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PHYSICS ACADEMY

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IIT-JAM

(MATHEMATICAL METHODS)

PREVIOUS YEAR'S QUESTIONS WITH ANSWER (CHAPTER-WISE)

- MATRIX ALGEBRA
- VECTOR ANALYSIS
- FOURIER SERIES
- ALGEBRA OF COMPLEX NUMBERS
- DIFFERENTIAL EQUATIONS
- OTHER QUESTIONS

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MATRIX ALGEBRA

1. Which of the following is **INCORRECT** for the matrix $M = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$.

[IIT-JAM 2005]

(a) It is its own inverse
(b) It is its own transpose
(c) It is non-orthogonal
(d) It has eigen values ± 1

2. The symmertric part of $P = \begin{pmatrix} a \\ b \end{pmatrix} (a - 2b)$ is. **[IIT-JAM 2006]**

(a) $\begin{pmatrix} a^2 - 2 & ba - 1 \\ ba - 1 & b^2 - 2 \end{pmatrix}$

(b) $\begin{pmatrix} a(a-2) & b \\ b & b^2 \end{pmatrix}$

(c) $\begin{pmatrix} a(a-1) & b(a-1) \\ b(a-1) & b^2 \end{pmatrix}$

(d) $\begin{pmatrix} a(a-2) & b(a-1) \\ b(a-1) & b^2 \end{pmatrix}$

3. $(x\ y)\begin{pmatrix} 5 & -7 \\ 7 & 3 \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} = 15.$ **[IIT-JAM 2007]**

The matrix equation of above represents

(a) a circle of radius $\sqrt{15}$
(b) an ellipse of semi major axis $\sqrt{5}$
(c) an ellipse of semi major axis 5
(d) a hyperbola

4. The product *PQ* of any two real, symmetric matrices *P* and *Q* is.

[IIT-JAM 2008]

(a) Symmetric for all *P* and *Q*
(b) Never symmetric
(c) Symmetric, if *PQ* = *QP*
(d) Anti-symmetric for all *P* and *Q*

5. A matrix is given b $M = \frac{1}{\sqrt{2}}\begin{pmatrix} i & 1 \\ 1 & i \end{pmatrix}$. The eigenvalues of *M* are.

[IIT-JAM 2010]

(a) Real and positive
(b) Purely imaginary with modulus 1
(c) Complex with modulus 1
(d) Real and negative

6. Given two (n × n) matrices $\hat{P}$ and $\hat{Q}$ is Hermitian and $\hat{Q}$ is skew (anti)-Hermitian. Which one of the following combinations of $\hat{P}$ and $\hat{Q}$ is necessarily a Hermitian matrix? **[IIT-JAM 2011]**

(a) $\hat{P}\hat{Q}$
(b) $i\hat{P}\hat{Q}$
(c) $\hat{P} + i\hat{Q}$
(d) $\hat{P} + \hat{Q}$

7. The inverse of the matrix $M = \begin{pmatrix} 0 & 1 & 1 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{pmatrix}$ is. **[IIT-JAM 2013]**

(a) M - I (b) M^2- I (c) I - M^2- (d) I - M

Where *I* is the identity matrix.

8. The trace of a 2 x 2 matrix is 4 and its determinant is 8 . If one of the eigenvalues is 2(1+e), the other eigenvalue is. **[IIT-JAM 2015]**

(a) $2(1 - i)$ (b) $2(1 + i)$

(c) $(1 + 2i)$ (d) $(1 - 2\text{i})$

9. The eigenvalues of the matrix representing the following pair of linear equations

x+ iy = 0

ix+ y = 0

are **[IIT-JAM 2016]**

(a) 1+ *i*, 1+ *I* (b) 1- *i*, 1- *i* (c) 1, *i* (d) 1- *i*, 1 - *i*

10. For the three matrices given below, which one of the choices is correct? $\sigma_1 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$, $\sigma_2 = \begin{pmatrix} 0 & \text{i} \\ -\text{i} & 0 \end{pmatrix}$, $\sigma_3 = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$, **[IIT-JAM 2017]**

