

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. If $2x^2 + (\cos\theta)x - 1 = 0$, $\theta \in [0, 2\pi]$ has roots α and β . Then the sum of maximum and minimum value of $\alpha^4 + \beta^4$.

- (1) $\frac{25}{16}$
(2) $\frac{9}{16}$
(3) $\frac{41}{16}$
(4) $\frac{8}{17}$

Answer (1)

Sol. $\alpha + \beta = \frac{-\cos\theta}{2}$

$$\alpha\beta = \frac{-1}{2} \Rightarrow \alpha^2\beta^2 = \frac{1}{4}$$

$$\Rightarrow \alpha^2 + \beta^2 = (\alpha + \beta)^2 - 2\alpha\beta$$

$$= \frac{\cos^2\theta + 1}{4}$$

$$\alpha^4 + \beta^4 = (\alpha^2 + \beta^2)^2 - 2\alpha^2\beta^2$$

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

For minimum, $\cos\theta = 0$

For maximum, $\cos\theta = 1$

$$\Rightarrow \text{Minimum} = 1 - \frac{1}{2} = \frac{1}{2}$$

$$\text{Maximum} = \frac{25}{16} - \frac{1}{2} = \frac{17}{16}$$

$$\Rightarrow \text{Sum} = \frac{1}{2} + \frac{17}{16} = \frac{25}{16}$$

2. If $\theta \in [0, 2\pi]$ satisfying the system of equations $2\sin^2\theta = \cos 2\theta$ and $2\cos^2\theta = 3\sin\theta$. Then the sum of all real values of θ is

- (1) $\frac{3\pi}{2}$ (2) π
(3) $\frac{\pi}{2}$ (4) $\frac{5\pi}{6}$

Answer (2)

Sol. $2\sin^2\theta = \cos 2\theta$

$$2\cos^2\theta = 3\sin\theta$$

$\Rightarrow$ Adding,

$$2 = 1 - 2\sin^2\theta + 3\sin\theta$$

$$\Rightarrow 2\sin^2\theta - 3\sin\theta + 1 = 0$$

$$2\sin^2\theta - 2\sin\theta - \sin\theta + 1 = 0$$

$$2\sin\theta(\sin\theta - 1) - 1(\sin\theta - 1) = 0$$

$$\sin\theta = 1, \frac{1}{2} \text{ but } 2\sin^2\theta = \cos 2\theta = 2$$

but not is not possible

$$\Rightarrow \theta = \frac{\pi}{6}, \left(\pi - \frac{\pi}{6} \right)$$

$$\Rightarrow \text{Sum of all values} = \frac{\pi}{6} + \pi - \frac{\pi}{6} = \pi$$

3. Let $A = \{1, 2, 3, 4\}$ and $B = \{1, 4, 9, 16\}$.

If $f : A \rightarrow B$, number of many-one functions from A to B are

- (1) 24 (2) 232
(3) 256 (4) 252

Answer (2)



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Sol. $n(A) = 4$

$n(B) = 4$

Number of many one functions =

Total functions – Number of one-one function
 $= 4^4 - 4! = 232$

4. 4 boys and 3 girls are to be seated in a row such that all girls seat together and two particular boys B_1 and B_2 are not adjacent to each other. Then the number of ways in which this arrangement can be done.

- (1) 432 (2) 430
 (3) 516 (4) 1002

Answer (1)

Sol. 4 boys and 3 girls.

