BRILLIANT® TUTORIALS
IIT-JEE CLASSROOM CENTRE

SOLUTIONS TO IIT-JEE 2008
Paper-I (Code: 0)

INSTRUCTIONS

Question paper format:

1. The question paper consists of 3 parts (Part I: Mathematics, Part II: Physics, Part III: Chemistry. Each part has 4 sections.
2. **Section I** contains 6 multiple choice questions. Each question has 4 choices (A), (B), (C) and (D), out of which **only one is correct.**
3. **Section II** contains 4 multiple choice correct answer type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **only one or more answers are correct.**
3. **Section III** contains 4 questions. Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason).
   - Bubble (A) if both the statements are TRUE and STATEMENT-2 is the correct explanation of STATEMENT-1.
   - Bubble (B) if both the statements are TRUE but STATEMENT-2 is NOT the correct explanation of STATEMENT-1.
   - Bubble (C) if STATEMENT-1 is TRUE and STATEMENT-2 is FALSE.
   - Bubble (D) if STATEMENT-1 is FALSE and STATEMENT-2 is TRUE.
4. **Section IV** contains 3 sets of Linked-Comprehension type questions. Each set consists of a paragraph followed by three questions. Each question has 4 choices (A), (B), (C) and (D), out of which **only one is correct.**

Marking Scheme:

1. For each question in **Section I**, you will be **awarded 3 marks** if you have darkened only the bubble corresponding to the correct answer and **zero mark** if no bubble is darkened. In all other cases, **minus one (–1) mark** will be awarded.
2. For each question in **Section II,** you will be **awarded 4 marks** if you darkened all the bubble(s) corresponding to the correct answer and **zero mark** for all other cases. It may be noted that there is **no negative marking for wrong answer**.
3. For each question in **Section III,** you will be **awarded 3 marks** if you darken only the bubble corresponding to the correct answer and **zero mark** if no bubble is darkened. In all other cases, **minus one (–1) mark** will be awarded.
4. For each question in **Section IV,** you will be **awarded 4 marks** if you darken only the bubble corresponding to the correct answer and **zero mark** if no bubble is darkened. In all other cases, **minus one (–1) mark** will be awarded.

SOLUTIONS TO IIT-JEE 2008
MATHEMATICS: Paper-I (Code: 0)

SECTION – I
Straight Objective Type

This section contains 6 multiple choice questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

Note: Questions with (*) mark are from syllabus of class XI.

***1.** Consider the two curves $C_1 : y^2 = 4x$; $C_2 : x^2 + y^2 - 6x + 1 = 0$. Then

(A) C_1 and C_2 touch each other only at one point (B) C_1 and C_2 touch each other exactly at two points

(C) C_1 and C_2 intersect (but do not touch) at exactly two points (D) C_1 and C_2 neither intersect nor touch each other

Sol.: Solving C_1 and C_2 simultaneously we get $x^2 - 2x + 1 = 0 \Rightarrow (x-1)^2 = 0$

At $x = 1$, $y = \pm 2$.

Hence C_1 and C_2 touch each other exactly at two points (1, 2) and (1, –2).

Correct choice: (B)

2. If $0 < x < 1$, then $\sqrt{1+x^2}\left[\left\{x\cos\left(\cot^{-1}x\right)+\sin\left(\cot^{-1}x\right)\right\}^2 - 1\right]^{\frac{1}{2}} =$

(A) $\dfrac{x}{\sqrt{1+x^2}}$ (B) x (C) $x\sqrt{1+x^2}$ (D) $\sqrt{1+x^2}$

Sol.: As $0 < x < 1$, $\cot^{-1}x = \cos^{-1}\dfrac{x}{\sqrt{1+x^2}} = \sin^{-1}\dfrac{1}{\sqrt{1+x^2}}$

Hence given expression reduces to $x\sqrt{1+x^2}$

Correct choice: (C)

3. The edges of a parallelopiped are of unit length and are parallel to non-coplanar unit vectors $\hat{a}, \hat{b}, \hat{c}$ such that $\hat{a}.\hat{b} = \hat{b}.\hat{c} = \hat{c}.\hat{a} = \dfrac{1}{2}$. Then, the volume of the parallelopiped is

(A) $\dfrac{1}{\sqrt{2}}$ (B) $\dfrac{1}{2\sqrt{2}}$ (C) $\dfrac{\sqrt{3}}{2}$ (D) $\dfrac{1}{\sqrt{3}}$

Sol.: Using $[\hat{a}\,\hat{b}\,\hat{c}]^2 = \begin{vmatrix} \hat{a}.\hat{a} & \hat{a}.\hat{b} & \hat{a}.\hat{c} \\ \hat{b}.\hat{a} & \hat{b}.\hat{b} & \hat{b}.\hat{c} \\ \hat{c}.\hat{a} & \hat{c}.\hat{b} & \hat{c}.\hat{c} \end{vmatrix} = \begin{vmatrix} 1 & 1/2 & 1/2 \\ 1/2 & 1 & 1/2 \\ 1/2 & 1/2 & 1 \end{vmatrix} = \dfrac{1}{2} \quad \Rightarrow \quad$ Volume i.e., $\left|[\hat{a}\,\hat{b}\,\hat{c}]\right| = \dfrac{1}{\sqrt{2}}$

Correct choice: (A)

***4.** Let a and b be non-zero real numbers. Then the equation $\left(ax^2 + by^2 + c\right)\left(x^2 - 5xy + 6y^2\right) = 0$ represents

(A) four straight lines, when $c = 0$ and a, b are of the same sign

(B) two straight lines and a circle, when $a = b$, and c is of sign opposite to that of a

(C) two straight lines and a hyperbola, when a and b are of the same sign and c is of sign opposite to that of a

(D) a circle and an ellipse, when a and b are of the same sign and c is of sign opposite to that of a

Sol.: $\left(x^2 - 5xy + 6y^2\right)$ factorises to $(x-2y)(x-3y)$

So they are lines and $ax^2 + by^2 + c = 0$ represents a circle if $a = b$; $ac < 0$ i.e., $x^2 + y^2 = -\dfrac{c}{a}$; $\left(-\dfrac{c}{a} > 0\right)$

Correct choice: (B)

***5.** Let $g(x)=\dfrac{(x-1)^n}{\log\cos^m(x-1)}$; $0<x<2$, m and n are integers, $m\neq 0$, $n>0$, and let p be the left hand derivative of $|x-1|$ at $x=1$. If $\lim\limits_{x\to 1^+} g(x)=p$, then

(A) $n=1,\ m=1$ (B) $n=1,\ m=-1$ (C) $n=2,\ m=2$ (D) $n>2,\ m=n$

Sol.: Left hand derivative of $|x-1|$ at $x=1$ is -1

$$\Rightarrow \lim_{x\to 1^+}\frac{(x-1)^n}{\log\left(\cos^m(x-1)\right)}=-1$$ Applying L'Hospital Rule we get

$$\lim_{x\to 1^+}\frac{n(x-1)^{n-1}}{-\dfrac{m\cos^{m-1}(x-1)\sin(x-1)}{\cos^m(x-1)}}=-1 \Rightarrow \lim_{x\to 1^+}-\frac{n}{m}\frac{(x-1)^{n-1}}{\tan(x-1)}=-1$$

As $n > 0$ and value of n for which limit tends to -1 is 2. $\Rightarrow \lim\limits_{x\to 1^+}-\dfrac{2}{m}=-1 \Rightarrow m=2$

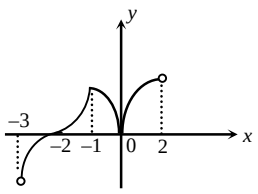
Correct choice: (C)

6. The total number of local maxima and local minima of the function $f(x)=\begin{cases}(2+x)^3 & , \ -3<x\le -1\\ x^{2/3} & , \ -1<x<2\end{cases}$ is

(A) 0 (B) 1 (C) 2 (D) 3

Sol.: As $f'(x)=\begin{cases}3(2+x)^2 & ; \ -3<x<-1\\ \dfrac{2}{3}\times\dfrac{1}{(x)^{1/3}} & ; \ -1<x<2\end{cases}$

Hence graph of $f(x)$ will be



Obliviously, $x=-1$ and $x=0$ are point of local maxima and point of local minima respectively.

Correct choice: (C)

SECTION – II
Multiple Correct Answers Type

This section contains 4 multiple correct answer(s) type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONE OR MORE** is/ are correct.

***7.** A straight line through the vertex P of a triangle PQR intersects the side QR at the point S and the circumcircle of the triangle PQR at the point T. If S is not the centre of the circumcircle, then

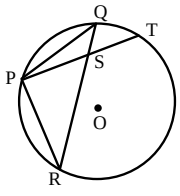
(A) $\dfrac{1}{PS}+\dfrac{1}{ST}<\dfrac{2}{\sqrt{QS\times SR}}$ (B) $\dfrac{1}{PS}+\dfrac{1}{ST}>\dfrac{2}{\sqrt{QS\times SR}}$

(C) $\dfrac{1}{PS}+\dfrac{1}{ST}<\dfrac{4}{QR}$ (D) $\dfrac{1}{PS}+\dfrac{1}{ST}>\dfrac{4}{QR}$

Sol.: $\because\ PS.ST=QS.SR$

$\therefore\ GM\ge HM$

$\Rightarrow \dfrac{1}{PS}+\dfrac{1}{ST}\ge\dfrac{2}{\sqrt{QS\times SR}}$ (equality occurs when $PS = ST$) …(i)



Also $AM\ge GM$ $\Rightarrow \dfrac{QS+SR}{2}\ge\sqrt{(QS).(SR)} \Rightarrow \dfrac{2}{\sqrt{(QS)(SR)}}\ge\dfrac{4}{QS+SR}$ …(ii)

Using (i) and (ii) $\Rightarrow \dfrac{1}{PS}+\dfrac{1}{ST}\ge\dfrac{4}{QS+SR}=\dfrac{4}{QR}$ …(iii)

Since $PS = ST$ and $QS = SR$ can't occur simultaneously, therefore equality in (iii) is not possible.

