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JEE

(Main)

PAPER-1 (B.E./B. TECH.)

2021

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COMPUTER BASED TEST (CBT)

Memory Based Questions & Solutions

Date: 26 August, 2021 (SHIFT-2) | TIME : (3.00 p.m. to 6.00 p.m)

Duration: 3 Hours | Max. Marks: 300

SUBJECT: MATHEMATICS

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Resonance | JEE MAIN-2021 | DATE : 26-08-2021 (SHIFT-2) | PAPER-2 | MEMORY BASED | MATHEMATICS

1. If matrix $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$, then the value of $A^{2025} - A^{2020}$ is:

Ans. (1)

Sol. $A = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$

$$A^2 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

$$A^3 = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 2 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

$$A^4 = \begin{bmatrix} 1 & 0 & 0 \\ 3 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

$$A^n = \begin{bmatrix} 1 & 0 & 0 \\ n-1 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

$$A^{2025} - A^{2020} = \begin{bmatrix} 1 & 0 & 0 \\ 2024 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} - \begin{bmatrix} 1 & 0 & 0 \\ 2019 & 1 & 1 \\ 1 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 5 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

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2. The value of $2 \sin\left(\frac{\pi}{8}\right) \sin\left(\frac{2\pi}{8}\right) \sin\left(\frac{3\pi}{8}\right) \dots \sin\left(\frac{7\pi}{8}\right)$ is:

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

Ans. (2)

Sol. $\Rightarrow 2 \sin\left(\frac{\pi}{8}\right) \sin\left(\frac{2\pi}{8}\right) \sin\left(\frac{3\pi}{8}\right) \dots \sin\left(\frac{7\pi}{8}\right)$

$$\Rightarrow 2 \sin\left(\frac{\pi}{8}\right) \sin\left(\frac{2\pi}{8}\right) \sin\left(\frac{3\pi}{8}\right) \dots \sin\left(\pi - \frac{2\pi}{8}\right) \sin\left(\pi - \frac{\pi}{8}\right)$$

$$\Rightarrow 2 \sin^2 \frac{\pi}{8} \sin^2\left(\frac{2\pi}{8}\right) \sin^2\left(\frac{3\pi}{8}\right) \sin^2\left(\frac{\pi}{2}\right)$$

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$$\Rightarrow \sin^2 \frac{\pi}{8} \sin^2\left(\frac{\pi}{2} - \frac{\pi}{8}\right)$$

$$\Rightarrow \sin^2 \frac{\pi}{8} \cos^2 \frac{\pi}{8}$$

$$\Rightarrow \sin^+ \frac{\pi}{8} - \cos^+ \frac{\pi}{8} = \frac{\sin^+ \pi}{4} = \frac{\pi}{4}$$

3. Evaluate $\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1 + \sin^2 x}{1 + \sin x} dx$

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

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

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

(4) $\frac{5\pi}{2}$

Ans. (2)

Sol. $I = \int_a^b f(x) dx$

$$f(a+b-x) = f(x)$$

$$I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1 + \sin^2 x}{1 + \sin x} dx \dots (i)$$

$$I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{1 + \sin^2 x}{1 + \sin x} dx \dots (ii)$$

Add equation (i) and (ii)

$$2I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} (1 + \sin^2 x) dx$$

$$2I = \pi + \frac{1}{2} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} (1 - \cos 2x) dx$$

$$2I = \pi + \frac{1}{2} \left[x - \frac{\sin 2x}{2} \right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$2I = \pi + \frac{1}{2} \pi = \frac{3\pi}{2}$$

$$\Rightarrow I = \frac{3\pi}{4}$$

4. The locus of mid-point of chord of the hyperbola $x^2 - y^2 = 4$ which touches $y^2 = 8x$ is :

(1) $x^3 + 2y^2 - y^2x = 0$

(2) $x^3 + 2y^2 + y^2x = 0$

(3) $x^3 - 2y^2 - y^2x = 0$

(4) $x^3 + 3y^2 - y^2x = 0$

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Sol. Tangent to $y^2 = 8x$ is $y = mx + \frac{4}{m}$

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$y = \frac{xh}{k} + \frac{k^2 - h^2}{k}$ is the equation of chord with mid-point (h, k)

Comparing the above equations we get,

$$m = \frac{h}{k} \text{ and } \frac{2}{m} = \frac{k^2 - h^2}{k}$$

$$2k^2 = k^2 - h^2$$

∴ Equation of locus is $x^3 + 2y^2 - y^2x = 0$

5. $\sum_{r=1}^{50} \tan^{-1} \left(\frac{1}{2r^2} \right) = P$, then $\tan P$ is