All girls together $\Rightarrow G_1 G_2 G_3$

3 girls and 2 boys can be seated in $3! \cdot 3!$ ways

Now B_1 and B_2 go into spaces.

$$\Rightarrow {}^4C_2 \times 2! \times 3! \times 3! = 432$$

5. If the sum $\sum_{r=0}^{30} \frac{r^2 \binom{30}{r}}{\binom{30}{r-1}} = \alpha \cdot 2^{29}$, then α is equal

to

- (1) 225 (2) 465
 (3) 345 (4) 425

Answer (2)

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

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

$$= \frac{30(31-r)29!}{(r-1)!(30-r)!}$$

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

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

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

$$= 30 \cdot 29 \cdot 2^{28} + 30 \cdot 2^{29}$$

$$= 30 \cdot 2^{28} (29 + 2) = (31 \times 15) \cdot 2^{29}$$

6. Consider a function $f(x) = \int_0^{x^2} \frac{t^2 - 8t + 15}{e^t} dt$. The

number of points of extrema are

- (1) 3 (2) 5
 (3) 7 (4) 9

Answer (2)

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

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

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

The extremum value of $f(x)$ are $x = 0, \pm\sqrt{5}, \pm\sqrt{3}$

$\therefore$ Number of extremum points are 5.

7. Let A and B are two events such that $P(A \cap B) = \frac{1}{10}$ and $P(A/B)$ and $P(B/A)$ are the

roots of the equation $12x^2 - 7x + 1 = 0$, then

$\frac{P(\bar{A} \cup \bar{B})}{P(\bar{A} \cap \bar{B})}$ is equal to

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

Answer (2)

$$\text{Sol. } P(A \cap B) = \frac{1}{10}$$



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$$P(A/B) + P(B/A) = \frac{7}{12}$$

$$\text{and } P(A/B) \cdot P(B/A) = \frac{1}{12}$$

$$\frac{P(A \cup B)}{P(B)} \cdot \frac{P(A \cap B)}{P(A)} = \frac{1}{12}$$

$$\Rightarrow P(A) \cdot P(B) = 12 \left(\frac{1}{12} \right)^2 = \frac{12}{100}$$

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

$$P(A) + P(B) = \frac{7}{10}$$

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

$$= \frac{7}{10} - \frac{1}{10} = \frac{6}{10}$$

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

$$\frac{1 - \frac{1}{10}}{1 - \frac{6}{10}} = \frac{\frac{9}{10}}{\frac{4}{10}} = \frac{9}{4}$$

8. Number of terms in an arithmetic progression is $2n$. Sum of terms occurring at even places is 40 and sum of terms occurring at odd places is 55. If the first term exceeds the last term by 27, then n equals to

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

Answer (2)

Sol. Let the AP be

$$a, a + d, a + 2d, \dots, a + (2n - 1)d$$

Now given that

$$(a + d) + (a + 3d) + \dots + (a + (2n - 1)d) = 40$$

$$na + n^2d = 40 \quad \dots(1)$$

$$\text{Also } a + (a + 2d) + (a + 4d) + \dots + (a + (2n - 2)d) = 55$$

$$na + dn(n - 1) = 55 \quad \dots(2)$$

$$\text{Also } a - (a + (2n - 1)d) = 27$$

$$-(2n - 1)d = 27 \quad \dots(3)$$

$$d = \frac{-27}{2n - 1}$$

$$(2) - (1)$$

$$dn(n - 1) - n^2d = 15$$

$$d[n^2 - n - n^2] = 15$$

$$\left(\frac{-27}{2n - 1} \right) (-n) = 15$$

$$27n = 30n - 15$$

$$15 = 3n$$

$$n = 5$$

9. The perpendicular distance of point $P(3, 4, 5)$ from the line

$$\vec{r} = 2\hat{i} - \hat{j} + \hat{k} + \lambda(4\hat{i} - \hat{j} + 5\hat{k}) \text{ is}$$

- (1) $\sqrt{\frac{19}{42}}$ (2) $\sqrt{\frac{19}{21}}$
(3) $\sqrt{\frac{42}{19}}$ (4) $\sqrt{\frac{21}{19}}$

Answer (1)