Correct choice: (B) and (D)

***8.** Let $P(x_1, y_1)$ and $Q(x_2, y_2)$, $y_1 < 0$, $y_2 < 0$, be the end points of the latus rectum of the ellipse $x^2 + 4y^2 = 4$. The equations of parabolas with latus rectum PQ are

(A) $x^2 + 2\sqrt{3}y = 3 + \sqrt{3}$ (B) $x^2 - 2\sqrt{3}y = 3 + \sqrt{3}$

(C) $x^2 + 2\sqrt{3}y = 3 - \sqrt{3}$ (D) $x^2 - 2\sqrt{3}y = 3 - \sqrt{3}$

Sol.: According to given conditions, end points of L.R are $P\left(\sqrt{3}, -\frac{1}{2}\right)$ $Q\left(-\sqrt{3}, -\frac{1}{2}\right)$

$\therefore$ Focus of parabola is $\left(0, -\frac{1}{2}\right)$ and length of L.R = $2\sqrt{3}$ $\Rightarrow$ $a = \frac{\sqrt{3}}{2}$

Vertex of parabola are $\left(0, -\frac{1}{2} + \frac{\sqrt{3}}{2}\right)$ or $\left(0, -\frac{1}{2} - \frac{\sqrt{3}}{2}\right)$

Hence equations of parabola are $x^2 = -4 \times \frac{\sqrt{3}}{2}\left\{y - \left(-\frac{1}{2} + \frac{\sqrt{3}}{2}\right)\right\}$ $\Rightarrow$ $x^2 + 2\sqrt{3}y = 3 - \sqrt{3}$

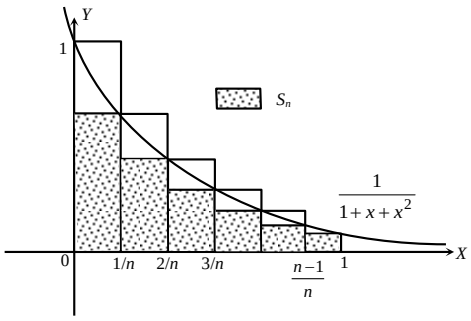
or $x^2 = 4 \times \frac{\sqrt{3}}{2}\left\{y - \left(-\frac{1}{2} - \frac{\sqrt{3}}{2}\right)\right\} \Rightarrow x^2 - 2\sqrt{3}y = 3 + \sqrt{3}$

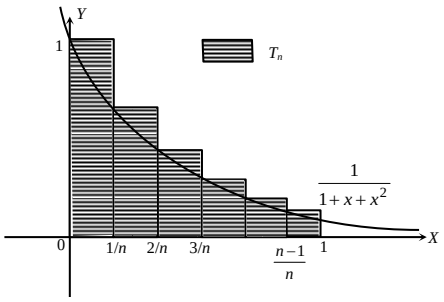
Correct choice: (B) and (C)

9. Let $S_n = \sum_{k=1}^{n} \frac{n}{n^2 + kn + k^2}$ and $T_n = \sum_{k=0}^{n-1} \frac{n}{n^2 + kn + k^2}$, for $n = 1, 2, 3, \ldots\ldots$. Then

(A) $S_n < \frac{\pi}{3\sqrt{3}}$ (B) $S_n > \frac{\pi}{3\sqrt{3}}$ (C) $T_n < \frac{\pi}{3\sqrt{3}}$ (D) $T_n > \frac{\pi}{3\sqrt{3}}$

Sol.:





$S_n < \int_0^1 \frac{dx}{1+x+x^2} < T_n$

$S_n < \frac{\pi}{3\sqrt{3}} < T_n$

Correct choice: (A) and (D)

10. Let $f(x)$ be a non-constant twice differentiable function defined on $(-\infty, \infty)$ such that $f(x) = f(1-x)$ and $f'\left(\frac{1}{4}\right) = 0$. Then,

(A) $f''(x)$ vanishes at least twice on [0, 1] (B) $f'\left(\frac{1}{2}\right) = 0$

(C) $\int_{-1/2}^{1/2} f\left(x + \frac{1}{2}\right) \sin x \, dx = 0$ (D) $\int_0^{1/2} f(t) e^{\sin \pi t} dt = \int_{1/2}^{1} f(1-t) e^{\sin \pi t} \, dt$

Sol.: $f(x) = f(1-x)$ …(i)

$\Rightarrow \quad f'(x) + f'(1-x) = 0 \quad \Rightarrow f'\left(\frac{1}{2}\right) = 0$ …(ii)

Correct choice: (B)

Also given that $f'\left(\frac{1}{4}\right) = 0$ …(iii)

$\therefore$ (ii) and (iii) $\Rightarrow$ $\frac{1}{4}$ and $\frac{1}{2}$ are two roots of $f'(x) = 0$

$\therefore$ $f''(x) = 0$ will have at least one root between $\frac{1}{4}$ and $\frac{1}{2}$

Also from (i) we get $f\left(\frac{1}{2} - x\right) = f\left(\frac{1}{2} + x\right)$ …(iv)

$\Rightarrow \quad f(x)$ is symmetric about $x = \frac{1}{2}$

$\therefore \quad f''(x)$ will also have one root between $\frac{1}{2}$ and $\frac{3}{4}$.

Correct choice: (A)

$$I = \int_{-1/2}^{1/2} f\left(x + \frac{1}{2}\right)\sin x \, dx$$

Let $g(x) = f\left(x + \frac{1}{2}\right)\sin x \Rightarrow g(-x) = f\left(\frac{1}{2} - x\right)\sin(-x) = -f\left(\frac{1}{2} + x\right)\sin x$ [using (iv)]

$= -g(x)$

$\therefore \quad g(x)$ is odd

$\Rightarrow I = 0$

Correct choice: (C)

$$I = \int_0^{1/2} f(t)e^{\sin \pi t}\, dt = \int_0^{1/2} f(1-t)e^{\sin \pi t} dt \quad \text{[using (i)]}$$

Let $1 - t = z$

$$\Rightarrow \quad I = -\int_1^{1/2} f(z)e^{\sin \pi z} dz = \int_{1/2}^{1} f(z)e^{\sin \pi z} dz = \int_{1/2}^{1} f(t)e^{\sin \pi t}\, dt = \int_{1/2}^{1} f(1-t)e^{\sin \pi t}\, dt$$

Correct choice: (D)

$\therefore$ Correct choice: (A), (B), (C) and (D)

SECTION – III
Reasoning Type

This section contains 4 reasoning type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

***11.** Let f and g be real valued functions defined on interval $(-1, 1)$ such that $g''(x)$ is continuous, $g(0) \neq 0$, $g'(0) = 0$, $g''(0) \neq 0$ and $f(x) = g(x)\sin x$.

STATEMENT–1: $\lim_{x\to 0}[g(x)\cot x - g(0)\operatorname{cosec} x] = f''(0)$.

and

STATEMENT–2: $f'(0) = g(0)$.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $f'(x) = g'(x)\sin x + g(x)\cos x \Rightarrow f'(0) = g'(0)\times 0 + g(0) = g(0)$, thus statement-2 is correct.

Now, $\lim_{x\to 0}\dfrac{g(x)\cos x - g(0)}{\sin x}$

$= \lim_{x\to 0}\dfrac{(g(x)\cos x + g'(x)\sin x) - g'(x)\sin x - g(0)}{\sin x} = \lim_{x\to 0}\dfrac{f'(x) - g'(x)\sin x - f'(0)}{\sin x}$

$= \lim_{x\to 0}\dfrac{(f'(x) - f'(0)) - g'(x)\sin x}{\sin x} = \lim_{x\to 0}\left(\dfrac{(f'(x) - f'(0))}{x\dfrac{\sin x}{x}} - g'(x)\right) = f''(0) - g'(0) = f''(0)$

Correct choice: (A)

12. Consider three planes $P_1 : x - y + z = 1$, $P_2 : x + y - z = -1$ and $P_3 : x - 3y + 3z = 2$. Let L_1, L_2, L_3 be the lines of intersection of the planes P_2 and P_3, P_3 and P_1, and P_1 and P_2, respectively.

STATEMENT–1: At least two of the lines L_1, L_2 and L_3 are non –parallel.

and

STATEMENT–2: The three planes do not have a common point.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $P_1 : x - y + z = 1$, $P_2 : x + y - z = -1$ and $P_3 : x - 3y + 3z = 2$

Line L_3 is intersection of planes P_1 and P_2, then direction cosine of L_3 is $\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 1 & 1 & -1 \end{vmatrix} = 2(\hat{j} + \hat{k})$

Line L_1 is intersection of planes P_2 and P_3, then direction cosine of L_1 is $\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & 1 & -1 \\ 1 & -3 & 3 \end{vmatrix} = -4(\hat{j} + \hat{k})$

Line L_2 is intersection of P_1 and P_3, then direction cosine of L_2 is $\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 1 & -3 & 3 \end{vmatrix} = -2(\hat{j} + \hat{k})$

Family of planes passing through intersection of P_1 and P_2 is $P_1 + \lambda P_2 = 0$. If plane P_3 satisfies $P_1 + \lambda P_2 = 0$ for any value of λ, then these three planes pass through same point.

$x(1+\lambda) + (\lambda - 1)y + z(1-\lambda) + (\lambda - 1) = 0$

$x-3y+3z=2$

$\frac{1+\lambda}{1}=\frac{-1+\lambda}{-3}=\frac{1-\lambda}{3}=\frac{1-\lambda}{2}$ …(i)

Clearly no value of λ exists which satisfies (i).