(1) $\frac{50}{51}$

(2) $\frac{100}{101}$

(3) $\frac{101}{100}$

(4) $\frac{51}{50}$

Ans. (1)

Sol. $\tan^{-1} \left(\frac{1}{2r^2} \right) = \tan^{-1} \left(\frac{2}{4r^2} \right)$

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

$$= \tan^{-1} \left(\frac{2}{1 + (2r-1)(2r+1)} \right)$$

$$= \tan^{-1} \left(\frac{(2r+1) - (2r-1)}{1 + (2r+1)(2r-1)} \right)$$

$$= \tan^{-1} (2r+1) - \tan^{-1} (2r-1)$$

$$\text{So, } \sum_{r=1}^{50} \tan^{-1} \left(\frac{1}{2r^2} \right) = \tan^{-1} (3) - \tan^{-1} (1)$$

$$+ \tan^{-1} (5) - \tan^{-1} (3)$$

$$+ \tan^{-1} (7) - \tan^{-1} (5)$$

$$+ \tan^{-1} (101) - \tan^{-1} (99)$$

$$= \tan^{-1} (101) - \tan^{-1} (1)$$

$$= \tan^{-1} \left(\frac{101-1}{1+101} \right)$$

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$$= \tan^{-1} \left(\frac{100}{102} \right) = P$$

$$\text{So, } \tan P = \frac{100}{102} = \frac{50}{51}$$

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6. If α, β are the roots of $x^2 - x + 2\lambda = 0$ and α, γ are the roots of $3x^2 - 4x + 27\lambda = 0$ then the value of $\frac{\beta\gamma}{\lambda}$ is

- (1) $\frac{18}{17}$ (2) $\frac{18}{19}$ (3) 1 (4) $\frac{17}{16}$

Ans. (2)
Sol. $\alpha + \beta = 1$ (i)

$$(ii) / (iv) \Rightarrow \frac{\beta}{\gamma} = \frac{2}{9} \text{(vi)}$$

$$\alpha, \beta = 2\lambda \text{(ii)}$$

$$\text{From (v) \& (vi)}$$

$$\alpha + \gamma = \frac{4}{3} \text{(iii)}$$

$$\beta = \frac{2}{21} \text{ \& } \gamma = \frac{3}{7}$$

$$\alpha, \gamma = 9\lambda \text{(iv)}$$

$$\text{From (i) \& (ii)}$$

$$\alpha = \frac{19}{21}, \lambda = \frac{19}{441}$$

$$(iii) - (i)$$

$$\frac{\beta\gamma}{\lambda} = \frac{18}{19}$$

$$\Rightarrow \gamma - \beta = \frac{1}{3} \text{ (v)}$$

7. If $2x^2 dy + (e^x - 2x) dx = 0$ & $y(e) = 1$

Ans. (1)

$$\text{Sol. } \frac{dy}{dx} = \frac{-e^x + 1}{2x^2 + x}$$

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

$$\text{Let } e^{-x} = t \text{(1)}$$

$$e^{-x} (-1) \frac{dy}{dx} = \frac{dt}{dx}$$

$$\frac{dt}{dx} + \frac{t}{x} = \frac{1}{2x^2}$$

$$\text{I.F.} = e^{\int \frac{1}{x} dx} = e^{\ln x} = x$$

$$tx = \int \frac{1}{2x^2} \cdot x dx + C$$

$$\text{Using equation (1)}$$

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

$$e^{-1} e = \frac{1}{2} + C \Rightarrow C = \frac{1}{2}$$

$$e^{-x} x = \frac{1}{2} (1 + \ln x)$$

$$\text{Put } x = 1 \text{ then } v \text{ is } \Rightarrow v = \frac{1}{2}$$

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8. The circle (C) touches the line $2y = x$ at point (2,1) and it intersect the circle $C_1 (x^2 + y^2 + 2y - 5 = 0)$ at P & Q. If PQ is diameter of C_1 , then calculate square of diameter of circle (C)

Ans. 245

Sol. Family of circle touching line $2y = x$ at point (2,1)

$$(x-2)^2 + (y-1)^2 + \lambda(x-2y) = 0 \text{(1)}$$

common chord PQ is

$$(x-2)^2 + (y-1)^2 + \lambda(x-2y) - x^2 - y^2 - 2y + 5 = 0$$

$$(\text{diameter of } C_1 \text{ passes through } (0,-1))$$

$$4 + 4 + 2\lambda - 1 + 2 + 5 = 0$$

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$$x^2 + y^2 - 11x + 12y + 5 = 0$$

$$r = \sqrt{\frac{121}{4} + 36 - 5} = \sqrt{\frac{121+144}{4}} = \sqrt{\frac{265}{4}}$$

$$4r^2 = 265$$

9. If A dice is rolled till 6 comes, then the probability of $P\left(\frac{x \geq 5}{x > 2}\right)$ is

- (1) $\frac{1}{6}$ (2) $\frac{24}{36}$ (3) $\frac{25}{36}$ (4) $\frac{18}{36}$

Ans. (3)