(a) $\sigma_1\sigma_2 = -\text{i}\sigma_3$ (b) $\sigma_1\sigma_2 = \text{i}\sigma_3$

(c) $\sigma_1\sigma_2 + \sigma_2\sigma_1 = \text{I}$ (d) $\sigma_3\sigma_2 = -\text{i}\sigma_1$

11. Let matrix M $= \begin{pmatrix} 4 & \text{x} \\ 6 & 9 \end{pmatrix}$. If det(M)=0, then **[IIT-JAM 2018]**

(a) *M* is symmetric (b) *M* is invertible

(c) one eigenvalue is 13 (d) Its eigenvectors are orthogonal

12. The eigenvalues of $\begin{pmatrix} 3 & \text{i} & 0 \\ -\text{i} & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$ are. **[IIT-JAM 2019]**

(a) 2,4and 6 (b) 2*i*,4*i* and 6

(c) 2*i*,4and 8 (d) 0,4 and 8

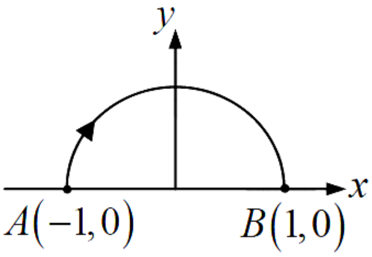
VECTOR ANALYSIS

13. The equation of a surface of revolution is $z = \pm\sqrt{\frac{3}{2}x^2 + \frac{3}{2}y^2}$. The unit vector normal to the surface at the point $A\left(\sqrt{\frac{2}{3}}, 0, 1\right)$ is. **[IIT-JAM 2010]**

(a) $\sqrt{\frac{3}{5}}\hat{\imath} + \frac{2}{\sqrt{10}}\hat{k}$ (b) $\sqrt{\frac{3}{5}}\hat{\imath} - \frac{2}{\sqrt{10}}\hat{k}$

(c) $\sqrt{\frac{3}{5}}\hat{\imath}+\frac{2}{\sqrt{5}}\hat{k}$ (d) $\sqrt{\frac{3}{10}}\hat{\imath}+\frac{2}{\sqrt{10}}\hat{k}$

14. The line integral $\int_A^B \vec{F}.d\vec{l}$, where $\vec{F}=\frac{x}{\sqrt{x^2+y^2}}\hat{x}+\frac{x}{\sqrt{x^2+y^2}}\hat{y}$, along the semi-circular path as shown in the figure below is. **[IIT-JAM 2011]**



(a) -2 (b) 0 (c) 2 (d) 4

15. If $\vec{F}$ is a constant vector and $\vec{r}$ is the position vector then $\vec{\nabla}(\vec{F}.\vec{r})$ would be. **[IIT-JAM 2012]**

(a) $(\vec{\nabla}.\vec{r})\vec{F}$ (b) $\vec{F}$ (c) $(\vec{\nabla}.\vec{F})\vec{r}$ (d) $|\vec{r}|\vec{F}$

16. For vectors $\vec{a}=\hat{\jmath}+\hat{k}, \vec{b}=2\hat{\imath}+3\hat{\jmath}-5\hat{k}$ and $\vec{c}=\hat{\jmath}-\hat{k}$, the vector product $\vec{a}\times(\vec{b}\times\vec{c})$ is. **[IIT-JAM 2014]**

(a) In the same direction as $\vec{c}$ (b) In the direction opposite to $\vec{c}$

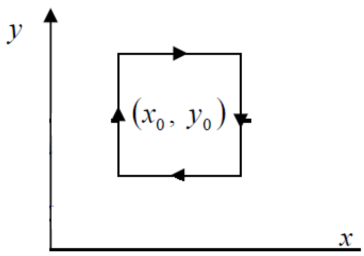
(c) In the same direction as $\vec{b}$ (d) In the direction opposite to $\vec{b}$

17. If the surface integral of the field $\vec{A}(x,y,z)=2\alpha x\hat{\imath}+\beta y\hat{\jmath}-3\gamma z\hat{k}$ over the closed surface of an arbitrary unit sphere is to be zero, then the relationship between α,β and γ is. **[IIT-JAM 2014]**