Correct choice: (D)

13. Consider the system of equations $x-2y+3z=-1$, $-x+y-2z=k$ and $x-3y+4z=1$.

STATEMENT–1: The system of equations has no solution for $k \neq 3$.

and

STATEMENT–2: The determinant $\begin{vmatrix} 1 & 3 & -1 \\ -1 & -2 & k \\ 1 & 4 & 1 \end{vmatrix} \neq 0$, for $k \neq 3$.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $x-2y+3z=-1$, $-x+y-2z=k$ and $x-3y+4z=1$

For these equations $\Delta=\begin{vmatrix} 1 & -2 & 3 \\ -1 & 1 & -2 \\ 1 & -3 & 4 \end{vmatrix}=0$

Now the system of equations has infinite solutions or no solution depending on $\Delta x, \Delta y, \Delta z$. If at least one of the $\Delta x, \Delta y, \Delta z$ is non-zero, then it has no solution otherwise infinite solutions.

$\Delta x=\begin{vmatrix} -1 & -2 & 3 \\ k & 1 & -2 \\ 1 & -3 & 4 \end{vmatrix}$, $\Delta x=0$ if $k=3$

$\Delta y=\begin{vmatrix} 1 & -1 & 3 \\ -1 & k & -2 \\ 1 & 1 & 4 \end{vmatrix}$, $\Delta y=0$ if $k=3$ and $\Delta z=\begin{vmatrix} 1 & -2 & -1 \\ -1 & 1 & k \\ 1 & -3 & 1 \end{vmatrix}$, $\Delta z=0$ at $k=3$

Thus system of equations has no solution if $k \neq 3$.

Correct choice: (A)

14. Consider the system of equations $ax+by=0$, $cx+dy=0$, where $a, b, c, d \in \{0, 1\}$.

STATEMENT–1: The probability that the system of equations has a unique solution is $\frac{3}{8}$.

and

STATEMENT–2: The probability that the system of equations has a solution is 1.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $ax+by=0$ and $cx+dy=0$

We have to choose a, b, c, d from $\{0, 1\}$

For a, b, c, d total number of options are 2^4. The equation has unique solution then $\frac{a}{c} \neq \frac{b}{d}$.

If $ad \neq bc$

$ad = 0$ and $bc = 1$

$ad = 0$, where (a, d) is $(0, 0), (1, 0), (0, 1)$ and $bc = 1$ if (b, c) is $(1, 1)$

Total cases of $ad = 0$ and $bc = 1$ is 3.

Similarly $ad = 1$ and $bc = 0$ gives 3 solutions then total solution for $ad \neq bc$ is 6.

Then probability that the system of equations has unique solution = $\frac{6}{16} = \frac{3}{8}$.

This system of equation has always a solution then probability is 1.

Correct choice: (B)

SECTION – IV
Linked Comprehension Type

This section contains 3 paragraphs. Based upon each paragraph, 3 multiple choice questions have to be answered. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

Paragraph for Question Nos. 15 to 17

A circle C of radius 1 is inscribed in an equilateral triangle PQR. The points of contact of C with the sides PQ, QR, RP are D, E, F respectively. The line PQ is given by the equation $\sqrt{3}x+y-6=0$ and the point D is $\left(\frac{3\sqrt{3}}{2}, \frac{3}{2}\right)$. Further, it is given that the origin and the centre of C are on the same side of the line PQ.

***15.** The equation of circle C is

(A) $\left(x-2\sqrt{3}\right)^2+(y-1)^2=1$

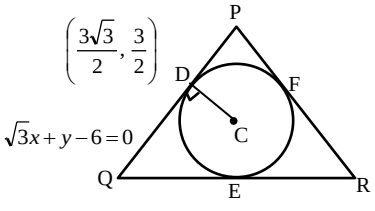
(B) $\left(x-2\sqrt{3}\right)^2+\left(y+\frac{1}{2}\right)^2=1$

(C) $\left(x-\sqrt{3}\right)^2+(y+1)^2=1$

(D) $\left(x-\sqrt{3}\right)^2+(y-1)^2=1$

Sol.: Equation of line CD in parametric form is

$$\frac{\left(x-\frac{3\sqrt{3}}{2}\right)}{\sqrt{3}/2} = \frac{\left(y-\frac{3}{2}\right)}{1/2} = r \text{ ; For centre } C, \quad r = \pm 1$$



Two possible co-ordinates of centre are $(2\sqrt{3}, 2); (\sqrt{3}, 1)$

According to the question $(\sqrt{3}, 1)$ lies on the same side where origin lies with respect to line PQ.

$\Rightarrow$ Centre C must be $(\sqrt{3}, 1)$

$\Rightarrow$ Equation of the circle is $\left(x-\sqrt{3}\right)^2+(y-1)^2=1$

Correct choice: (D)

***16.** Points E and F are given by

(A) $\left(\frac{\sqrt{3}}{2}, \frac{3}{2}\right), \left(\sqrt{3}, 0\right)$ (B) $\left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right), \left(\sqrt{3}, 0\right)$

(C) $\left(\frac{\sqrt{3}}{2}, \frac{3}{2}\right), \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$ (D) $\left(\frac{3}{2}, \frac{\sqrt{3}}{2}\right), \left(\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$

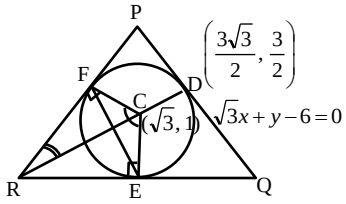
Sol.: By simple geometry $PD = \sqrt{3}$ (ΔPQR is equilateral)

Considering equation of PQ in parametric form co-ordinates of P and Q are $\left(2\sqrt{3}, 0\right)$ and $\left(\sqrt{3}, 3\right)$.

Point C divides the join of P and E in the ratio 2 : 1

Similarly, C divides join of Q and F in the ratio 2 : 1

$\Rightarrow$ Co-ordinates of E and F are $\left(\frac{\sqrt{3}}{2}, \frac{3}{2}\right)$ and $\left(\sqrt{3}, 0\right)$



Correct choice: (A)

***17.** Equations of the sides QR, RP are

(A) $y = \frac{2}{\sqrt{3}}x + 1,\ y = -\frac{2}{\sqrt{3}}x - 1$ (B) $y = \frac{1}{\sqrt{3}}x,\ y = 0$

(C) $y = \frac{\sqrt{3}}{2}x + 1,\ y = -\frac{\sqrt{3}}{2}x - 1$ (D) $y = \sqrt{3}x,\ y = 0$

Sol.: Equation of line PR which is parallel to DE and passes through F is $(y - 0) = 0\left(x - \sqrt{3}\right) \Rightarrow y = 0$.

Similarly, equation of line QR which is parallel to DF and passes through the point E is $\left(y - \frac{3}{2}\right) = \left(\frac{3/2 - 0}{\frac{3\sqrt{3}}{2} - \sqrt{3}}\right)\left(x - \frac{\sqrt{3}}{2}\right)$

$\Rightarrow \quad y = \sqrt{3}x$.

Correct choice: (D)

Paragraph for Question Nos. 18 to 20

Consider the functions defined implicitly by the equation $y^3 - 3y + x = 0$ on various intervals in the real line. If $x \in (-\infty, -2) \cup (2, \infty)$, the equation implicitly defines a unique real valued differentiable function $y = f(x)$. If $x \in (-2, 2)$ the equation implicitly defines a unique real valued differentiable function $y = g(x)$ satisfying $g(0) = 0$.

18. If $f\left(-10\sqrt{2}\right) = 2\sqrt{2}$, then $f''\left(-10\sqrt{2}\right) =$

(A) $\frac{4\sqrt{2}}{7^3 3^2}$ (B) $-\frac{4\sqrt{2}}{7^3 3^2}$ (C) $\frac{4\sqrt{2}}{7^3 3}$ (D) $-\frac{4\sqrt{2}}{7^3 3}$

Sol.: $\frac{dy}{dx} = \frac{1}{3\left(1 - y^2\right)} \quad \Rightarrow \quad \frac{d^2y}{dx^2} = \frac{2y}{9\left(1 - y^2\right)^3}$

At $x = -10\sqrt{2}$, $y = 2\sqrt{2}$, then

$$\left.\frac{d^2y}{dx^2}\right|_{\text{at } x = -10\sqrt{2}} = f''\left(-10\sqrt{2}\right) = \frac{-4\sqrt{2}}{9 \times 7^3} = \frac{-4\sqrt{2}}{7^3 \times 3^2}$$

Correct choice: (B)

19. The area of the region bounded by the curve $y = f(x)$, the x-axis, and lines $x = a$ and $x = b$, where $-\infty < a < b < -2$, is

(A) $\int_a^b \frac{x}{3\left((f(x))^2 - 1\right)}\,dx + bf(b) - af(a)$

(B) $-\int_a^b \frac{x}{3\left((f(x))^2 - 1\right)}\,dx + bf(b) - af(a)$

(C) $\int_a^b \frac{x}{3\left((f(x))^2 - 1\right)}\,dx - bf(b) + af(a)$

(D) $-\int_a^b \frac{x}{3\left((f(x))^2 - 1\right)}\,dx - bf(b) + af(a)$

Sol.: From given equation $y^3 - 3y + x = 0 \Rightarrow x = 3y - y^3 < -2 \Rightarrow (y+1)^2(y-2) > 0 \Rightarrow y = f(x)$ is positive for $x < -2$.