Sol. $P\left(\frac{x \geq 5}{x > 2}\right) = \frac{P(x \geq 5 \cap x > 2)}{P(x > 2)}$

$$= \frac{P(x=5) + P(x=6) + P(x=7) + \dots}{P(x=3) + P(x=4) + P(x=5) + \dots}$$

$$= \frac{\left(\frac{5}{6}\right)^4 \cdot \frac{1}{6} + \left(\frac{5}{6}\right)^5 \cdot \frac{1}{6} + \dots}{\left(\frac{5}{6}\right)^2 \cdot \frac{1}{6} + \left(\frac{5}{6}\right)^3 \cdot \frac{1}{6} + \dots}$$

$$= \frac{\left(\frac{5}{6}\right)^4 \cdot \frac{1}{6}}{1 - \frac{5}{6}} = \frac{\left(\frac{5}{6}\right)^4}{\left(\frac{1}{6}\right)} = 25$$

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10. The mean and variance of the 4 observations 3, 7, x, y (where $x > y$) is 5 and 10 respectively. The mean of the observations $4 + x + y$, $7 + x$, $x + y$, $x - y$ will be :
- (1) 10 (2) 12 (3) 8 (4) 14

Ans. (2)

Sol. $\frac{3+7+x+y}{4} = 5$

$$\Rightarrow x + y = 10 \quad \dots\dots\dots(1)$$

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$$10 = \frac{9+49+x^2+y^2}{4} - 25$$

$$\Rightarrow x^2 + y^2 = 82 \quad \dots\dots\dots(2)$$

from (1) and (2) $\Rightarrow x = 9, y = 1$

$$\therefore \text{mean} = \frac{4+x+y+7+x+x+y+x-y}{4}$$

$$= \frac{11+4x+y}{4} = \frac{11+36+1}{4} = 12$$

11. Let the plane P passes through the point (1, 2, 3) and it contains the line of intersection of $r(\hat{i} + \hat{j} + 4\hat{k}) = 16$ and $r(-\hat{i} + \hat{j} + \hat{k}) = 6$. Then which of the following point does not lie on P ?

- (1) (-8, 8, 6) (2) (-4, 3, 5) (3) (8, -5, 1) (4) (-8, 8, 5)

Ans. (4)

Sol. Equation of the plane

$$(x + y + 4z - 16) + \lambda(-x + y + z - 6) = 0$$

it passes through the point (1, 2, 3)

$$(1 + 2 + 12 - 16) + \lambda(-1 + 2 + 3 - 6) = 0$$

$$\Rightarrow -1 - 2\lambda = 0 \Rightarrow \lambda = -\frac{1}{2}$$

$$\text{Plane P : } (1 - \lambda)x + (1 + \lambda)y + (4 + \lambda)z = 16 + 6\lambda$$

$$\Rightarrow \frac{3}{2}x + \frac{1}{2}y + \frac{7}{2}z = 13$$

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12. If $f(x) = \left(\frac{2}{x}\right)^{x^2}$ then the maximum value of $f(x)$ is

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

Ans. (2)

Sol. $f'(x) = 0$ for maximum value

Let $y = \left(\frac{2}{x}\right)^{x^2}$

$$\ln y = x^2 \ln \frac{2}{x}$$

$$\frac{1}{y} y' = 2x \ln \frac{2}{x} + x^2 \cdot \frac{1}{\frac{2}{x}} \times \frac{-2}{x^2}$$

$$y' = (y) x \left(2 \ln \frac{2}{x} - 1\right)$$

$$y' = \left(\frac{2}{x}\right)^{x^2} x \left(2 \ln \frac{2}{x} - 1\right)$$

$$2 \ln \frac{2}{x} = 1$$

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$$\left(\frac{2}{x}\right) = e^{\frac{1}{2}}$$

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

Then maximum value will be

$$f\left(2 e^{-\frac{1}{2}}\right) = \left(\frac{2}{2 e^{-\frac{1}{2}}}\right)^{4 e^{-1}} = e^{2 e^{-1}}$$

