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JEE
(Advanced)

PAPER-2

2021

COMPUTER BASED TEST (CBT)
Questions

Date: 03 October, 2021

(Paper 1 - 9:00 am – 12:00 pm | Paper 2 – 2:30 pm to 5:30 pm)

Duration : 3 Hrs. | Total Marks : 180






SUBJECT: MATHEMATICS

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SECTION 1

- This section contains **SIX (06)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:
 - Full Marks* : +4 If only (all) the correct option(s) is(are) chosen;
 - Partial Marks* : +3 If all the four options are correct but ONLY three options are chosen;
 - Partial Marks* : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;
 - Partial Marks* : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;
 - Zero Marks* : 0 If unanswered;
 - Negative Marks* : -2 In all other cases.
- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to correct answers, then
 - choosing ONLY (A), (B) and (D) will get +4 marks;
 - choosing ONLY (A) and (B) will get +2 marks;
 - choosing ONLY (A) and (D) will get +2 marks;
 - choosing ONLY (B) and (D) will get +2 marks;
 - choosing ONLY (A) will get +1 mark;
 - choosing ONLY (B) will get +1 mark;
 - choosing ONLY (D) will get +1 mark;
 - choosing no option(s) (i.e. the question is unanswered) will get 0 marks and
 - choosing any other option(s) will get -2 marks.

Q.1 Let

$$S_1 = \{(i, j, k) : i, j, k \in \{1, 2, \dots, 10\}\},$$

$$S_2 = \{(i, j) : 1 \leq i < j + 2 \leq 10, i, j \in \{1, 2, \dots, 10\}\},$$

$$S_3 = \{(i, j, k, l) : 1 \leq i < j < k < l, i, j, k, l \in \{1, 2, \dots, 10\}\}$$

and

$$S_4 = \{(i, j, k, l) : i, j, k \text{ and } l \text{ are distinct elements in } \{1, 2, \dots, 10\}\}.$$

If the total number of elements in the set S_r is n_r , $r = 1, 2, 3, 4$, then which of the following statements is (are) **TRUE** ?

- (A) $n_1 = 1000$ (B) $n_2 = 44$ (C) $n_3 = 220$ (D) $\frac{n_4}{12} = 420$

Q.2 Consider a triangle PQR having sides of lengths p, q and r opposite to the angles P, Q and R , respectively. Then which of the following statements is (are) **TRUE** ?

(A) $\cos P \geq 1 - \frac{p^2}{2qr}$

(B) $\cos R \geq \left(\frac{q-r}{p+q}\right) \cos P + \left(\frac{p-r}{p+q}\right) \cos Q$

(C) $\frac{q+r}{p} < 2 \sqrt{\frac{\sin Q \sin R}{\sin P}}$

(D) If $p < q$ and $p < r$, then $\cos Q > \frac{p}{r}$ and $\cos R > \frac{p}{q}$

Q.3 Let $f: \left[-\frac{\pi}{2}, \frac{\pi}{2}\right] \rightarrow \mathbb{R}$ be a continuous function such that

$$f(0) = 1 \text{ and } \int_0^{\frac{\pi}{3}} f(t) dt = 0$$

Then which of the following statements is (are) **TRUE** ?

(A) The equation $f(x) - 3 \cos 3x = 0$ has at least one solution in $\left(0, \frac{\pi}{3}\right)$

(B) The equation $f(x) - 3 \sin 3x = -\frac{6}{\pi}$ has at least one solution in $\left(0, \frac{\pi}{3}\right)$

(C) $\lim_{x \rightarrow 0} \frac{x \int_0^x f(t) dt}{1 - e^{x^2}} = -1$

(D) $\lim_{x \rightarrow 0} \frac{\sin x \int_0^x f(t) dt}{x^2} = -1$

- Q.4 For any real numbers α and β , let $y_{\alpha,\beta}(x)$, $x \in \mathbb{R}$, be the solution of the differential equation

