SECTION – A

MULTIPLE CHOICE QUESTIONS (MCQ)

1. For an integer $k \geq 0$. P_k denote the vector space of all real polynomials in one variable of degree less than or equal to k. Define a linear transformation: $T : P_2 \to P_3$ by $Tf(x) = f''(x) + xf(x)$. Which of the following polynomials is not in the range of T?

1. $x + x^2$
2. $x + 1$
3. $x^2 + x^3 + 2$
4. $x + x^3 + 2$

2. How many elements of the group Z_{50} have order 10?

1. 5
2. 4
3. 8
4. 10

3. Let $f: \mathbb{R} \to \mathbb{R}$ be a continuous function satisfying $f(x) = f(x + 1)$ for all $x \in \mathbb{R}$. Then

1. there is no $x_0 \in \mathbb{R}$ such that $f(x_0 + \pi) = f(x_0)$.
2. f is not necessarily bounded above.
3. there exist a unique $x_0 \in \mathbb{R}$ such that $f(x_0 + \pi) = f(x_0)$.
4. there exist infinitely many $x_0 \in \mathbb{R}$ such that $f(x_0 + \pi) = f(x_0)$.

4. Let $f: \mathbb{R} \to \mathbb{R}$ be a continuous function such that for all $x \in \mathbb{R}$, $\int_0^1 f(xt)dt = 0$ (*). Then

1. there is an f satisfying (*) that is 0 at infinitely many points, but is not identically zero.
2. there is an f satisfying (*) that takes both positive and negative values.
3. there is an f satisfying (*) that is identically 0 on (0,1) but not identically 0 on the whole of $\mathbb{R}$
4. f must be identically 0 on the whole of $\mathbb{R}$

5. Let $0 < a < 1$ be a real number. The number of differentiable function $y: [0, 1] \to [0, \infty)$, having continuous derivatives on [0, 1] and satisfying $y' = (y(t))^a, t \in [0, 1], y(0) = 0$, is

1. finite but more than two.
2. exactly one.
3. infinite.
4. exactly two.

6. For every $n \in \mathbb{N}$, let $f_n: \mathbb{R} \to \mathbb{R}$ be a function. From the given choices , pick the statement that is the negation of "For every $x \in \mathbb{R}$ and for every real number $\epsilon > 0$ there exists an integer N > 0 such that $\sum_{i=1}^{p} |f_{N+i}(x)| < \epsilon$ for every integer $p > 0$."

1. There exists $x \in \mathbb{R}$ and there exist a real number $\epsilon > 0$ such that for every integer N > 0 and for every integer $p > 0$ the inequality $\sum_{i=1}^{p} |f_{N+i}(x)| \geq \epsilon$ holds.
2. For every $x \in \mathbb{R}$ and for every real number $\epsilon > 0$, there does not exist any integer $N > 0$ such that $\sum_{i=1}^{p} |f_{N+i}(x)| < \epsilon$ for every integer $p > 0$.
3. For every $x \in \mathbb{R}$ and for every real number $\epsilon > 0$, there does not exist any integer $N > 0$ such that $\sum_{i=1}^{p} |f_{N+i}(x)| \geq \epsilon$ for every integer $p > 0$.
4. There exists $x \in \mathbb{R}$ and there exist a real number $\epsilon > 0$ such that for every integer N > 0 there exists an integer$p > 0$ the inequality $\sum_{i=1}^{p} |f_{N+i}(x)| \geq \epsilon$ holds.

7. **Let $n > 1$ be an integer. Consider the following two statements for an arbitrary n x n matrix A with complex entries.**
I. If $A^k = I_n$ for some integer $k \geq 1$, then all the eigenvalues of A are k^{th} roots of unity .
II. If, for some integer $k \geq 1$, all the eigenvalues of A are k^{th} roots of unity, then $A^k = I_n$.
Then
1. neither I nor II is TRUE.
2. I is FALSE but II is TRUE.
3. both I and II are TRUE
4. I is TRUE but II is FALSE

8. **Which one of the following subset of $\mathbb{R}$ has a non-empty interior?**
1. The set$\{b \in \mathbb{R} : x^2 + bx + 1 = 0$ has distinct roots$\}$.
2. The set $\{a \in \mathbb{R} : \sin(a) = 1\}$.
3. The set of all irrational numbers in $\mathbb{R}$
4. The set of all rational number in $\mathbb{R}$