(a) $\alpha+\beta/6-\gamma=0$ (b) $\alpha/3+\beta/6-\gamma/2=0$

(c) $\alpha/2+\beta-\gamma/3=0$ (d) $2/\alpha+1/\beta-3/\gamma=0$

18. The line integral $\oint \vec{A}.d\vec{l}$ of a vector field $\vec{A}(x,y)=\frac{1}{r^2}(-y\hat{\imath}+x\hat{\jmath})$ where $r^2=x^2+y^2$ is taken around a square (see figure) of side of unit length and centered at (x_0, y_0) with $|x_0|>\frac{1}{2}$ and $|y_0|>\frac{1}{2}$. If the value of the integral is L, then **[IIT-JAM 2014]**



(a) L depends on (x_0, y_0)

(b) L is independent of (x_0, y_0) y and its value is -1

(c) L is independent of (x_0, y_0) y and its value is 0
(d) L is independent of (x_0, y_0) y and its value is 2

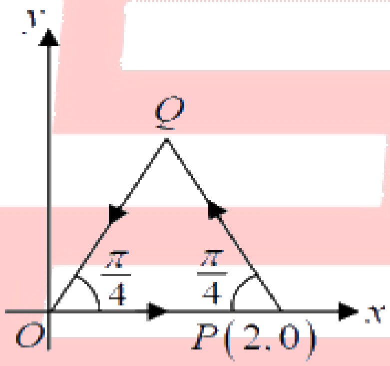
19. Consider a vector field $\vec{F} = y\hat{\imath} + xz^3\hat{\jmath} - zy\hat{k}$. Let C be the circle $x^2 + y^3 = 4$ on the plane $z = 2$, oriented counter-clockwise. The value of the contour integral $\oint_C \vec{F}.d\vec{r}$ is. **[IIT-JAM 2015]**

(a) 28π (b) 4π (c) -4π (d) -28π

20. The tangent line to the curve $x^2 + xy + 5 = 0$ at (1,1) is represented by. **[IIT-JAM 2016]**

(a) $y = 3x - 2$ (b) $y = -3x + 4$
(c) $x = 3y - 2$ (d) $x = -3y + 4$

21. Consider a closed triangular contour traversed in counter-clockwise direction, as shown in the figure. The value of the integral $\oint \vec{F}.\vec{dl}$ evaluated along this contour, for a vector field, $\vec{F} = y\hat{e}_x - x\hat{e}_y$, is ……………..($\hat{e}_x, \hat{e}_y$ and $\hat{e}_z$ and unit vectors in Cartesian-coordinate system). **[IIT-JAM 2016]**



22. A hemispherical shell is placed on the x-y plane centered at the origin. For a vector Field $\vec{E} = (-y\hat{e}_x + x\hat{e}_y)/(x^2 + y^2)$, the value of the integral $\int_S (\vec{\nabla} \times \vec{E}).d\vec{a}$ over the hemispherical surface is………π. ($d\vec{a}$ is the elemental surface area, $\hat{e}_x$, $\hat{e}_y$ and $\hat{e}_z$ are unit vectors in Cartesian-coordinate system). **[IIT-JAM 2016]**

23. The integral of the vector $\vec{A}(\rho, \varphi, z) = \frac{40}{\rho}\cos\varphi\hat{\rho}$ (standard notation for cylindrical coordinates is used) over the volume of a cylinder of height L and radius R_0 is: **[IIT-JAM 2017]**

(a) $20\pi R_0 L(\hat{\imath} + \hat{\jmath})$ (b) 0
(c) $40\pi R_0 L\hat{\jmath}$ (c) $40\pi R_0 L\hat{\imath}$

24. The volume integral of the function $f(r, \theta, \phi) = r^2 \cos\theta$ over the region $\left(0 \leq r \leq 2, 0 \leq \theta \leq \frac{\pi}{3} \text{ and } 0 \leq \phi \leq 2\pi\right)$ is………… (Specify your answer upto two digits after the decimal point) **[IIT-JAM 2017]**