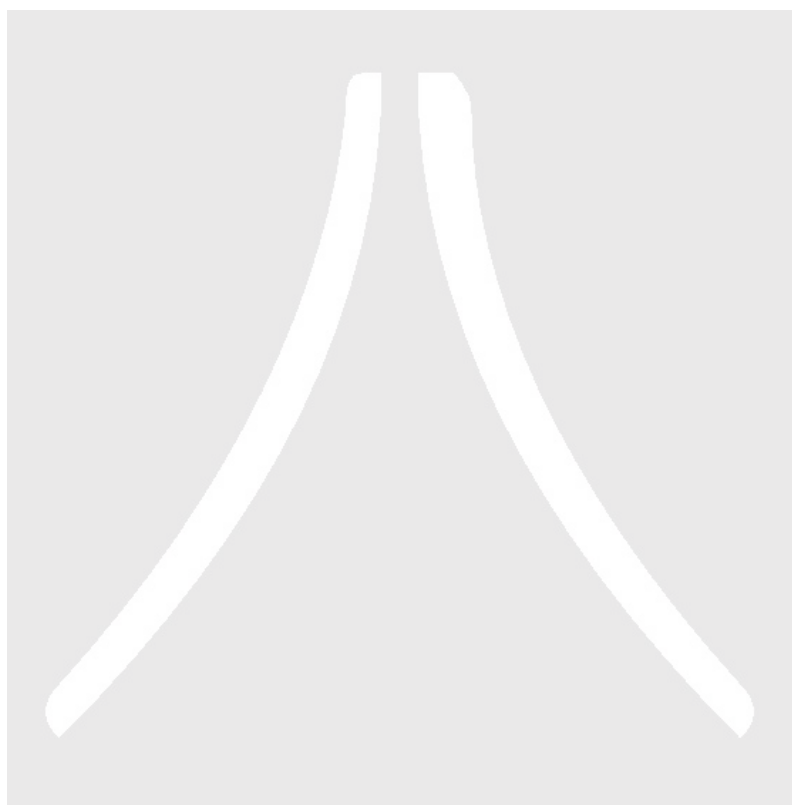
$$\frac{dy}{dx} + \alpha y = x e^{\beta x}, \quad y(1) = 1.$$

Let $S = \{y_{\alpha,\beta}(x) : \alpha, \beta \in \mathbb{R}\}$. Then which of the following functions belong(s) to the set S ?

- (A) $f(x) = \frac{x^2}{2} e^{-x} + \left(e - \frac{1}{2}\right) e^{-x}$
- (B) $f(x) = -\frac{x^2}{2} e^{-x} + \left(e + \frac{1}{2}\right) e^{-x}$
- (C) $f(x) = \frac{e^x}{2} \left(x - \frac{1}{2}\right) + \left(e - \frac{e^2}{4}\right) e^{-x}$
- (D) $f(x) = \frac{e^x}{2} \left(\frac{1}{2} - x\right) + \left(e + \frac{e^2}{4}\right) e^{-x}$
- Q.5 Let O be the origin and $\vec{OA} = 2\hat{i} + 2\hat{j} + \hat{k}$, $\vec{OB} = \hat{i} - 2\hat{j} + 2\hat{k}$ and $\vec{OC} = \frac{1}{2}(\vec{OB} - \lambda \vec{OA})$ for some $\lambda > 0$. If $|\vec{OB} \times \vec{OC}| = \frac{9}{2}$, then which of the following statements is (are) **TRUE**?
- (A) Projection of \vec{OC} on \vec{OA} is $-\frac{3}{2}$
- (B) Area of the triangle OAB is $\frac{9}{2}$
- (C) Area of the triangle ABC is $\frac{9}{2}$
- (D) The acute angle between the diagonals of the parallelogram with adjacent sides \vec{OA} and \vec{OC} is $\frac{\pi}{3}$

Q.6 Let E denote the parabola $y^2 = 8x$. Let $P = (-2, 4)$, and let Q and Q' be two distinct points on E such that the lines PQ and PQ' are tangents to E . Let F be the focus of E . Then which of the following statements is (are) **TRUE** ?

- (A) The triangle PFQ is a right-angled triangle
- (B) The triangle QPQ' is a right-angled triangle
- (C) The distance between P and F is $5\sqrt{2}$
- (D) F lies on the line joining Q and Q'



SECTION 2

- This section contains **THREE (03)** question stems.
- There are **TWO (02)** questions corresponding to each question stem.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value corresponding to the answer in the designated place using the mouse and the on-screen virtual numeric keypad.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:
Full Marks : +2 If **ONLY** the correct numerical value is entered at the designated place;
Zero Marks : 0 In all other cases.