9. **Let $P: \mathbb{R} \to \mathbb{R}$ be a continuous function such that $P(x) > 0$ for all $x \in \mathbb{R}$. Let y be a twice differentiable function on $\mathbb{R}$ satisfying $y''(x) + P(x)y'(x) - y(x) = 0$ for all $x \in \mathbb{R}$. Suppose that there exists two real numbers $a, b(a < b)$ such that $y(a) = y(b) = 0$. Then**
1. $y(x) = 0$ for all $x \in [a, b]$.
2. $y(x)$ changes sign on (a, b)
3. $y(x) < 0$ for all $x \in [a, b]$.
4. $y(x) > 0$ for all $x \in [a, b]$.

10. **Let p and t be positive real numbers. Let D_t be the closed disc of radius t centered at (0,0), i.e., $D_1 = \{(x, y) \in\in \mathbb{R}^2 : x^2 + y^2 \leq t^2\}$. Define $I(p, t) = \iint_{D_t} \frac{dxdy}{(p^2+x^2+y^2)^p}$. Then $\lim_{t\to\infty} I(p, t)$ is finite**
1. only if $p < 1$.
2. only if $p > 1$.
3. for no value of p.
4. only if $p = 1$.

11. **Let $D \subseteq \mathbb{R}^2$ be defined by $D = \mathbb{R}^2 \setminus \{(x, 0) : x \in \mathbb{R}\}$. Consider the function $f: D \to \mathbb{R}$ defined by $f(x, y) = x \sin \frac{1}{y}$. Then**
1. f is a continuous function on D and cannot be extended continuously to any point outside D.
2. f is a continuous function on D and can be be extended continuously to $D \cup \{0,0\}$.
3. f is a discontinuous function on D
4. f is a continuous function on D and can be extended continuously to the whole of $\mathbb{R}^2$

12. **Consider the function $f(x) = \begin{cases} 1 & \text{if } x \in (\mathbb{R} \setminus \mathbb{Q}) \cup \{0\}, \\ 1 - \frac{1}{p} & \text{if } x = \frac{n}{p}, n \in \mathbb{Z} \setminus \{0\}, p \in \mathbb{N} \text{ and } \gcd(n, p) = 1 \end{cases}$. Then**
1. f is a continuous to all $x \in \mathbb{Q}$.
2. f is not continuous at $x \in \mathbb{R} \setminus \mathbb{Q}$.
3. f is not continuous at $x = 0$.
4. all $x \in \mathbb{Q} \setminus \{0\}$ are strict local minima for f

13. **Let $f: [0, 1] \to [0, \infty)$ be a continuous function such that $(f(t))^2 < 1 + 2\int_0^t f(s)ds$, for all $t \in [0, 1]$. Then**
1. $f(t) = 1 + t$ for all $t \in [0,1]$.
2. $f(t) < 1 + \frac{t}{2}$ for all $t \in [0,1]$.
3. $f(t) < 1 + t$ for all $t \in [0,1]$.
4. $f(t) > 1 + t$ for all $t \in [0,1]$.

14. Define $S = \lim_{n\to\infty}\left(1-\frac{1}{2^2}\right)\left(1-\frac{1}{3^2}\right)\ldots\left(1-\frac{1}{n^2}\right)$. Then

1. $S = 1/2$.
2. $S = 3/4$.
3. $S = 1$.
4. $S = 1/4$.

15. Let $f : \mathbb{N} \to \mathbb{N}$ be a bijective map such that $\sum_{n=1}^{\infty}\frac{f(n)}{n^2} < +\infty$ The number of such bijective maps is

1. infinite
2. exactly one
3. zero
4. finite but more than one.

16. Which one of the following statements is true?

1. $(\mathbb{Q}/\mathbb{Z}, +)$ is isomorphic to $(\mathbb{Q}/2\mathbb{Z}, +)$.
2. $(\mathbb{Z}, +)$ is isomorphic to $(\mathbb{R}, +)$.
3. $(\mathbb{Z}, +)$ is isomorphic to $(\mathbb{Q}, +)$.
4. $(\mathbb{Q}/\mathbb{Z}, +)$ is isomorphic to $(\mathbb{Q}, +)$.

