7}}$

62. The alkane from below having two secondary hydrogens is:

(1) 2,2,3,3-Tetramethylpentane
(2) 2,2,4,4-Tetramethylhexane
(3) 4-Ethyl-3,4-dimethyloctane
(4) 2,2,4,5-Tetramethylheptane

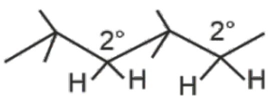
Answer (1)

Sol. 2,2,3,3-Tetramethylpentane



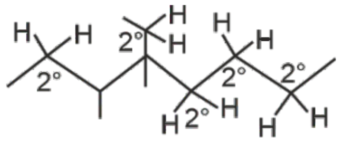
2 secondary Hydrogen

2,2,4,4-Tetramethylhexane



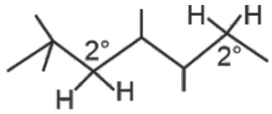
4 secondary Hydrogen

4-Ethyl-3,4-dimethyloctane



10 secondary Hydrogen

2,2,4,5-Tetramethylheptane



4 secondary Hydrogen

63. The correct order of the following complexes in terms of their crystal field stabilization energies is:

(1) $[Co(NH_3)_4]^{2+} < [Co(NH_3)_6]^{2+} < [Co(en)_3]^{3+} < [Co(NH_3)_6]^{3+}$

(2) $[Co(NH_3)_4]^{2+} < [Co(NH_3)_6]^{2+} < [Co(NH_3)_6]^{3+} < [Co(en)_3]^{3+}$

(3) $[Co(en)_3]^{3+} < [Co(NH_3)_6]^{3+} < [Co(NH_3)_6]^{2+} < [Co(NH_3)_4]^{2+}$

(4) $[Co(NH_3)_6]^{2+} < [Co(NH_3)_6]^{3+} < [Co(NH_3)_4]^{2+} < [Co(en)_3]^{3+}$

Answer (2)

Sol. Crystal field splitting energy $(\Delta) \propto$ charge or oxidation state of central metal atom.

Crystal field splitting energy $(\Delta) \propto$ Field strength of ligand (and chelation)

Crystal field stabilisation energy (CFSE) = $[-0.4\ t_{2g} + 0.6\ eg]\Delta_o$ (for octahedral)

For,

$[Co(en)_3]^{3+}$: Co^{3+} : $t_{2g}^6 eg^0$; CFSE $= -2.4(\Delta_0)_1$

$[Co(NH_3)_6]^{3+}$: Co^{3+} : $t_{2g}^6 eg^0$; CFSE $= -2.4(\Delta_0)_2$

$[Co(NH_3)_6]^{2+}$: Co^{2+} : $t_{2g}^5 eg^2$; CFSE $= -0.8(\Delta_0)_3$

$[Co(NH_3)_4]^{2+}$: Co^{2+} : $e^4 t_2^3$; CFSE $= -1.2\Delta_t$

$\left(\text{as} : (\Delta_t) = \frac{4}{9}(\Delta_0)_3\right)$

$\because\ \Delta_t < (\Delta_0)_3 < (\Delta_0)_2 < (\Delta_0)_1$

64. Given below are two statements:

Statement (I): Nitrogen, sulphur, halogen and phosphorus present in an organic compound are detected by Lassaigne's Test.

Statement (II): The elements present in the compound are converted from covalent form into ionic form by fusing the compound with Magnesium in Lassaigne's test.

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

Answer (4)

Sol. For Lassaigne's test, sodium is used and not magnesium to convert covalent to ionic form.

65. Given below are two statements:

Statement (I): An element in the extreme left of the periodic table forms acidic oxides.

Statement (II): Acid is formed during the reaction between water and oxide of a reactive element present in the extreme right of the periodic table.

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

(1) Both Statement I and Statement II are true

(2) Both Statement I and Statement II are false

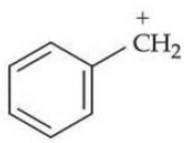
(3) Statement I is false but Statement II is true

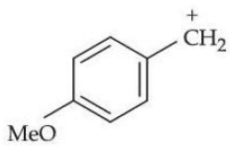
(4) Statement I is true but Statement II is false

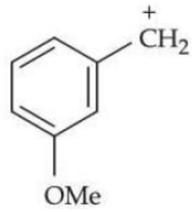
Answer (3)

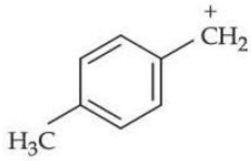
Sol. Group I elements forms basic oxides. Group 17 elements forms acids with their oxides on reaction with water.

66. The most stable carbocation from the following is:

(1) 

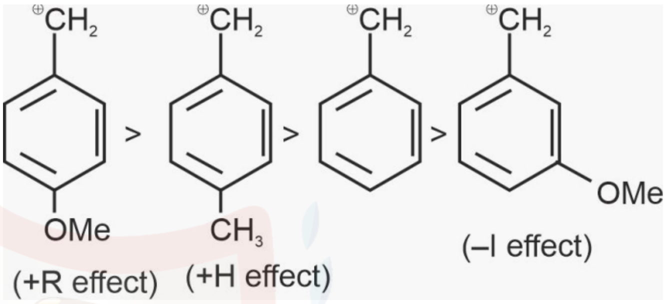
(2) 

(3) 

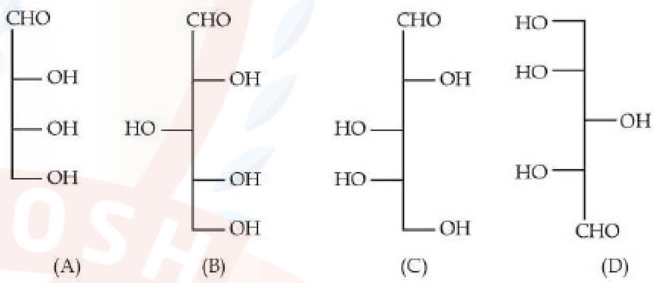
(4) 