Question Stem for Question Nos. 7 and 8**Question Stem**

Consider the region $R = \{(x, y) \in \mathbb{R} \times \mathbb{R} : x \geq 0 \text{ and } y^2 \leq 4 - x\}$. Let \mathcal{F} be the family of all circles that are contained in R and have centers on the x -axis. Let C be the circle that has largest radius among the circles in \mathcal{F} . Let (α, β) be a point where the circle C meets the curve $y^2 = 4 - x$.

Q.7 The radius of the circle C is ____ .

Q.8 The value of α is ____ .

Question Stem for Question Nos. 9 and 10

Question Stem

Let $f_1: (0, \infty) \rightarrow \mathbb{R}$ and $f_2: (0, \infty) \rightarrow \mathbb{R}$ be defined by

$$f_1(x) = \int_0^x \prod_{j=1}^{21} (t-j)^j dt, \quad x > 0$$

and

$$f_2(x) = 98(x-1)^{50} - 600(x-1)^{49} + 2450, \quad x > 0,$$

where, for any positive integer n and real numbers a_1, a_2, \dots, a_n , $\prod_{i=1}^n a_i$ denotes the product of a_1, a_2, \dots, a_n . Let m_i and n_i , respectively, denote the number of points of local minima and the number of points of local maxima of function f_i , $i = 1, 2$, in the interval $(0, \infty)$.

Q.9 The value of $2m_1 + 3n_1 + m_1n_1$ is ____.

Q.10 The value of $6m_2 + 4n_2 + 8m_2n_2$ is ____.

Question Stem for Question Nos. 11 and 12

Question Stem

Let $g_i: \left[\frac{\pi}{8}, \frac{3\pi}{8}\right] \rightarrow \mathbb{R}$, $i = 1, 2$, and $f: \left[\frac{\pi}{8}, \frac{3\pi}{8}\right] \rightarrow \mathbb{R}$ be functions such that

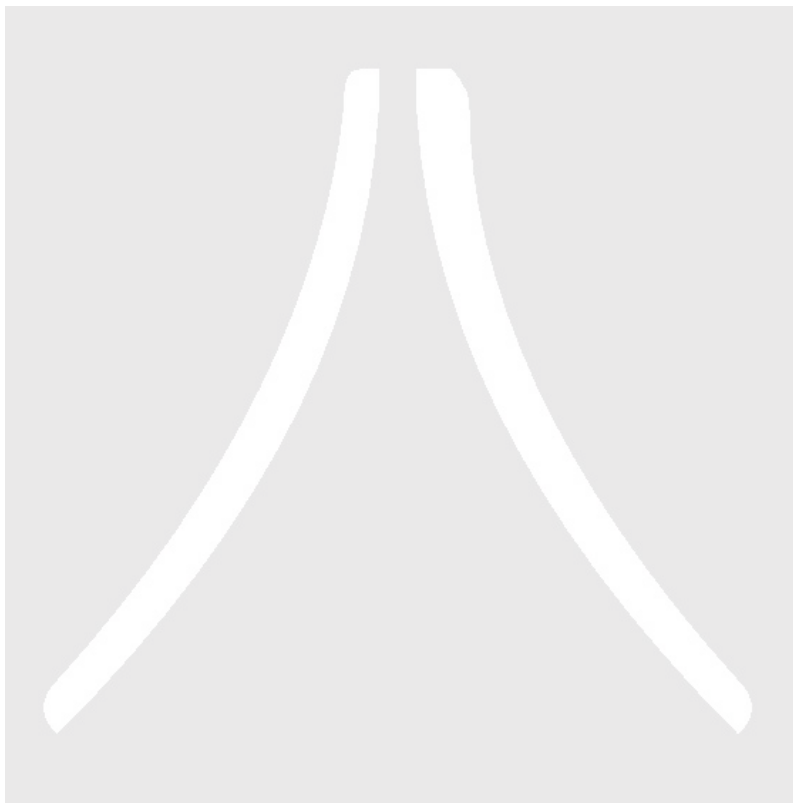
$$g_1(x) = 1, g_2(x) = |4x - \pi| \text{ and } f(x) = \sin^2 x, \text{ for all } x \in \left[\frac{\pi}{8}, \frac{3\pi}{8}\right]$$

Define

$$S_i = \int_{\frac{\pi}{8}}^{\frac{3\pi}{8}} f(x) \cdot g_i(x) dx, \quad i = 1, 2$$

Q.11 The value of $\frac{16S_1}{\pi}$ is ____.

Q.12 The value of $\frac{48S_2}{\pi^2}$ is ____.