17. Let G is a finite abelian group of odd order. Consider the following two statements:
I. The map $f: G \to G$defined by$f(g) = g^2$ is a group isomorphism.
II. The product $\prod_{g\in G} g = e$.

1. Both I and II are TRUE
2. II is TRUE but I is FALSE
3. I is TRUE but II is False
4. Neither I nor II is TRUE

18. Let $M_n(\mathbb{R})$ be the real vector space of all $n \times m$ matrices with real entries $n \geq 2$. Let $A \in M_n(\mathbb{R})$. Consider the subspace W of $M_n(\mathbb{R})$ spanned by $\{I_n, A, A^2 \ldots\ldots\}$. Then the dimension of Wover $\mathbb{R}$ is necessarily

1. n^2
2. n
3. at most n.
4. ∞

19. Leg g be an element of S_7 such that g commutes with the element (2, 6, 4, 3). The number of such g is

1. 48
2. 4
3. 24
4. 6

20. Let $f: \mathbb{R} \to \mathbb{R}$ be an infinitely differentiable function such that for all $a, b \in R$ with $a < b$, $\frac{f(b)-f(a)}{b-a} = f'\left(\frac{a+b}{2}\right)$. Then

1. f must be a linear polynomial
2. f must be a polynomial of degree less than or equal to 2
3. f must be a polynomial of degree greater than 2
4. f is not a polynomial.

21. Consider the two series I. $\sum_{n=1}^{\infty}\frac{1}{n^{2+(1/n)}}$ and II. $\sum_{n=1}^{\infty}\frac{1}{n^{2-n^2/n}}$. Which one of the following holds?

1. I converges and II diverges
2. I diverges and II converges
3. Both I and II diverge
4. Both I and II converge

22. **Consider the surface $S = \{(x, y, xy) \in \mathbb{R}^3 : x^2 + y^2 \leq 1\}$. Let $\vec{F} = y\hat{\imath} + x\hat{\jmath} + \hat{k}$. If $\hat{n}$ is the continuous unit normal field to the surface S with positive z-component, then $\iint_S \vec{F}.\hat{n}ds$ equals**

1. 2π.
2. $\frac{\pi}{4}$.
3. π.
4. $\frac{\pi}{2}$.

23. **Let $n \geq 2$ be an integer. Let $A : \mathbb{C}^n \to \mathbb{C}^n$ be the linear transformation defined by $A(z_1, z_2, \ldots, z_n) = (z_n, z_1, z_2, \ldots, z_{n-1})$. Which one of the following statements is true for every $n \geq 2$?**

1. Every eigenvalue of A is either 0 or 1
2. A is nilpotent
3. All eigenvalues of A are of molecules 1.
4. A is singular.

24. **Let $f : [0, 1] \to [0, 1]$ be a non- constant continuous function such that $f \circ f = f$. Define $E_f = \{x \in [0, 1] : f(x) = x\}$.** Then

1. E_f need not be an interval
2. E_f neither open nor closed
3. E_f is an interval
4. E_f is empty

25. **Consider the family of curves $x^2 - y^2 = ky$ with parameter $\in \mathbb{R}$. The equation of the orthogonal trajectory to this family passing through (1, 1) is given by**

1. $x^3 + 3xy^2 = 4$
2. $y^2 + 2x^2y = 3$
3. $x^2 + 2xy = 3$
4. $x^3 + 2xy^2 = 3$

26. **Which one of the following statements is true?**

1. There exists a normal subgroup of S_5 of index 7
2. There exists a cyclic subgroup of S_5 of order
3. Exactly half of the element in any even order subgroup of S_5 must be even permutation
4. Any abelian subgroup of S_5 is trivial

27. **Let A be an $n \times n$ invertible matrix and C be an $n \times n$ nilpotent matrix. If $X = \begin{pmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{pmatrix}$ is a $2n \times 2n$ matricx (each X_{ij} being $n \times n$) that the $2n \times 2n$ matrix $B = \begin{pmatrix} A & 0 \\ 0 & C \end{pmatrix}$, then**

1. X_{11} and X_{22} are necessarily zero matrices.
2. X_{12} and X_{21} are necessarily zero matrices.
3. X_{12} and X_{22} are necessarily zero matrices.
4. X_{11} and X_{21} are necessarily zero matrices.