Also, $y' = \frac{1}{3\left(1 - y^2\right)} \Rightarrow f'(x) = \frac{1}{3\left(1 - (f(x))^2\right)}$

Required area is $= \int_a^b f(x)\,dx = \int_a^b 1.\,f(x)dx = [xf(x)]_a^b - \int_a^b x\,f'(x)dx = (bf(b) - af(a)) - \int_a^b x.\,f'(x)\,dx$

$$= (bf(b) - af(a)) + \int_a^b \frac{x}{3\left((f(x))^2 - 1\right)}dx$$

Correct choice: (A)

20. $\int_{-1}^{1} g'(x)dx =$

(A) $2g(-1)$ (B) 0 (C) $-2g(1)$ (D) $2g(1)$

Sol.: $y^3 - 3y + x = 0$, $x \in (-2, 2)$

For given function if (x_0, y_0) lies on it so does $(-x_0, -y_0) \Rightarrow g(x)$ is odd function.

$\therefore \quad g(-1) = -g(1)$ and $g(0) = 0$; $\int_{-1}^{1} g'(x)dx = 2\int_0^1 g'(x)dx = 2g(1)$

Correct choice: (D)

Paragraph for Question Nos. 21 to 23

Let A, B, C be three sets of complex numbers as defined below:

$A = \{z : \text{Im}\, z \geq 1\}$

$B = \{z : |z - 2 - i| = 3\}$

$C = \{z : \text{Re}((1-i)z) = \sqrt{2}\}$.

***21.** The number of elements in the set $A \cap B \cap C$ is

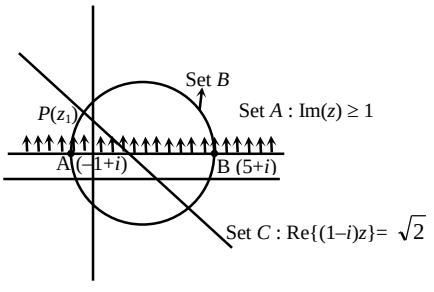
(A) 0 (B) 1 (C) 2 (D) ∞

Sol.: Set A represents all the points in argand plane for which $\text{Im}(z) \geq 1$.

Set B represents all the points on the circle and set C represents all the points on the straight line as shown in the figure.

Clearly, there is only one point 'z_1' which lies in $A \cap B \cap C$.

Correct choice: (B)



***22.** Let *z* be any point in $A \cap B \cap C$. Then $|z+1-i|^2 + |z-5-i|^2$ lies between

(A) 25 and 29 (B) 30 and 34 (C) 35 and 39 (D) 40 and 44

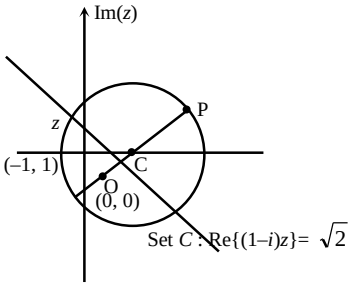
Sol.: Since *AB* is the diameter of circle. Hence $PA^2 + PB^2 = AB^2 = 6^2 = 36$

Correct choice: (C)

***23.** Let *z* be any point in $A \cap B \cap C$ and let *w* be any point satisfying $|w-2-i| < 3$. Then $|z|-|w|+3$ lies between

(A) –6 and 3 (B) –3 and 6 (C) –6 and 6 (D) –3 and 9

Sol.: As $\text{Re}\{(1-i)z\} = \sqrt{2} \Rightarrow \dfrac{(1-i)z + (1+i)\bar{z}}{2} = \sqrt{2}$ …(i)



Also $|z-2-i| = 3$

$\Rightarrow \quad z.\bar{z} - \{(1+i)\bar{z} + (1-i)z\} - (z+\bar{z}) - 4 = 0$ …(ii)

From equation (i) and (ii) $\Rightarrow \quad z.\bar{z} = 2\sqrt{2} + (z+\bar{z}) + 4$

$\Rightarrow \quad |z|^2 = \sqrt{2} + 4 + 2\,\text{Re}(z)$. From figure it is clear that $-1 < \text{Re}(z) < 0$

$\Rightarrow \quad 2 + 2\sqrt{2} < |z|^2 < 4 + 2\sqrt{2}$

$4.828 < |z|^2 < 6.828$(approx.) $\Rightarrow \quad 2.197 < |z| < 2.613$ (approx.)

Also $|w|_{\min} = 0$ and $|w|_{\max} = OC + CP = \sqrt{1^2 + 2^2} + 3 = 3 + \sqrt{5}$

$\therefore \quad -(\sqrt{5} - 2.197) < |z| + 3 - |w| < 5.613$

Correct choice: (B), (C), (D)

PHYSICS: Paper-I (Code: 0)

PART II

Useful Data:

Planck's constant $h = 4.1 \times 10^{-15}$ eV.s

Velocity of light $c = 3 \times 10^8$ m/s

SECTION – I
Straight Objective Type

This section contains 6 multiple choice questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

***24.** Students I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and / or record time for different number of oscillations. The observations are shown in the table.

Least count for length = 0.1 cm

Least count for time = 0.1 s

Student	Length of the pendulum (cm)	Number of oscillations (n)	Total time for (n) oscillations (s)	Time period (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

If E_I, E_{II} and E_{III} are the percentage errors in g, i.e. $\left(\frac{\Delta g}{g}\times 100\right)$ for students I, II and III, respectively,

(A) $E_I = 0$ (B) E_I is minimum (C) $E_I = E_{II}$ (D) E_{II} is maximum

Sol.: $\frac{\Delta g}{g}\times 100 = \left(\frac{\Delta l}{l} + 2\frac{\Delta T}{T}\right)\times 100$

For student I, $E_I = \frac{\Delta g}{g}\times 100 = \left(\frac{0.1}{64} + 2\times\frac{0.1}{128}\right)\times 100 = \frac{5}{16}\%$

For student II, $E_{II} = \frac{\Delta g}{g}\times 100 = \left(\frac{0.1}{64} + 2\times\frac{0.1}{64}\right)\times 100 = \frac{15}{32}\%$

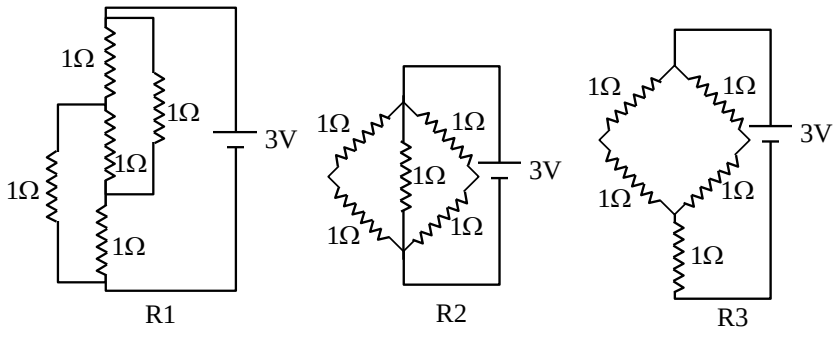
For student III, $E_{III} = \frac{\Delta g}{g}\times 100 = \left(\frac{0.1}{20} + 2\times\frac{0.1}{36}\right)\times 100 = \frac{19}{18}\%$

$\therefore$ Percentage error is minimum for student I

Correct choice: (B)

25. Figure shows three resistor configurations R1, R2 and R3 connected to 3V battery. If the power dissipated by the configuration R1, R2 and R3 is P1, P2 and P3, respectively, then

Figure:



(A) P1 > P2 > P3 (B) P1 > P3 > P2 (C) P2 > P1 > P3 (D) P3 > P2 > P1

Sol.: For R1, $(R_{eq})_1 = 1\Omega$

For R2, $(R_{eq})_2 = 0.5\Omega$

For R3, $(R_{eq})_3 = 2\Omega$ $\because$ $P \propto \frac{1}{R}$ (as V = constant) $\therefore$ $P_2 > P_1 > P_3$

Correct choice: (C)

26. Which one of the following statements is **WRONG** in the context of X-rays generated from a X-ray tube?

(A) Wavelength of characteristic X-rays decreases when the atomic number of the target increases

(B) Cut-off wavelength of the continuous X-rays depends on the atomic number of the target

(C) Intensity of the characteristic X-rays depends on the electric power given to the X-ray tube

(D) Cut-off wavelength of the continuous X-rays depends on the energy of the electrons in the X-ray tube

Sol.: $\therefore$ $\lambda_{\text{cut-off}} = \frac{hc}{eV}$

Correct choice: (B)

27. Two beams of red and violet colours are made to pass separately through a prism (angle of the prism is 60^0). In the position of minimum deviation, the angle of refraction will be

(A) 30^0 for both the colours

(B) greater for the violet colour

(C) greater for the red colour

(D) equal but not 30^0 for both the colours

Sol.: In case of minimum deviation, $r = A/2 \Rightarrow r = 30^0$

Correct choice: (A)

***28.** An ideal gas is expanding such that PT^2 = constant. The coefficient of volume expansion of the gas is

(A) $\frac{1}{T}$ (B) $\frac{2}{T}$ (C) $\frac{3}{T}$ (D) $\frac{4}{T}$

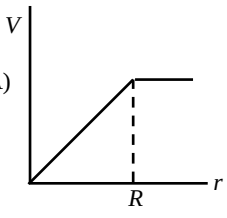
Sol.: $PT^2 = \text{constant} = K$ $\therefore$ $\frac{KV}{nR} = T^3$ (Using $PV = nRT$)

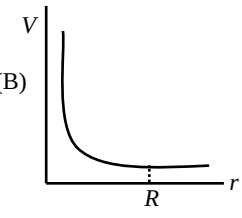
Differentiating, $\frac{KdV}{nR} = 3T^2 dT$ or $\frac{dV}{VdT} = \frac{3}{T}$

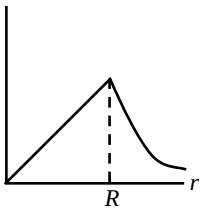
Correct choice: (C)

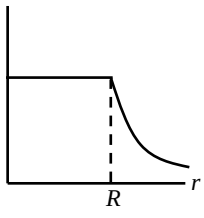
***29.** A spherically symmetric gravitational system of particles has a mass density $\rho = \begin{cases} \rho_0 & for \quad r \le R \\ 0 & for \quad r > R \end{cases}$

Where ρ_0 is a constant. A test mass can undergo circular motion under the influence of the gravitational field of particles. Its speed V as a function of distance $r(0 < r < \infty)$ from the centre of the system is represented by

(A) 

(B) 

(C) 

(D) 

Sol.: For $r \le R$; $V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{G \times \frac{4}{3}\pi r^3 \times \rho_0}{r}}$ or $V \propto r$ … (i)

For $r > R$; $V = \sqrt{\frac{GM}{r}} = \sqrt{\frac{G \times \frac{4}{3}\pi R^3 \rho_0}{r}}$ $V \propto \frac{1}{r^{1/2}}$ … (ii)

Correct choice: (C)

SECTION – II
Multiple Correct Answers Type

This section contains 4 multiple correct answer(s) type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONE OR MORE** is/ are correct.