Answer (2)

Sol. The order of stability of carbocations given is:



67. Identify the number of structure/s from the following which can be correlated to D-glyceraldehyde



(1) four

(2) three

(3) one

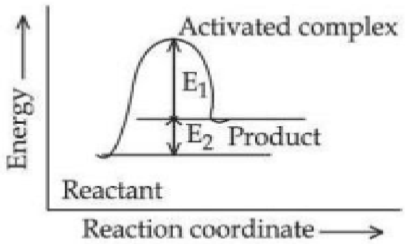
(4) two

Answer (2)

Sol. For D-configuration, when -CHO is at top, -OH at the lowest chiral center should be on right side.

Hence, (A), (B) and (D) can be correlated to D-glyceraldehyde.

68. Consider the given figure and choose the correct option



(1) Activation energy of backward reaction is E_1 and product is more stable than reactant

(2) Activation energy of forward reaction is $E_1 + E_2$ and product is less stable than reactant

(3) Activation energy of forward reaction is $E_1 + E_2$ and product is more stable than reactant

(4) Activation energy of both forward and backward reaction is $E_1 + E_2$ and reactant is more stable than product

Answer (2)

Sol. E_1 : Activation energy for backward reaction.

$E_1 + E_2$: Activation Energy for forward reaction.

Product has more energy than reactant

69. Arrange the following compounds in increasing order of their dipole moment:

HBr, H_2S, NF_3 and $CHCl_3$

(1) $NF_3 < HBr < H_2S < CHCl_3$

(2) $H_2S < HBr < NF_3 < CHCl_3$

(3) $HBr < H_2S < NF_3 < CHCl_3$

(4) $CHCl_3 < NF_3 < HBr < H_2S$

Answer (1)

Sol. $\mu_{HBr} = 0.78\,D$

$\mu_{H_2S} = 0.95\,D$

$\mu_{NF_3} = 0.24\,D$

$\mu_{CHCl_3} = 1.01\,D$

Hence dipole moment of

$NF_3 < HBr < H_2S < CHCl_3$

70. The maximum covalency of a non-metallic group 15 element 'E' with weakest E – E bond is

(1) 6 (2) 3

(3) 5 (4) 4

Answer (4)

Sol. E-E bond strength decreases down the group 15. But N-N bond is weakest due to e^- repulsion

SECTION - B

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

71. Consider the following cases of standard enthalpy of reaction $\left(\Delta H_r^\circ \text{ in kJ mol}^{-1}\right)$

$C_2H_6(g) + \frac{7}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)\ \Delta H_1^\circ$

$= -1550$

C(graphite) + O_2(g) → CO_2(g) $\Delta H_2^\circ = -393.5$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)\ \Delta H_3^\circ = -286$

The magnitude of $\Delta H^\circ_{f\ C_2H_6\,(g)}$ is __________ kJ mol^{-1} (Nearest integer).

Answer (95)

Sol. $C_2H_6(g) + \frac{7}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)\ \Delta H_1^\circ$

$= -1550$ …(i)

C(graphite) + O_2(g) → CO_2(g) $\Delta H_2^\circ = -393.5$ …(ii)

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)\ \Delta H_3^\circ = -286$ …(iii)

From 2 × eq^n(ii) + 3 × eq^n(iii) – eq^n(i)

$2C_{(graphite)} + 3H_2(g) \rightarrow C_2H_6(g)$: $\Delta H^\circ_{f\ C_2H_6}$

$\left(\Delta H_f^\circ\right)_{C_2H_6} = 2 \times (-393.5) + 3 \times (-286) - (-1550)$

= –95 kJ/mol

72. The compound with molecular formula C_6H_6, which gives only one monobromo derivative and takes up four moles of hydrogen per mole for complete hydrogenation has _________ π electrons.

Answer (8)

Sol. Since 4 moles of H_2 is being added for complete hydrogenation the degree of unsaturation = 4

No. of π electrons in C_6H_6 = 4 × 2 = 8

73. Niobium (Nb) and ruthenium (Ru) have "x" and "y" number of electrons in their respective 4*d* orbitals. The value of x + y is __________.

Answer (11)

Sol. Ru : $[Kr]4d^7 5s^1$; Nb : $[Kb]4d^4 5s^1$

x = 7, y = 4

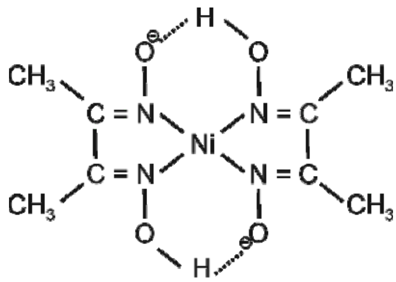
x + y = 11

74. The complex of Ni^{2+} ion and dimethyl glyoxime contains ________ number of Hydrogen (H) atoms.

Answer (14)

Sol. Ni^{2+} with(dmg) forms $[Ni(dmg)_2]^{2+}$ having 2 H-Bonds as shown:

The no. of H atoms = 14



75. 20 mL of 2 M NaOH solution is added to 400 mL of 0.5 M NaOH solution. The final concentration of the solution is __________ × 10^{-2} M. (Nearest integer)

Answer (57)

Sol. $[NaOH]_{final} = \frac{20 \times 2 + 400 \times 0.5}{420} = \frac{40 + 200}{420} = \frac{240}{420}$

= 0.57 M

$[NaOH]_{final} = 57 \times 10^{-2}$ M

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