28. **Let y be the solution $(1 + x)y''(x) + y'(x) - \frac{1}{1+x}y(x) = 0, x \in (-1, \infty), y(0) = 1, y'(0) = 0$. Then**

1. y attains its minimum at $x = 0$.
2. y is bounded on $(-1, 0]$
3. y is bounded on $(0, \infty)$
4. $y(x) \geq 2$ on $(-1, \infty]$

29. **Let y be a twice differentiable function on $\mathbb{R}$ satisfying $y''(x) = 2 + e^{-|x|}, x \in \mathbb{R}$, $y(0) = -1, y'(0) = 0$. Then**

1. $y = 0$ has exactly one root.
2. there exists an $x_0 \in \mathbb{R}$ such that $y(x_0) \geq y(x)$ for all $x \in \mathbb{R}$
3. $y = 0$ has more than two roots
4. $y = 0$ has exactly two roots

30. **Consider the following statements.**

I. The group $(\mathbb{Q}, +)$ has no proper subgroup of finite index

II. The group $(\mathbb{C} \setminus \{0\}, \cdot)$ has no proper subgroup of finite index.

Which one of the following statements is true?

1. Neither I and II is TRUE
2. Both I and II are TRUE
3. I is TRUE but II is FALSE
4. II is TRUE but I is FALSE

SECTION -B

MULTIPLE SELECT QUESTIONS (MSQ)

1. **Consider the four function from $\mathbb{R}$ to $\mathbb{R}$: $f_1(x) = x^4 + 3x^2 + 7x + 1$, $f_2(x) = x^3 + 3x^2 + 4x$, $f_3(x) = \arctan(x)$ and $f_4(x) = \begin{cases} x & \text{if } x \notin \mathbb{Z} \\ 0 & \text{if } x \in \mathbb{Z} \end{cases}$. Which of the following subset of $\mathbb{R}$ are open?**
   1. The range of f_4
   2. The range of f_2
   3. The range of f_1
   4. The range of f_3

2. **Let $f: (a, b) \to \mathbb{R}$ be a differentiable function on (a, b). Which of the following statements is /are true?**
   1. If $f'(x_0) > 0$ for some $x_0 \in (a, b)$, then f is increasing in a neighbourhood of x_0.
   2. $f' > 0$ in (a, b) implies that f is increasing in (a, b)
   3. If $f'(x_0) > 0$ for some $x_0 \in (a, b)$, then there exists a $\delta > 0$ such that $f(x) > f(x_0)$ for all $x \in (x_0, x_0 + \delta)$
   4. f is increasing in (a, b) implies that $f' > 0$ in (a, b).

3. **Let $m > 1$ and $n > 1$ be integers. Let A be an $m \times n$ matrix such that for some $m \times 1$ matrix b_1, the equation $Ax = b_1$ has infinitely many solution. Let b_2 denote an $m \times 1$ different from b_1. Then $Ax = b_2$ has**
   1. a unique solution for some b_2
   2. no solution for some b_2
   3. finitely many solution for some b_2
   4. infinitely many solutions for some b_2

4. **Let $f: \mathbb{R} \to \mathbb{R}$ be a function with the property that for every $y \in \mathbb{R}$, the value of the expression $\sup_{x \in \mathbb{R}}[xy - f(x)]$ is finite. Define $g(y) = \sup_{x \in \mathbb{R}}[xy - f(x)]$ for $y \in \mathbb{R}$. Then**
   1. f must satisfy $\lim_{|x| \to \infty} \frac{f(x)}{|x|} = -\infty$
   2. g is even if f is even
   3. g is odd f is even
   4. f must satisfy $\lim_{|x| \to \infty} \frac{f(x)}{|x|} = +\infty$

5. **Which of the following subset of $\mathbb{R}$ is/are connected?**
   1. The set $\{x \in \mathbb{R} : x^3 + x + 1 \geq 0\}$
   2. The set $\{x \in \mathbb{R} : x^3 - 1 \geq 0\}$
   3. the set $\{x \in \mathbb{R} : x\}$ is irrational
   4. The set $\{x \in \mathbb{R} : x^3 - 2x + 1 \geq 0\}$