***30.** Two balls, having linear momenta $\vec{p}_1 = p\hat{i}$ and $\vec{p}_2 = -p\hat{i}$, undergo a collision in free space. There is no external force acting on the balls. Let $\vec{p}_1'$ and $\vec{p}_2'$ be their final momenta. The following option(s) is (are) **NOT ALLOWED** for any non-zero value of p, a_1, a_2, b_1, b_2, c_1 and c_2.

(A) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j}$

(B) $\vec{p}_1' = c_1\hat{k}$, $\vec{p}_2' = c_2\hat{k}$

(C) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j} + c_1\hat{k}$, $\vec{p}_2' = a_2\hat{i} + b_2\hat{j} - c_1\hat{k}$

(D) $\vec{p}_1' = a_1\hat{i} + b_1\hat{j}$, $\vec{p}_2' = a_2\hat{i} + b_1\hat{j}$

Sol.: Since initial linear momentum of two balls system is zero, therefore final linear momentum of the system must also be zero.

Final linear momentum of the system can not be zero in case of options (A) and (D).

Correct choice: (A) and (D)

31. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below.

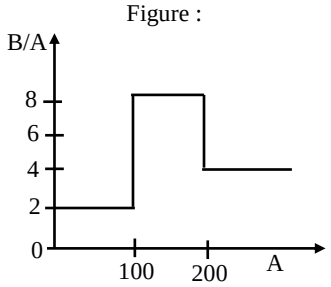
(A) Fusion of two nuclei with mass numbers lying in the range of 1 < A < 50 will release energy

(B) Fusion of two nuclei with mass numbers lying in the range of 51 < A < 100 will release energy

(C) Fission of a nucleus lying in the mass range of 100 < A < 200 will release energy when broken into equal fragments

(D) Fission of a nucleus lying in the mass range of 200 < A < 260 will release energy when broken into equal fragments

Figure :

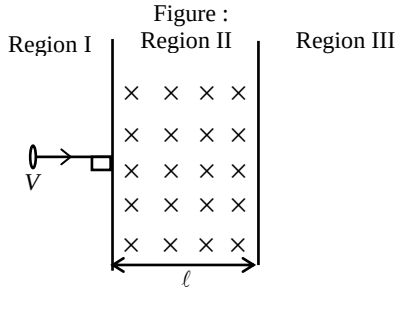


Sol.: When binding energy of product is greater than the binding energy of reactants, the energy will be released.

Correct choice: (B) and (D)

32. A particle of mass m and charge q, moving with velocity V enters Region II normal to the boundary as shown in the figure. Region II has a uniform magnetic field B perpendicular to the plane of the paper. The length of the Region II is ℓ. Choose the correct choice(s).

Figure :



(A) The particle enters Region III only if its velocity $V > \frac{q\ell B}{m}$

(B) The particle enters Region III only if its velocity $V < \frac{q\ell B}{m}$

(C) Path length of the particle in Region II is maximum when velocity $V = \frac{q\ell B}{m}$

(D) Time spent in Region II is same for any velocity V as long as the particle returns to Region I

Sol.: To enter the particle in region III, $R > \ell$

$$\frac{mV}{qB} > \ell \Rightarrow \qquad V > \frac{qB\ell}{m}.$$

Path length of the particle in region II will be maximum for $\ell = R \Rightarrow \ell = \frac{mV}{qB} \quad \Rightarrow \qquad V = \frac{q\ell B}{m}$

As long as particle returns to region I, time spent is given by $\frac{T}{2} = \frac{\pi m}{qB}$ which is independent of velocity

Correct choice: (A), (C) and (D)

33. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s).

(A) If $d = \lambda$, the screen will contain only one maximum

(B) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen

(C) If the intensity of light falling on slit **1** is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase.

(D) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit **1**, the intensities of the observed dark and bright fringes will increase

Sol.: Path difference $\Delta x = d\sin\theta = n\lambda$

When $d = \lambda$, $\sin\theta = n$ but, $\sin\theta \le 1$ $\therefore$ $n \le 1$

To form bright fringe on the screen $n = 0\ (<1)$ is possible.

When $\lambda < d < 2\lambda$, central maximum and first order maximum will be formed on the screen.

Correct choice: (A) and (B)

SECTION – III
Reasoning Type

This section contains 4 reasoning type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

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34. STATEMENT–1

In a Meter Bridge experiment, null point for an unknown resistance is measured. Now, the unknown resistance is put inside an enclosure maintained at a higher temperature. The null point can be obtained at the same point as before by decreasing the value of the standard resistance.

and

STATEMENT–2

Resistance of a metal increases with increase in temperature.

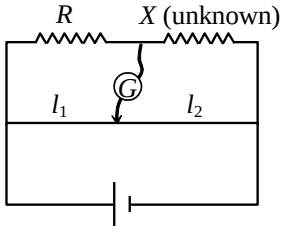
(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.
(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.
(C) STATEMENT–1 is True, STATEMENT–2 is False.
(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $\frac{R}{l_1} = \frac{X}{l_2}$

On increasing the temperature, X increases.

Therefore R should be increased to keep the null point same.

Correct choice: (D)



***35.** STATEMENT–1

An astronaut in an orbiting space station above the Earth experiences weightlessness.

and

STATEMENT–2

An object moving around the Earth under the influence of Earth's gravitational force is in a state of 'free-fall'

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: **Correct choice: (A)**

***36.** STATEMENT–1

Two cylinders, one hollow (metal) and the other solid (wood) with the same mass and identical dimensions are simultaneously allowed to roll without slipping down an inclined plane from the same height. The hollow cylinder will reach the bottom of the inclined plane first.

and

STATEMENT–2

By the principle of conservation of energy, the total kinetic energies of both the cylinders are identical when they reach the bottom of the incline.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: $a_{cm} = \dfrac{g\sin\theta}{1+\dfrac{I}{mR^2}}$, $\quad I_{hollow} > I_{solid}$

So, $a_{cm(\text{hollow})} < a_{cm(\text{solid})}$

$\therefore$ Solid cylinder reaches the bottom of the inclined plane first.

Correct choice: (D)

***37.** STATEMENT–1

The stream of water flowing at high speed from a garden hose pipe tends to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.

and

STATEMENT–2

In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant.

(A) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is** a correct explanation for STATEMENT–1.

(B) STATEMENT–1 is True, STATEMENT–2 is True; STATEMENT–2 **is NOT** a correct explanation for STATEMENT–1.

(C) STATEMENT–1 is True, STATEMENT–2 is False.

(D) STATEMENT–1 is False, STATEMENT–2 is True.

Sol.: By equation of continuity, Av = constant

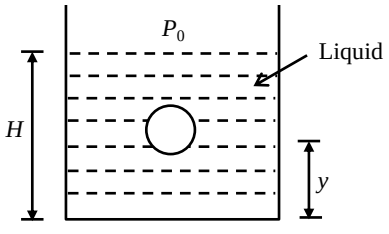
Correct choice: (A)

SECTION – IV
Linked Comprehension Type

This section contains 3 paragraphs. Based upon each paragraph, 3 multiple choice questions have to be answered. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

Paragraph for Question Nos. 38 to 40

A small spherical monoatomic ideal gas bubble $\left(\gamma = \frac{5}{3}\right)$ is trapped inside a liquid of density ρ_ℓ (see figure). Assume that the bubble does not exchange any heat with the liquid. The bubble contains n moles of gas. The temperature of the gas when the bubble is at the bottom is T_0, the height of the liquid is H and the atmospheric pressure is P_0 (Neglect surface tension).