13. Let $a_1, a_2, a_3, \dots, a_{10}$ in A.P. common difference -3 and $b_1, b_2, b_3, \dots, b_{10}$ are in G.P. with common ratio

Ans. (2021)

Sol. $C_k = a_k + b_k$

where $a_k = a_1 + (k-1)(-3)$

and $b_k = b_1 \cdot 2^{k-1}$

$$C_k = a_1 + (k-1)(-3) + b_1 \cdot 2^{k-1}$$

$$\sum_{k=1}^{10} C_k = \sum_{k=1}^{10} a_k + \sum_{k=1}^{10} b_k$$

$$C_2 = a_1 - 3 + b_1(2) = 12$$

$$C_3 = a_1 - 6 + 4b_1 = 13$$

by solving

$$2b_1 - 3 = 1 \Rightarrow b_1 = 2 \text{ and } a_1 = 11$$

$$\sum_{k=1}^{10} C_k = \frac{10}{2} (22 + 9(-3)) + 2(2^{10} - 1)$$

$$= -25 + 2046 = 2021$$

14. If $(\sqrt{3} + i)^{100} = 2^{99} (p + iq)$ then p & q are the roots of the equation

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

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

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

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

Ans. (4)

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$$2^{100} \left(\cos \frac{50\pi}{6} + i \sin \frac{50\pi}{6} \right) = 2^{99} (p + iq)$$

$$2^{100} e^{i \frac{50\pi}{3}} = 2^{99} (p + iq)$$

$$2 \left(\cos \frac{50\pi}{3} + i \sin \frac{50\pi}{3} \right) = p + iq$$

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$$2 \left(\frac{-1}{2} + i \frac{\sqrt{3}}{2} \right) = p + iq$$

$$p = -1, q = \sqrt{3}$$

p and q Roots of the equation

$$x^2 - (\sqrt{3} - 1)x - \sqrt{3} = 0$$

15. If the function $f(x) = 2x^3 - 6x^2 - 18x$ has local maxima at $x = a$ and local minima at $x = b$ and the area bounded by $y = f(x)$ from $x = a$ to $x = b$ is A . Then the value of $4A$ is :

Ans. 404

Sol. $f'(x) = 6x^2 - 12x - 18$

$$= 6(x^2 - 2x - 3)$$

$$= 6(x - 3)(x + 1)$$

$$\begin{array}{c} + \quad - \quad - \quad + \\ -1 \quad \quad \quad 3 \end{array}$$

$$a = -1, b = 3$$

$$\left[\frac{x^4}{2} - 2x^3 - 9x^2 \right]_{-1}^3 + \left[\frac{x^4}{2} - 2x^3 - 9x^2 \right]_0^{-1}$$

$$A = \int_{-1}^0 (2x^3 - 6x^2 - 18x) dx + \int_0^3 (2x^3 - 6x^2 - 18x) dx$$

$$= 0 - \left(\frac{1}{2} + 2 - 9 \right) + \left(\frac{81}{2} - 54 - 81 \right)$$

$$\Rightarrow A = 101 \Rightarrow 4A = 404 \text{ sq. unit}$$

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16. Minimum value of 'n' for which $\frac{(2i)^n}{(1-i)^{n-2}}$ is positive integer

Ans. (16)

Sol. $\frac{(2i)^n}{(-2i)^{n-2}} = \frac{(2i)^{\frac{n+2}{2}}}{(-1)^{\frac{n-2}{2}}}$ is positive integer

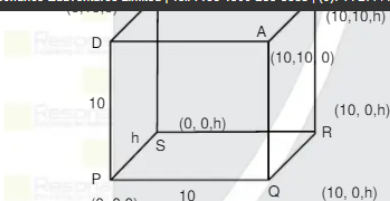
Clearly n must be even n = 2, 4 rejected

So for n = 6 $\Rightarrow (2i)^4 = 16$

17. Angle between two body diagonals PB & CQ of a cuboid is $\cos^{-1}\left(\frac{1}{5}\right)$ and length and breadth are equal in length, which is 10. Find height of cuboid :

(1) $5\sqrt{2}$ (2) 50 (3) 25 (4) $5\sqrt{5}$

Ans. (1)



Sol.

$$\vec{QC} = -10\hat{i} + 10\hat{j} + h\hat{k}$$

$$\vec{PB} = 10\hat{i} + 10\hat{j} + h\hat{k}$$

$$\cos\theta = \frac{-100 + 00 + h^2}{(\sqrt{200 + h^2})^2}$$

$$\frac{1}{5} = \frac{h^2}{200 + h^2}$$

$$200 = 4h^2$$

$$h^2 = 50$$

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

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