25. Let $f(x,y) = x^3 - 2y^3$. The curve along which $\nabla^2 f = 0$ is. **[IIT-JAM 2018]**

(a) $x = \sqrt{2}y$ (b) $x = 2y$

(c) $x = \sqrt{6}y$ (d) $x = \frac{-y}{2}$

26. A curve is given by $\vec{r}(t) = t\hat{\imath} + t^2\hat{\jmath} + t^3\hat{k}$. The unit vector of the tangent to the curve at t =1 is. **[IIT-JAM 2018]**

(a) $\frac{\hat{\imath}+\hat{\jmath}+\hat{k}}{\sqrt{3}}$ (b) $\frac{\hat{\imath}+\hat{\jmath}+\hat{k}}{\sqrt{6}}$

(c) $\frac{\hat{\imath}+2\hat{\jmath}+2\hat{k}}{3}$ (d) $\frac{\hat{\imath}+2\hat{\jmath}+3\hat{k}}{\sqrt{14}}$

27. If $\phi(x,y,z)$is a scalar function which satisfies the Laplace equation, then the gradient of ϕ is. **[IIT-JAM 2019]**

(a) Solenoidall and irrigational (b) Solenoidall but not irrotational

(c) Irrotational but not solenoid (d) Neither Solenoidall nor irrotational

28. A unit vector perpendicular to the plane containing $\vec{A} = \hat{\imath} + \hat{\jmath} - 2\hat{k}$ and $\vec{B} = 2\hat{\imath} - \hat{\jmath} + \hat{k}$ is. **[IIT-JAM 2019]**

(a) $\frac{1}{\sqrt{26}}(-\hat{\imath} + 3\hat{\jmath} - 4\hat{k})$ (b) $\frac{1}{\sqrt{19}}(-\hat{\imath} + 3\hat{\jmath} - 3\hat{k})$

(a) $\frac{1}{\sqrt{35}}(-\hat{\imath} + 5\hat{\jmath} - 3\hat{k})$ (d) $\frac{1}{\sqrt{26}}(-\hat{\imath} - \hat{\jmath} - 3\hat{k})$

29. The gradient of scalar field S(x, y, z) has the following characteristic(s). **[IIT-JAM 2019]**

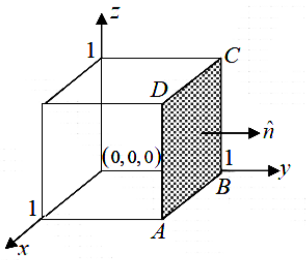
(a) Line integral of a gradient is path-independent

(b) Closed line integral of a gradient is zero

(c) Gradient of *S* is a measure of the maximum rate of change in the field *S*

(d) Gradient of *S* is a scalar quantity

30. The flux of the function $\vec{F} = (y^2)\hat{x} + (3xy - z^2)\hat{y} + (4yz)\hat{z}$ passing through the surface ABC along $\hat{n}$ is__________(Round off to 2 decimal places). **[IIT-JAM 2019]**



FOURIER SERIES

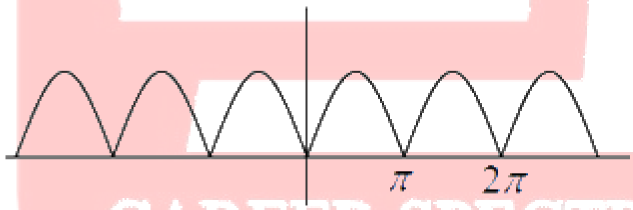
31. A periodic function can be expressed in a Fourier series of the form, $f(x) = \sum_{n=0}^{\infty}(a_n \cos(nx) + b_n \sin(nx))$. The functions $f_1(x) = cos^2x$ and $f_2(x) = sin^2x$ are expanded in their respective Fourier series. If the coefficients for the first series are $a_n^{(1)}$ and $b_n^{(1)}$, and the coefficients for the second series are $a_n^{(2)}$ and $b_n^{(2)}$, then which of the following is correct? **[IIT-JAM 2005]**