***38.** As the bubble moves upwards, besides the buoyancy force the following forces are acting on it

(A) Only the force of gravity

(B) The force due to gravity and the force due to the pressure of the liquid

(C) The force due to gravity, the force due to the pressure of the liquid and the force due to viscosity of the liquid

(D) The force due to gravity and the force due to viscosity of the liquid

Sol.: **Correct choice: (D)**

***39.** When the gas bubble is at height y from the bottom, its temperature is

(A) $T_0\left(\frac{P_0+\rho_\ell gH}{P_0+\rho_\ell gy}\right)^{2/5}$ (B) $T_0\left(\frac{P_0+\rho_\ell g(H-y)}{P_0+\rho_\ell gH}\right)^{2/5}$

(C) $T_0\left(\frac{P_0+\rho_\ell gH}{P_0+\rho_\ell gy}\right)^{3/5}$ (D) $T_0\left(\frac{P_0+\rho_\ell g(H-y)}{P_0+\rho_\ell gH}\right)^{3/5}$

Sol.: For adiabatic process $T.P^{\frac{1-\gamma}{\gamma}} = \text{constant}$

$$T_0.(P_0+\rho_\ell gH)^{-2/5} = T.[P_0+\rho_\ell g(H-y)]^{-2/5}$$

$$T = T_0\left[\frac{P_0+\rho_\ell gH}{P_0+\rho_\ell g(H-y)}\right]^{-2/5} = T_0\left[\frac{P_0+\rho_\ell g(H-y)}{P_0+\rho_\ell gH}\right]^{2/5}$$

Correct choice: (B)

***40.** The buoyancy force acting on the gas bubble is (Assume R is the universal gas constant)

(A) $\rho_\ell nRgT_0\frac{(P_0+\rho_\ell gH)^{2/5}}{(P_0+\rho_\ell gy)^{7/5}}$ (B) $\frac{\rho_\ell nRgT_0}{(P_0+\rho_\ell gH)^{2/5}[P_0+\rho_\ell g(H-y)]^{3/5}}$

(C) $\rho_\ell nRgT_0\frac{(P_0+\rho_\ell gH)^{3/5}}{(P_0+\rho_\ell gy)^{8/5}}$ (D) $\frac{\rho_\ell nRgT_0}{(P_0+\rho_\ell gH)^{3/5}[P_0+\rho_\ell g(H-y)]^{2/5}}$

Sol.: $V = \frac{nRT}{P} \Rightarrow V = \frac{nRT_0}{[P_0+\rho_\ell g(H-y)]}\left[\frac{P_0+\rho_\ell g(H-y)}{P_0+\rho_\ell gH}\right]^{2/5}$

Buoyant force $= \rho_\ell gV = \frac{\rho_\ell nRgT_0}{(P_0+\rho_\ell gH)^{2/5}[P_0+\rho_\ell g(H-y)]^{3/5}}$

Correct choice: (B)

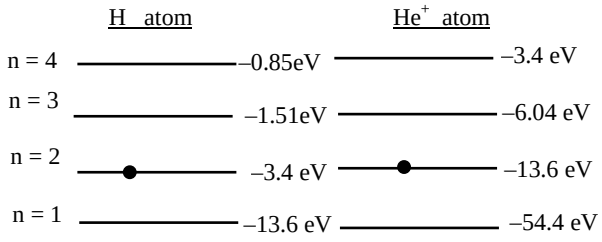
Paragraph for Question Nos. 41 to 43

In a mixture of H – He^+ gas (He^+ is singly ionized He atom), H atoms and He^+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He^+ ions (by collisions). Assume that the Bohr model of atom is exactly valid.

41. The quantum number n of the state finally populated in He^+ ions is

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

Sol.:



Energy transfer by H atom to He^+ is 10.2 eV. Subsequently He^+ gets excited to n = 4.

Correct choice: (C)

42. The wavelength of light emitted in the visible region by He^+ ions after collisions with H atoms is

(A) 6.5×10^{-7} m (B) 5.6×10^{-7} m (C) 4.8×10^{-7} m (D) 4.0×10^{-7} m

Sol.: Only the energy corresponding to transition for n = 4 to n = 3 falls in visible region.

So $\lambda = \dfrac{hc}{2.64\,\text{eV}} = 4.8 \times 10^{-7}$ m

Correct choice: (C)

43. The ratio of the kinetic energy of the n = 2 electron for the H atom to that of He^+ ion is

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 1 (D) 2

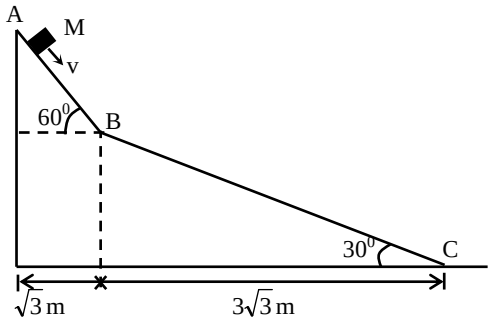
Sol.: $\dfrac{KE_H}{KE_{He}} = \dfrac{Z_H^2}{Z_{He}^2} = \dfrac{1}{4}$

Correct choice: (A)

Paragraph for Question Nos. 44 to 46

A small block of mass M moves on a frictionless surface of an inclined plane, as shown in figure. The angle of the incline suddenly changes from 60^0 to 30^0 at point B. The block is initially at rest at A. Assume that collisions between the block and the incline are totally inelastic (g = 10 m/s^2)

Figure :

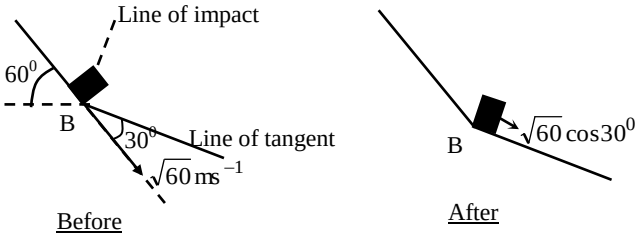


***44.** The speed of the block at point B immediately after it strikes the second incline is

(A) $\sqrt{60}$ m/s (B) $\sqrt{45}$ m/s (C) $\sqrt{30}$ m/s (D) $\sqrt{15}$ m/s

Sol.: Let speed of block just before it strikes the second inclined plane be v then,

$$\frac{1}{2}mv^2 = mg\left(\sqrt{3}\tan 60^0\right) \Rightarrow v = \sqrt{60}\ \text{m/s}$$



Before After

Speed of block immediately after it strikes the second incline is $\sqrt{45}$ m/s (because in perfectly inelastic collision the component of velocity along line of impact becomes zero.

Correct choice: (B)

***45.** The speed of the block at point C, immediately before it leaves the second incline is

(A) $\sqrt{120}$ m/s (B) $\sqrt{105}$ m/s (C) $\sqrt{90}$ m/s (D) $\sqrt{75}$ m/s

Sol.: By conservation of mechanical energy

$$\frac{1}{2}mv_C^2 = \frac{1}{2}m\left(\sqrt{45}\right)^2 + mg\left(3\sqrt{3}\tan 30^0\right)$$

$$v_C^2 = 45 + 60 = 105 \quad \Rightarrow \quad v_C = \sqrt{105}\ \text{m/s}$$

Correct choice: (B)

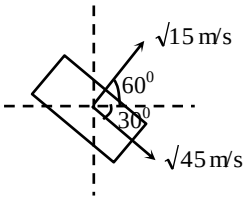
***46.** If collision between the block and the incline is completely elastic, then the vertical (upward) component of the velocity of the block at point B, immediately after it strikes the second incline is

(A) $\sqrt{30}$ m/s (B) $\sqrt{15}$ m/s (C) 0 (D) $-\sqrt{15}$ m/s

Sol.: If collision is completely elastic, then vertical component of velocity becomes,

$$\sqrt{45}\sin 30^0 - \sqrt{15}\sin 60^0 = \frac{\sqrt{45}}{2} - \frac{\sqrt{15}\times\sqrt{3}}{2} = 0$$

Correct choice: (C)



CHEMISTRY: Paper-I (Code: 0)

SECTION – I
Straight Objective Type

This section contains 6 multiple choice questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

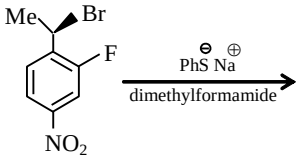
***47.** Hyperconjugation involves overlap of the following orbitals

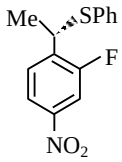
(A) $\sigma - \sigma$ (B) $\sigma - p$ (C) $p - p$ (D) $\pi - \pi$

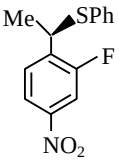
Sol.: Hyperconjugation involves overlapping of σ C–H bonding electrons with p-orbital of unsaturated system, carbocation or carbon free radical.

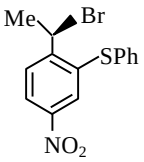
Correct choice: (B)

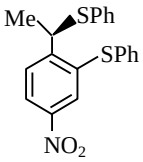
48. The major product of the following reaction is



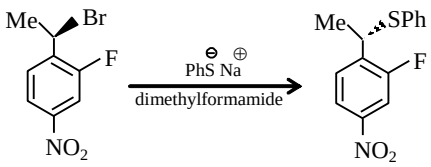
(A) 

(B) 

(C) 

(D) 

Sol.: The given compound is an alkyl as well as an aryl halide. PhS^- being a weak base cannot cause nucleophilic substitution by benzyne mechanism. S_NAr mechanism is also ruled out because NO_2 group is present at the meta position with respect to fluorine atom. So, the compound will react by S_N2 mechanism.



Correct choice: (A)

49. Aqueous solution of $Na_2S_2O_3$ on reaction with Cl_2 gives

(A) $Na_2S_4O_6$ (B) $NaHSO_4$ (C) NaCl (D) NaOH

Sol.: Cl_2 is a stronger oxidising agent than I_2. So $Na_2S_2O_3$ on oxidation gives $NaHSO_4$ rather than sodium tetrathionate.

$$Na_2S_2O_3 + 4Cl_2 + 5H_2O \longrightarrow 2NaHSO_4 + 8HCl$$

Correct choice: (B)

50. Native silver metal forms a water soluble complex with a dilute aqueous solution of NaCN in the presence of

(A) nitrogen (B) oxygen (C) carbon dioxide (D) argon

Sol.: Silver metal is oxidized by oxygen in presence of cyanide ion to Ag^+, which then forms a complex with CN^-, i.e.$[Ag(CN)_2]^-$.