6. **Let G be a finite group of order 28. Assume that G contains a subgroup of order 7. Which of the following statements is/are true?**
   1. G contains a unique subgroup of order 7
   2. G contains a normal subgroup of order 7
   3. G contains at least two subgroup of order 7
   4. G contains no normal subgroup of order 7

7. **Let V be a finite dimensional vector space and $T: V \to V$ be a linear transformation. Let $R(T)$ denote the range of T and $\mathcal{N}(T)$ denote the null space $\{v \in V : Tv = 0\}$ of T. If rank (T) = rank (T^2), then which of the following is/are necessarily true?**
   1. $\mathcal{N}(T) = \{0\}$
   2. $\mathcal{N}(T) = \mathcal{N}(T^2)$
   3. $\mathcal{N}(T) \cap \mathcal{R}(T) = \{0\}$
   4. $\mathcal{R}(T) = \mathcal{R}(T^2)$

8. **Consider the two function $f(x,y)=x+y$ and $g(x,y)=xy-16$ defined on $\mathbb{R}^2$. Then**

1. the function g has no global extreme values subject to the condition $f=0$.
2. The function f attains global extreme value at (4, 4) and $(-4,-4)$ subject to the condition $g=0$.
3. the function g has a global extreme value at (0,0) subject to the condition $f=0$
4. The function f has no global extreme value subject to the condition $g=0$

9. **Consider the equation $x^{2021}+x^{2020}+\cdots+x-1=0$. Then**

1. no real root is positive
2. exactly one real root is negative
3. exactly one real root is positive
4. all real roots are positive

10. **Let $D=\mathbb{R}^2\setminus\{(0,0)\}$. Consider the two function $u,v: D\to\mathbb{R}$ defined by $(x,y)=x^2-y^2$ and $v(x,y)=xy$. Consider the gradients ∇u and ∇v of the function u and v, respectively. Then**

1. ∇u and ∇v do not exist at some points (x,y) of D
2. ∇u and ∇v are perpendicular at each point (x,y) of D
3. ∇u and ∇v at each points (x,y) of $\mathbb{R}^2$
4. ∇u and ∇v are parallel at each points (x,y) of D

SECTION -C

NUMERICAL ANSWER TYPE (NAT)

1. The number of cycles of length 4 in S_6 is _____.

2. The value of $\lim_{n\to\infty}(3^n+5^n+7^n)^{\frac{1}{n}}$ is.

3 Let $B=\{(x,y,z)\in\mathbb{R}^3: x^2+y^2+z^2\le 1\}$ and define $u(x,y,z)=\sin((1-x^2-y^2-z^2)^2)$ for $(x,y,z)\in B$. Then the value of $\iiint_B\left(\frac{\partial^2u}{\partial x^2}+\frac{\partial^2u}{\partial y^2}+\frac{\partial^2u}{\partial z^2}\right)dxdydz$ is _____.

4. Let V be the real vector space of all continuous function $f:[0,2]\to\mathbb{R}$ such that the restriction of f to the interval [0,1] is a polynomial of degree less than or equal to 2, the restriction of f to the interval [1, 2] is a polynomial of degree less than or equal to 3 and $f(0)=0$ Then the dimension of V is equal to _____

5. Consider the set $A=\{a\in\mathbb{R}: x^2=a(a+1)(a+2)$ has a real root}. The number of connected components of A is _____

6. Let $\vec{F}=(y+1)e^y\cos(x)\,\hat{\imath}+(y+2)e^y\sin(x)\hat{\jmath}$ be a vector field in $\mathbb{R}^2$ and C be a continuously differentiable path with the starting point (0,1) and the end point $\left(\frac{\pi}{2},0\right)$. Then $\int_C\vec{F}.d\vec{r}$ equals _____

7. The number of group homomorphisms from the group $\mathbb{Z}_4$ to the group S_3 is _____

8. The value of $\frac{\pi}{2}\lim_{n\to\infty}\cos\left(\frac{\pi}{4}\right)\cos\left(\frac{\pi}{8}\right)\ldots\cos\left(\frac{\pi}{2^{n+1}}\right)$ is _____