(a) $a_n^{(1)} = \frac{1}{2}$ and $b_n^{(2)} = \frac{-1}{2}$
(b) $b_2^{(1)} = \frac{1}{2}$ and $a_2^{(2)} = \frac{-1}{2}$
(c) $a_2^{(1)} = \frac{1}{2}$ and $a_2^{(2)} = \frac{-1}{2}$
(b) $b_2^{(1)} = \frac{1}{2}$ and $b_2^{(2)} = \frac{-1}{2}$

32. $f(x)$ is a periodic function of x with a period of 2π. In the interval $-\pi < x < \pi$, $f(x)$ is given by $f(x) = \begin{cases} 0, & -\pi < x < 0 \\ \sin x, & 0 < x < \pi \end{cases}$ In the expansion of *f(x)* as a Fourier series of sine and cosine functions, the coefficient of cos (2x) is. **[IIT-JAM 2007]**

(a) $\frac{2}{3\pi}$
(b) $\frac{1}{\pi}$
(c) 0
(a) $-\frac{2}{3\pi}$

33. In the Fourier series of the periodic function (shown in the figure) $f(x) = |\sin x| = \sum_{n=0}^{\infty}[\alpha_n \cos nx + \beta_n \sin nx]$. Which of the following coefficients are non-zero? **[IIT-JAM 2009]**

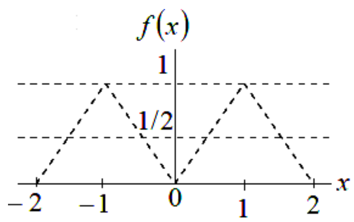


(a) α_n for odd n
(b) α_n for even n
(c) β_n for odd n
(d) β_n for even n

34. Given that $f(1) = 1, f'(1) = 1$, and $f''(1) = 1$, the value of $f(1/2)$ is ……….. **[IIT-JAM 2013]**

Ans.: 0.606

35. The Fourier series for an arbitrary periodic function with period 2L , is given by $f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\frac{n\pi x}{L} + \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{L}$. For the particular periodic function shown in the figure the value of a_0 is. **[IIT-JAM 2015]**



(a) 0 (b) 0.5 (c) 1 (d) 2

36. Fourier series of a given function f(x) in the interval 0 to L is. $f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\left(\frac{2\pi nx}{L}\right) + \sum_{n=1}^{\infty} b_n \sin\left(\frac{2\pi nx}{L}\right)$. If f(x)= x in the region (0, π), b_2 ……………… **[IIT-JAM 2016]**

37. For the Fourier series of the following function of period 2π. $f(x) = \begin{cases} 0 & -\pi < x < 0 \\ 1 & 0 < x < \pi \end{cases}$ **[IIT-JAM 2017]**

the ratio (to the nearest integer) of the Fourier coefficients of the first and the third harmonic is:

(a) 1 (b) 2 (c) 3 (d) 6

38. The function $f(x) = \begin{cases} x, & -\pi < x < 0 \\ -x, & 0 < x < \pi \end{cases}$ is expanded as a Fourier series of the form $a_0 + \sum_{n=1}^{\infty} a_n \cos(nx) + \sum_{n=1}^{\infty} b_n \sin(nx)$. Which of the following is true? **[IIT-JAM 2018]**

(a) $a_0 \neq 0, b_n = 0$ (b) $a_0 \neq 0, b_n \neq 0$

(c) $a_0 = 0, b_n = 0$ (d) $a_0 = 0, b_n \neq 0$

ALGEBRA OF COMPLEX NUMBERS

39. The value of $\sqrt{i} + \sqrt{-i}$, where $i = \sqrt{-1}$, is **[IIT-JAM 2013]**

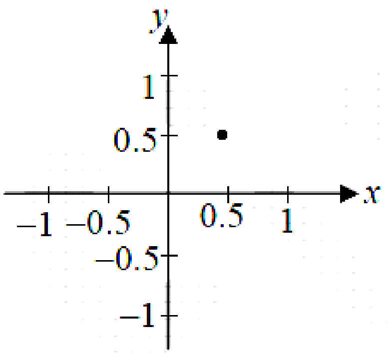
(a) 0 (b) $\frac{1}{\sqrt{2}}$ (c) $\sqrt{2}$ (d) $-\sqrt{2}$