Correct choice: (B)

51. Under the same reaction conditions, initial concentration of 1.386 mol dm^{-3} of a substance becomes half in 40 seconds and 20 seconds through first order and zero order kinetics, respectively. Ratio $\left(\frac{k_1}{k_0}\right)$ of the rate constants for first order (k_1) and zero order (k_0) of the reactions is

(A) 0.5 mol^{-1} dm^3 (B) 1.0 mol dm^{-3} (C) 1.5 mol dm^{-3} (D) 2.0 mol^{-1} dm^3

Sol.: For Ist order reaction, $k_1 = \frac{0.693}{t_{1/2(\text{first})}} = \frac{0.693}{40}\text{sec}^{-1}$

For zero order reaction, $k_0 = \frac{[A_o]}{2t_{1/2(\text{zero})}} = \frac{1.386}{2\times 20}\text{mol dm}^{-3}\text{ sec}^{-1}$

$$\frac{k_1}{k_0} = \frac{0.693\times2\times20}{40\times1.386} = \frac{1}{2} = 0.5 \text{ mol}^{-1} \text{ dm}^3$$

Correct choice: (A)

***52.** 2.5 mL of $\frac{2}{5}$ M weak monoacidic base ($K_b = 1 \times 10^{-12}$ at 25°C) is titrated with $\frac{2}{15}$ M HCl in water at 25°C. The concentration of H^+ at equivalence point is ($K_w = 1 \times 10^{-14}$ at 25°C)

(A) 3.7×10^{-13} M (B) 3.2×10^{-7} M (C) 3.2×10^{-2} M (D) 2.7×10^{-2} M

Sol.: $BOH + HCl \longrightarrow BCl + H_2O$

$$2.5 \times 10^{-3} \times \frac{2}{5} = x \times 10^{-3} \times \frac{2}{15}$$

$$x = 7.5 \text{ ml}$$

$$[BCl] = \frac{2.5\times\frac{2}{5}}{10} = 0.1 \text{ M}$$

$$B^+ + H_2O \rightleftharpoons BOH + H^+$$

$0.1(1-h)$ $0.1\,h$ $0.1\,h$

$$K_h = \frac{K_w}{K_b} = \frac{[BOH][H^+]}{[B^+]} = \frac{0.1\,h^2}{(1-h)}$$

$$\frac{1\times10^{-14}}{1\times10^{-12}} = 1\times10^{-2} = \frac{0.1\,h^2}{(1-h)}$$

$h = 0.27$ (We cannot ignore the value of h w.r.t. 1 because it is more than 0.1)

$\therefore [H^+] = 0.1 \times 0.27 = \mathbf{2.7 \times 10^{-2}\ M}$.

Correct choice: (D)

SECTION – II
Multiple Correct Answers Type

This section contains 4 multiple correct answer(s) type questions. Each question has 4 choices (A), (B), (C) and (D), out of which **ONE OR MORE** is/are correct.

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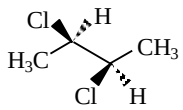
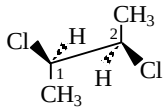
53. The correct statement(s) about the compound given below is(are)



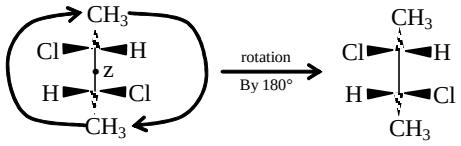
(A) The compound is optically active. (B) The compound possesses centre of symmetry.

(C) The compound possesses plane of symmetry. (D) The compound possesses axis of symmetry.

Sol.: The given compound can be represented in saw–horse projection as



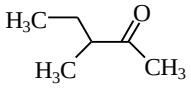
This does not have a plane or a centre of symmetry. So it is optically active. The compound on rotation about C_1–C_2, keeping C_2 fixed and C_1 rotated by 180° gives the structure.

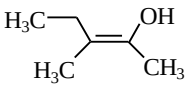


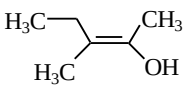
The compound possesses 180° axis of symmetry (two fold axis of symmetry) passing through point z perpendicular to the plane of paper.

Correct choice: (A) & (D)

54. The correct statement(s) concerning the structures **E**, **F** and **G** is (are)


(E)


(F)


(G)

(A) **E**, **F** and **G** are resonance structures.
(B) **E**, **F** and **E**, **G** are tautomers.
(C) **F** and **G** are geometrical isomers.
(D) **F** and **G** are diastereomers.

Sol.: **(E)** is a keto form and **(F)** & **(G)** are its enol forms. **(F)** and **(G)** are also geometrical isomers, which also come under the category of diastereomers.

Correct choice: (B), (C) & (D)

55. A solution of colourless salt **H** on boiling with excess NaOH produces a non–flammable gas. The gas evolution ceases after sometime. Upon addition of Zn dust to the same solution, the gas evolution restarts. The colourless salt(s) **H** is (are)

(A) NH_4NO_3 (B) NH_4NO_2 (C) NH_4Cl (D) $(NH_4)_2SO_4$

Sol.: The colourless salt (H) must be an ammonium salt because on boiling with excess of NaOH it produces NH_3 (non–flammable) gas. To this solution, when Zn dust is added, only nitrates and nitrites will liberate NH_3 again (Zn acts as a reducing agent).

$$4Zn + NO_3^- + 7OH^- \longrightarrow 4ZnO_2^{2-} + NH_3 + 2H_2O$$

$$3Zn + NO_2^- + 5OH^- \longrightarrow 3ZnO_2^{2-} + NH_3 + H_2O$$

Correct choice: (A) & (B)

***56.** A gas described by van der Waals equation

(A) behaves similar to an ideal gas in the limit of large molar volumes.

(B) behaves similar to an ideal gas in the limit of large pressures.

(C) is characterized by van der Waals coefficients that are dependent on the identity of the gas but are independent of the temperature.

(D) has the pressure that is lower than the pressure exerted by the same gas behaving ideally.

Sol.: A real gas following van der Waals equation behaves like an ideal gas at low pressures (or large molar volumes). Van der Waals coefficients ('a' and 'b') are characteristic of a gas and are independent of the temperature. The pressure exerted by the real gas is smaller than the pressure exerted by the gas under ideal conditions as some pressure is lost by the real gas due to inter molecular attractions.

Correct choice: (A), (C) & (D).

SECTION – III
Reasoning Type

This section contains 4 reasoning type questions. Each question has 4 choices (A), (B), (C) and (D) out of which **ONLY ONE** is correct.

***57.** STATEMENT-1: Bromobenzene upon reaction with Br_2/Fe gives 1,4-dibromobenzene as the major product.

and

STATEMENT-2: In Bromobenzene, the inductive effect of the bromo group is more dominant than the mesomeric effect in directing the incoming electrophile.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1.

(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1.

(C) STATEMENT-1 is True, STATEMENT-2 is False.

(D) STATEMENT-1 is False, STATEMENT-2 is True.

Sol.: STATEMENT-2 is true because inductive effect is permanent effect and inductive effect of halogen always dominates its mesomeric effect. But this statement is unable to explain the formation of 1,4-dibromobenzene as the major product. The correct reason for the formation of given product is that Br is ortho/para directing due to resonance stabilization of arenium ion. The prominent attack of Br^+ takes place at para position due to steric effect.

Correct choice: (B)

***58.** STATEMENT-1: Pb^{4+} compounds are stronger oxidizing agents than Sn^{4+} compounds.

and

STATEMENT-2: The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to 'inert pair effect'.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1.

(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1.

(C) STATEMENT-1 is True, STATEMENT-2 is False.

(D) STATEMENT-1 is False, STATEMENT-2 is True.

Sol.: Pb^{4+} is less stable than Sn^{4+}, therefore Pb^{4+} is a stronger oxidizing agent than Sn^{4+}. Due to inert pair effect, stability of higher oxidation state of group 14 elements decreases down the group. Thus, STATEMENT-1 is true and STATEMENT-2 is false.

Correct choice: (C)

59. STATEMENT-1: The plot of atomic number (*y*–axis) versus number of neutrons (*x*–axis) for stable nuclei shows a curvature towards *x*–axis from the line of 45° slope as the atomic number is increased.

and

STATEMENT-2: Proton–proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides.

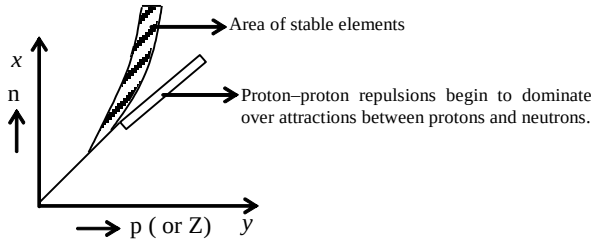
(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1.

(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1.

(C) STATEMENT-1 is True, STATEMENT-2 is False.

(D) STATEMENT-1 is False, STATEMENT-2 is True.

Sol.:



Proton–proton repulsions begin to dominate over attractions between protons and neutrons as the value of Z increases. Therefore, STATEMENT-2 is true. In order to stabilize the heavier nuclides, more number of neutrons are to be added so that the attractive forces between protons and neutrons overcome the repulsive forces among protons. Therefore, STATEMENT-2 is the correct explanation of STATEMENT-1.

Correct choice: (A)

***60.** STATEMENT-1: For every chemical reaction at equilibrium, standard Gibbs energy of reaction is zero.

and

STATEMENT-2: At constant temperature and pressure, chemical reactions are spontaneous in the direction of decreasing Gibbs energy.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is** a correct explanation for STATEMENT-1.

(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 **is NOT** a correct explanation for STATEMENT-1.

(C) STATEMENT-1 is True, STATEMENT-2 is False.

(D) STATEMENT-1 is False, STATEMENT-2 is True.

Sol.: For every chemical reaction at equilibrium, Gibbs free energy change (ΔG) of reaction is zero but standard Gibbs free energy change ($\Delta G°$) may not be zero. Thus STATEMENT-1 is false but STATEMENT-2 is true.