9. Let $y:\left(\frac{9}{10},3\right)\to\mathbb{R}$ be a differentiable function satisfying $(x-2y)\frac{dy}{dx}+(2x+y)=0, x\in\left(\frac{9}{10},3\right)$, and $y(1)=1$. Then $y(2)$ equal _____

10. Consider the subset $S=\{(x,y): x^2+y^2>0\}$ of $\mathbb{R}^2$. Let $P(x,y)=\frac{y}{x^2+y^2}$ and $Q(x,y)=\frac{x}{x^2+y^2}$ for $(x,y)\in S$. If C denotes the unit circle traversed in the counter clockwise direction, then the value of $\frac{1}{\pi}\int_C(Pdx+Qdy)$ is _____

11. Let $A=\begin{pmatrix}1&0&0&0\\0&1&0&0\\0&0&-1&0\\0&0&0&-1\end{pmatrix}$. Consider the linear map T_A from the real vector space $M_4(\mathbb{R})$ to itself defind by $T_A(X)=AX-XA$, for all $X\in M_4(\mathbb{R})$. The dimension of the range of T_A is_____

12. The determinant of the matrix $\begin{pmatrix}2021&2020&2020&2020\\2021&2021&2020&2020\\2021&2021&2021&2020\\2021&2021&2021&2021\end{pmatrix}$ is _____

13. Let $A=\begin{pmatrix}2&-1&3\\2&-1&3\\3&2&-1\end{pmatrix}$. Then the largest eigencalue of A is_____

14. Let S be the surface defined by $\{(x,y,z)\in\mathbb{R}^3: z=1-x^2-y^2, z\ge 0\}$. Let $\vec{F}=-y\hat{\imath}+(x-1)\hat{\jmath}+z^2\hat{k}$ and $\hat{n}$ be the continuous unit normal field to the surface S with positive z-component. Then the value of $\frac{1}{\pi}\iint_S(\nabla\times\vec{F})\cdot\hat{n}\,dS$ is _____

15. The least possible value of k, accurate up to two decimal places, for which the followig problem $y''(t) + 2y'(t) + ky(t) = 0, t \in \mathbb{R}, y(0) = 0, y(1) = 0, y(1/2) = 1$, has a solution is _____

16. Consider those contiuous function $f: \mathbb{R} \to \mathbb{R}$ that have the property that given any $x \in \mathbb{R}$, $f(x) \in \mathbb{Q}$ if and only if $f(x+1) \in \mathbb{R}/\mathbb{Q}$. The number of such functions is _____

17. The largest positive number a such that $\int_0^5 f(x)dx + \int_0^3 f^{-1}(x)dx \geq a$, for every strictly increasing surjective continuous function $f: [0, \infty) \to [0, \infty)$ is _____

18. The number of elements of order two in the group S_4 is equal to _____

19. Define the sequence $S_n = \begin{cases} \frac{1}{2^n}\sum_{j=0}^{n-2} 2^{2j} & \text{if } n > 0 \text{ is even} \\ \frac{1}{2^n}\sum_{j=0}^{n-1} 2^{2j} & \text{if } n > 0 \text{ is odd} \end{cases}$. Define $\sigma_m = \frac{1}{m}\sum_{n=1}^{m} S_n$. The number of limit points of the sequence $\{\sigma_m\}$ is _____

20. The value of $\lim_{n\to\infty} \int_0^1 e^{x^2} \sin(nx)\, dx$ is _____

Answers

Section: A

1	2	3	4	5	6	7	8	9	10
D	A	D	A	A	B	C	C	D	B
11	12	13	14	15	16	17	18	19	20
D	D	B	A	B	A	A	A	A	C
21	22	23	24	25	26	27	28	29	30
A	B	C	C	B	B	C	A	B	B

Section: B

31	32	33	34	35
A,B	A,B	B,D	A,D	A,C
36	37	38	39	40
A,B	B,C	B,C,D	A,B,C	A,C

Section: C

41	42	43	44	45
90	7	0	-2	2
46	47	48	49	50
5	4	3	1	1
51	52	53	54	55
9	10.8 to 10.9	0	15	0
56	57	58	59	60
2021	0	2	4	8

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