Sol. $P(3, 4, 5)$

$$L: \vec{r} = \vec{r} = 2\hat{i} - \hat{j} + \hat{k} + \lambda(4\hat{i} - \hat{j} + 5\hat{k})$$

$$\text{Any point on } L \text{ can be. } A(2 + 4\lambda, -1 - \lambda, 1 + 5\lambda)$$

$$\text{Now } \overrightarrow{AP} \cdot (4\hat{i} - \hat{j} + 5\hat{k}) = 0$$

$$((4\lambda - 1)\hat{i} - (\lambda + 5)\hat{j} + (5\lambda - 4)\hat{k}) \cdot (4\hat{i} - \hat{j} + 5\hat{k}) = 0$$

$$16\lambda + 4 + \lambda + 5 + 25\lambda - 20 = 0$$

$$42\lambda = 19$$

$$\lambda = \frac{19}{42}$$

$$\text{Now } |AP| = \sqrt{(4\lambda - 1)^2 + (\lambda + 5)^2 + (5\lambda - 4)^2}$$

$$= \sqrt{\frac{19}{42}}$$



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10. In the expansion of $\left(x + \sqrt{x^3 - 1}\right)^5 + \left(x - \sqrt{x^3 - 1}\right)^5$, where α , β , γ and δ are the coefficient of x , x^3 , x^5 and x^7 respectively. If $\alpha u - \beta v = 18$, $\gamma u + \delta v = 20$ then $u + v$ equal to.

- (1) $\frac{-14}{15}$ (2) $\frac{-13}{15}$
 (3) $\frac{-3}{5}$ (4) $\frac{-2}{3}$

Answer (1)

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

$$\left[\int_0^3 (x)^5 + \int_1^5 x^4 \sqrt{x^3 - 1} + \int_2^5 x^3 (\sqrt{x^3 - 1})^2 + \dots \right] +$$

$$\left[\int_0^5 x^5 - \int_1^5 x^4 \sqrt{x^3 - 1} + \int_2^5 x^3 (\sqrt{x^3 - 1})^2 + \dots \right]$$

$$= 2 \left[x^5 + \int_2^5 x^3 (x^3 - 1) + \int_4^5 x (x^3 - 1)^2 \right]$$

$$= 2[x^5 + 10x^6 - 10x^3 + 5x(x^6 + 1 - 2x^3)]$$

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

Coefficient of $x = 10 = \alpha$
 Coefficient of $x^3 = -20 = \beta$
 Coefficient of $x^5 = 2 = \gamma$
 Coefficient of $x^7 = 10 = \delta$

$$10u + 20v = 18 \quad \dots(i)$$

$$2u + 10v = 20$$

$$u = \frac{-11}{3}$$

$$v = \frac{41}{15}$$

$$u + v = \frac{41}{15} - \frac{11}{3}$$

$$= \frac{-14}{15}$$

11. Let $A(6, 8)$, $B(10 \cos \alpha, -10 \sin \alpha)$ and $C(-10 \sin \alpha, -10 \cos \alpha)$ be 3 points and if orthocentre of the triangle ABC is $(0, 9)$ then $100 \sin^2 \alpha$ is equal to

- (1) $\frac{25}{4}$ (2) 25
 (3) $\frac{15}{4}$ (4) $\frac{5}{4}$

Answer (1)

Sol. Notice, origin is equidistance from A, B and C

$\Rightarrow (0, 0)$ is circumcentre



Since centroid divides orthocentre and circumcentre in 2 : 1 ratio.

$$\Rightarrow \frac{6 + 10 \cos \alpha + (-10 \sin \alpha)}{3} = \frac{2(0) + 1(0)}{3} = 0$$

$$\Rightarrow 15 \sin \alpha - 10 \cos \alpha = 6$$

Alos $\frac{8 - 10 \sin \alpha - 10 \cos \alpha}{3} = \frac{2(0) + 1(9)}{3} = 3$

$$\Rightarrow 8 - 10 \sin \alpha - 10 \cos \alpha = 9$$

$$10(\sin \alpha + \cos \alpha) = -1$$

$$10(\sin \alpha - \cos \alpha) = -6$$

$$20 \sin \alpha = 5$$

$$10 \sin \alpha = \frac{5}{2}$$

$$100 \sin^2 \alpha = \frac{25}{4}$$

12. If z be a complex number such that $|z - 3| \leq 1$, then the equation of line with largest slope passing through origin and z