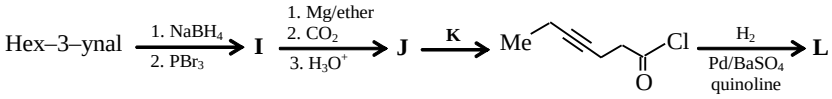
Correct choice: (D)

SECTION – IV
Linked Comprehension Type

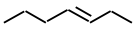
This section contains 3 paragraphs. Based upon each paragraph, 3 multiple choice questions have to be answered. Each question has 4 choices (A), (B), (C) and (D), out of which **ONLY ONE** is correct.

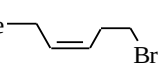
Paragraph for Question Nos. 61 to 63

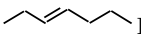
In the following reaction sequence, products **I**, **J** and **L** are formed. **K** represents a reagent.

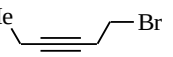


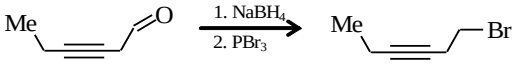
61. The structure of the product **I** is

(A) 

(B) 

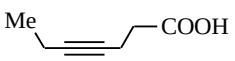
(C) 

(D) 

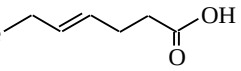
Sol.: 

Correct choice: (D)

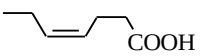
62. The structures of compounds **J** and **K**, respectively, are

(A) 

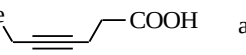
and $SOCl_2$

(B) 

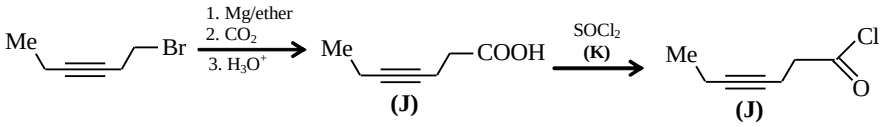
and SO_2Cl_2

(C) 

and $SOCl_2$

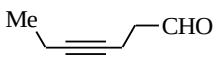
(D) 

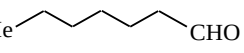
and CH_3SO_2Cl

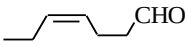
Sol.: 

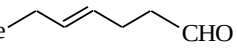
Correct choice: (A)

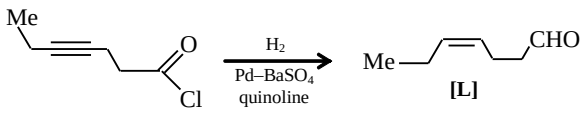
63. The structure of product **L** is

(A) 

(B) 

(C) 

(D) 

Sol.: 

Correct choice: (C)

Paragraph for Question Nos. 64 to 66

There are some deposits of nitrates and phosphates in earth's crust. Nitrates are more soluble in water. Nitrates are difficult to reduce under the laboratory conditions but microbes do it easily. Ammonia forms large number of complexes with transition metal ions. Hybridization easily explains the ease of sigma donation capability of NH_3 and PH_3. Phosphine is a flammable gas and is prepared from white phosphorus.

64. Among the following, the correct statement is

(A) Phosphates have no biological significance in humans.

(B) Between nitrates and phosphates, phosphates are less abundant in earth's crust.

(C) Between nitrates and phosphates, nitrates are less abundant in earth's crust.

(D) Oxidation of nitrates in possible in soil.

Sol.: Nitrates are less abundant than phosphates in earth's crust as they are soluble in water. Moreover, they can also be reduced by numerous microbes present in the earth's crust.

Correct choice: (C)

65. Among the following, the correct statement is

(A) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional.

(B) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional.

(C) Between NH_3 and PH_3, NH_3 is a better electron donor because the lone pair of electrons occupies sp^3 orbital and is more directional.

(D) Between NH_3 and PH_3, PH_3 is a better electron donor because the lone pair of electrons occupies spherical 's' orbital and is less directional.

Sol.: NH_3 is a better electron donor than PH_3 because the lone pair of electrons on N–atom occupies sp^3 orbital and is more directional due to smaller size of N–atom.

Correct choice: (C)

66. White phosphorus on reaction with NaOH gives PH_3 as one of the products. This is a

(A) dimerization reaction. (B) disproportionation reaction.

(C) condensation reaction. (D) precipitation reaction.

Sol.: $\overset{0}{P_4} + 3NaOH + 3H_2O \longrightarrow 3NaH_2\overset{+1}{P}O_2 + \overset{-3}{P}H_3$

This is an example of disproportionation reaction.

Correct choice: (B)

Paragraph for Question Nos. 67 to 69

Properties such as boiling point, freezing point and vapour pressure of a pure solvent change when solute molecules are added to get homogeneous solution. These are called colligative properties. Applications of colligative properties are very useful in day–to–day life. One of its examples is the use of ethylene glycol and water mixture as anti–freezing liquid in the radiator of automobiles.

A solution **M** is prepared by mixing ethanol and water. The mole fraction of ethanol in the mixture is 0.9.

Given: Freezing point depression constant of water $(K_f^{water}) = 1.86$ K kg mol^{-1}

Freezing point depression constant of ethanol $(K_f^{ethanol}) = 2.0$ K kg mol^{-1}

Boiling point elevation constant of water $(K_b^{water}) = 0.52$ K kg mol^{-1}

Boiling point elevation constant of ethanol $(K_b^{ethanol}) = 1.2$ K kg mol^{-1}

Standard freezing point of water = 273 K

Standard freezing point of ethanol = 155.7 K

Standard boiling point of water = 373 K

Standard boiling point of ethanol = 351.5 K

Vapour pressure of pure water = 32.8 mm Hg

Vapour pressure of pure ethanol = 40 mm Hg

Molecular weight of water = 18 g mol^{-1}

Molecular weight of ethanol = 46 g mol^{-1}

In answering the following questions, consider the solutions to be ideal dilute solutions and solutes to be non–volatile and non–dissociative.

67. The freezing point of the solution **M** is

(A) 268.7 K (B) 268.5 K

(C) 234.2 K (D) 150.9 K

Sol.: As the mole fraction of ethanol in the mixture is 0.9. So ethanol is the solvent and water is solute. The freezing point of the solution assuming water to be the non–volatile solute should be less than the freezing point of the pure solvent (ethanol). Hence, freezing point of solution should be less than 155.7 K. $\therefore$ (D) is the obvious choice.

Correct choice: (D)

68. The vapour pressure of the solution **M** is

(A) 39.3 mm Hg (B) 36.0 mm Hg

(C) 29.5 mm Hg (D) 28.8 mm Hg

Sol.: Vapour pressure of solution = $P^{o}_{solvent}\ X_{solvent}$ (It is given that solute is to be treated as non-volatile and non-dissociative)

$= 40 \times 0.9$

$=$ **36.0 mm Hg**.

Correct choice: (B)

69. Water is added to the solution **M** such that the mole fraction of water in the solution becomes 0.9. The boiling point of this solution is

(A) 380.4 K (B) 376.2 K

(C) 375.5 K (D) 354.7 K

Sol.: Mole fraction of water in solution = 0.9.

$\therefore$ Water becomes the solvent and ethanol is solute and has to be considered has non-volatile and non-dissociative.

Mole fraction of ethanol in solution = 0.1

Molality of ethanol in solution = $\frac{0.1}{0.9\times18}\times1000 = 6.17$

$\Delta T_b = K_b\ m = 0.52 \times 6.17 = 3.2$

$\therefore$ Boiling point of the solution = 373 + 3.2 = **376.2 K**.

Correct choice: (B)

Paper-I

Code → / Q. No. ↓	0	1	2	3	4	5	6	7	8	9
1	B	C	C	C	A	C	B	B	C	C
2	C	B	B	C	B	C	A	C	B	A
3	A	C	A	B	C	B	C	C	C	B
4	B	B	B	A	C	A	C	C	C	C
5	C	A	C	B	C	C	B	B	A	B
6	C	C	C	C	B	B	C	A	B	C
7	B, D	A, D	B, C	A,B,C, D	A,D	B, D	B,C	A,B, C,D	A,B,C, D	A, D
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12	D	A	B	A	A	A	A	A	A	D
13	A	B	A	D	B	A	D	A	A	B
14	B	A	D	A	D	B	B	D	B	A
15	D	B	B	D	B	B	D	B	D	B
16	A	A	C	A	A	C	A	A	A	C
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18	B	B	D	B	B	D	B	D	B	B
19	A	C	A	C	C	A	C	A	A	A
20	D	B,C,D	D	B,C,D	B,C,D	D	B,C,D	D	D	D
21	B	D	B	B	D	B	B	B	B	D
22	C	A	A	A	A	A	A	C	C	A
23	B, C, D	D	D	D	D	D	D	B,C, D	B,C,D	D

Paper-I

Code → / Q. No. ↓	0	1	2	3	4	5	6	7	8	9
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27	A	B	A	B	C	B	C	C	C	C
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38	D	C	B	D	C	B	D	C	D	B
39	B	C	B	B	C	B	B	C	B	B
40	B	A	C	B	A	C	B	A	B	C
41	C	B	D	B	B	D	B	D	C	C
42	C	B	B	B	B	B	B	B	C	C
43	A	C	B	C	C	B	C	B	A	A
44	B	D	C	C	D	C	C	B	B	D
45	B	B	C	C	B	C	C	B	B	B
46	C	B	A	A	B	A	A	C	C	B

Paper-I

Code → / Q. No. ↓	0	1	2	3	4	5	6	7	8	9
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60	D	B	C	B	C	D	D	C	D	A
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66	B	B	C	B	B	C	B	C	B	B
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