SECTION 3

- This section contains **TWO (02) paragraphs**. Based on each paragraph, there are **TWO (02)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:
Full Marks : +3 If **ONLY** the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : -1 In all other cases.

Paragraph

Let

$$M = \{(x, y) \in \mathbb{R} \times \mathbb{R} : x^2 + y^2 \leq r^2\},$$

where $r > 0$. Consider the geometric progression $a_n = \frac{1}{2^{n-1}}$, $n = 1, 2, 3, \dots$. Let $S_0 = 0$ and, for $n \geq 1$, let S_n denote the sum of the first n terms of this progression. For $n \geq 1$, let C_n denote the circle with center $(S_{n-1}, 0)$ and radius a_n , and D_n denote the circle with center (S_{n-1}, S_{n-1}) and radius a_n .

Q.13 Consider M with $r = \frac{1025}{513}$. Let k be the number of all those circles C_n that are inside M . Let l be the maximum possible number of circles among these k circles such that no two circles intersect. Then

- (A) $k + 2l = 22$ (B) $2k + l = 26$ (C) $2k + 3l = 34$ (D) $3k + 2l = 40$

Q.14 Consider M with $r = \frac{(2^{199}-1)\sqrt{2}}{2^{198}}$. The number of all those circles D_n that are inside M is

- (A) 198 (B) 199 (C) 200 (D) 201

Paragraph

Let $\psi_1: [0, \infty) \rightarrow \mathbb{R}$, $\psi_2: [0, \infty) \rightarrow \mathbb{R}$, $f: [0, \infty) \rightarrow \mathbb{R}$ and $g: [0, \infty) \rightarrow \mathbb{R}$ be functions such that $f(0) = g(0) = 0$,

$$\psi_1(x) = e^{-x} + x, \quad x \geq 0,$$

$$\psi_2(x) = x^2 - 2x - 2e^{-x} + 2, \quad x \geq 0,$$

$$f(x) = \int_{-x}^x (|t| - t^2)e^{-t^2} dt, \quad x > 0$$

and

$$g(x) = \int_0^{x^2} \sqrt{t} e^{-t} dt, \quad x > 0.$$

Q.15 Which of the following statements is **TRUE** ?

(A) $f(\sqrt{\ln 3}) + g(\sqrt{\ln 3}) = \frac{1}{3}$

(B) For every $x > 1$, there exists an $\alpha \in (1, x)$ such that $\psi_1(x) = 1 + \alpha x$

(C) For every $x > 0$, there exists a $\beta \in (0, x)$ such that $\psi_2(x) = 2x(\psi_1(\beta) - 1)$

(D) f is an increasing function on the interval $\left[0, \frac{3}{2}\right]$

Q.16 Which of the following statements is **TRUE** ?

(A) $\psi_1(x) \leq 1$, for all $x > 0$

(B) $\psi_2(x) \leq 0$, for all $x > 0$

(C) $f(x) \geq 1 - e^{-x^2} - \frac{2}{3}x^3 + \frac{2}{5}x^5$, for all $x \in \left(0, \frac{1}{2}\right)$

(D) $g(x) \leq \frac{2}{3}x^3 - \frac{2}{5}x^5 + \frac{1}{7}x^7$, for all $x \in \left(0, \frac{1}{2}\right)$

SECTION 4

- This section contains **THREE (03)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:
Full Marks : +4 If **ONLY** the correct integer is entered;
Zero Marks : 0 In all other cases.

Q.17 A number is chosen at random from the set $\{1, 2, 3, \dots, 2000\}$. Let p be the probability that the chosen number is a multiple of 3 or a multiple of 7. Then the value of $500p$ is ___ .

Q.18 Let E be the ellipse $\frac{x^2}{16} + \frac{y^2}{9} = 1$. For any three distinct points P, Q and Q' on E , let $M(P, Q)$ be the mid-point of the line segment joining P and Q , and $M(P, Q')$ be the mid-point of the line segment joining P and Q' . Then the maximum possible value of the distance between $M(P, Q)$ and $M(P, Q')$, as P, Q and Q' vary on E , is ___ .

Q.19 For any real number x , let $[x]$ denote the largest integer less than or equal to x . If

$$I = \int_0^{10} \left[\sqrt{\frac{10x}{x+1}} \right] dx ,$$

then the value of $9I$ is ___ .

END OF THE QUESTION PAPER

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