- (1) $x - 2\sqrt{2}y = 0$ (2) $x + 2\sqrt{2}y = 0$
 (3) $2\sqrt{2}x + y = 0$ (4) $2\sqrt{2}x - y = 0$

Answer (1)



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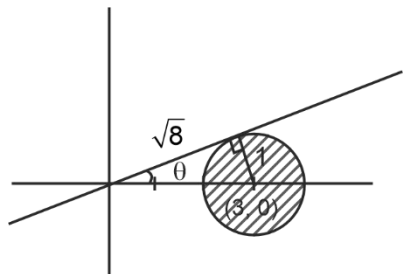


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Sol.



$$\tan \theta = \frac{1}{\sqrt{8}} = \frac{1}{2\sqrt{2}}$$

Therefore, equation of line with maximum slope is

$$(y - 0) = \frac{1}{2\sqrt{2}}(x - 0)$$

$$\Rightarrow y = \frac{x}{2\sqrt{2}}$$

13. A relation R is defined on set A , $A = \{1, 2, 3\}$ and $R = \{(1, 2), (2, 3)\}$. Elements are added such that R becomes reflexive and transitive but not symmetric. Find the number of such relations.

- (1) 3
(2) 4
(3) 2
(4) 9

Answer (1)

Sol. Transitivity

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

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

$$(2, 1) \quad (3, 2) \quad (3, 1)$$

(3, 1) cannot be taken.

- (2, 1) taken and (3, 2) not taken.
- (3, 2) taken and (2, 1) not taken.
- Both not taken.

Therefore 3 relations are possible.

14.
15.
16.
17.
18.

19.

20.

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 $\vec{a}$ and $\vec{b}$ be two unit vectors such that angle between $\vec{a}$ and $\vec{b}$ is $\frac{\pi}{3}$. If $\lambda\vec{a} + 3\vec{b}$ and $2\vec{a} + \lambda\vec{b}$ are perpendicular to each other, then the product of all possible values of λ is _____

Answer (6)

Sol. $|\vec{a}| = 1, |\vec{b}| = 1$

$$\vec{a} \cdot \vec{b} = |\vec{a}| |\vec{b}| \cos \frac{\pi}{3} = \frac{1}{2}$$

$\lambda\vec{a} + 3\vec{b}$ and $2\vec{a} + \lambda\vec{b}$ are perpendicular

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

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

$$\Rightarrow 5\lambda + (\lambda^2 + 6)\left(\frac{1}{2}\right) = 0$$

$$\Rightarrow 10\lambda + \lambda^2 + 6 = 0$$

$$\Rightarrow \lambda^2 + 10\lambda + 6 = 0$$

Product of possible values of $\lambda = 6$

22. If A is the 3×3 matrix of order 3×3 , such that $\det(A) = \frac{1}{2}$, $\text{tr}(A) = 10$ and B be another matrix of order 3×3 and defined as $B = \text{adj}(\text{adj}(2A))$, then $\det(B) + \text{tr}(B)$ is equal to (where $\text{tr}(A)$ denotes trace of matrix A)

Answer (336)

Sol. $B = \text{adj}(\text{adj}(2A))$

$$B = |2A|^{n-2} (2A), [\text{Using } \text{adj}(\text{adj } P) = |P|^{n-2} \cdot P],$$

for $n = 3$

$$= |2A|(2A)$$

$$= 2^3 |A|(2A)$$



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$$= 8 \times \frac{1}{2}(2A)$$

$$= 4(2A)$$

$$B = 8A$$

$$|B| = |8A|$$

$$= 8^3|A|$$

$$|B| = 8^3 \times \frac{1}{2} = 256$$

$$B = 8A$$

[each element is multiplied 8 times]

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

$$= 80$$

$$|B| + \text{tr}(B) = 256 + 80$$

$$= 336$$

23. Consider two curves $E_1: \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ with eccentricity e_1 and $E_2: \frac{x^2}{A^2} + \frac{y^2}{B^2} = 1$ with eccentricity e_2 . If $\frac{e_1}{e_2} = \frac{1}{3}$ and distance between foci of both curves is $2\sqrt{3}$ and $a - A = 4$, then the sum of lengths of latus rectum of both curves is

Answer (12)

Sol. Since, distance between foci

$$\text{for } E_1 = 2ae, \text{ for } E_2 = 2Ae_2$$

$$\Rightarrow 2ae_1 = 2\sqrt{3} = 2Ae_2$$

$$\Rightarrow ae_1 = Ae_2$$

$$\Rightarrow \frac{e_1}{e_2} = \frac{A}{a} = \frac{1}{3} \Rightarrow a = 3A$$

$$\text{Also } a - A = 4 \Rightarrow A = 2, a = 6$$

$$\text{Now, } 2(6)e_1 = 2\sqrt{3} \Rightarrow e_1 = \frac{\sqrt{3}}{6}$$

$$2(2)e_2 = 2\sqrt{3} \Rightarrow e_2 = \frac{\sqrt{3}}{2}$$

$$e_1^2 = \frac{1-b^2}{a^2} = \frac{3}{36} = \frac{1-b^2}{36} \Rightarrow \frac{b^2}{36} = \frac{33}{36}$$

$$b^2 = 33$$

$$e_2^2 = \frac{1-B^2}{A^2} = \frac{3}{4} = \frac{1-B^2}{4} \Rightarrow B^2 = 1$$

$$\text{Length of latus rectum of } E_1 = \frac{2b^2}{a}$$

$$\text{Length of latus rectum of } E_2 = \frac{2B^2}{A}$$

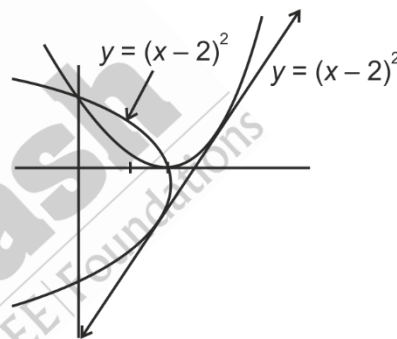
$\Rightarrow$ Sum of lengths of latus rectum

$$= \frac{2(33)}{6} + \frac{2(1)}{2} = 11 + 1 = 12$$

24. The number of maximum number of common tangents to the curves $y = (x-2)^2$ and $y^2 = 16 - 8x$ is

Answer (1)

Sol.



Clearly, one tangent is possible. Based on the graphs of these parabola.

25. Let $P(10, -2, -1)$ and Q be the point of perpendicular drawn from point $R(1, 7, 6)$ on the line joining the points $(2, -5, 11)$ and $(-6, 7, -5)$. Then the length PQ is

Answer (13)

$$\text{Sol. } L_1: \frac{x-2}{8} = \frac{y+5}{-12} = \frac{z-11}{16}$$

$$L_1: \frac{x-2}{2} = \frac{y+5}{-3} = \frac{z-11}{4}$$

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Avg point of L_1 be $A(2\lambda + 2, -3\lambda - 5, 4\lambda + 11)$

$R(1, 7, 6)$

$$RA \cdot (2\hat{i} - 3\hat{j} + 4\hat{k}) = 0$$

$$((2\lambda + 1)\hat{i} + (-3\lambda - 12)\hat{j} + (4\lambda + 5)\hat{k}) \cdot (2\hat{i} - 3\hat{j} + 4\hat{k}) = 0$$

$$4\lambda + 2 + 9\lambda + 36 + 16\lambda + 20 = 0$$

$$29\lambda = -58$$

$$\lambda = -2$$

$\therefore$ Foot of perpendicular = $(-2, 1, 3)Q$

$$PQ = \sqrt{(10+2)^2 + (1+2)^2 + (3+1)^2}$$

$$= \sqrt{144 + 9 + 16}$$

$$= 13$$



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