40. The phase of the complex number (1+i)i in the polar representation is. **[IIT-JAM 2015]**

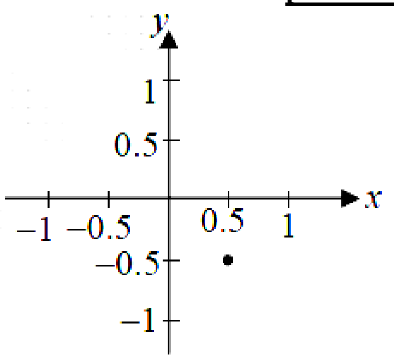
(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) $\frac{3\pi}{2}$ (d) $\frac{5\pi}{2}$

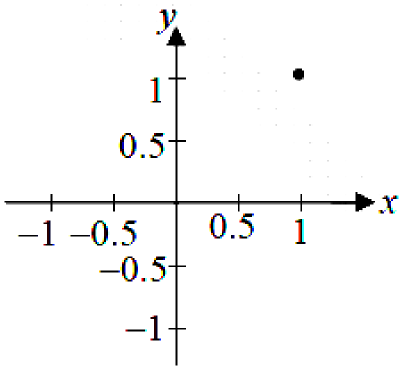
41. Which of the following points represent the complex number $= \frac{1}{1-i}$? **[IIT-JAM 2016]**

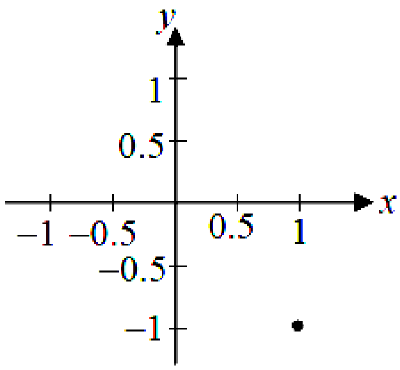
(a)



(b)



(c) 

(d) 

42. The coefficient of x^3 in the Taylor expansion of sin (sin x) around $x = 0$ is ______. (Specify your answer upto two digits after the decimal point). **[IIT-JAM 2018]**

DIFFERENTIAL EQUATIONS

43. The solution of the differential equation $dz(x,y) + xz(x,y)dx + yz(x,y)dy = 0$ is ……………… **[IIT-JAM 2013]**

44. Consider the equation $\frac{dy}{dx} = \frac{y^2}{x}$ with the boundary y(1) = 1. Out of the following the range of x in which y is real and finite is. **[IIT-JAM 2015]**

(a) $-\infty \le x \le -3$ (b) $-3 \le x \le 0$
(c) $0 \le x \le 3$ (d) $3 \le x \le \infty$

45. Consider the differential equation $y'' + 2y' + y = 0$. If $y(0) = 0$ and $y'(0) = 1$, then the value of y(2) is……………… (Specify your answer to two digits after the decimal point). **[IIT-JAM 2017]**

OTHER QUESTIONS

46. The work done by a force in moving a particle of mass m from any point (x, y) to a neighboring point (x+dx, y+dy) is given by $dW = 2xydx + x^2dy$. The work done for a complete cycle around a unit circle is. **[IIT-JAM 2008]**

(a) 0 (b) 1 (c) 3 (d) 2π

47. The value of $\sum_{n=0}^{\infty} r^n \sin(n\theta)$ for r = 0.5 and $\theta = \frac{\pi}{3}$ is. **[IIT-JAM 2014]**

(a) $\frac{1}{\sqrt{3}}$ (b) $\sqrt{\frac{2}{3}}$ (c) $\sqrt{\frac{3}{2}}$ (d) $\sqrt{3}$

48. Consider the coordinate transformation $x' = \frac{x+y}{\sqrt{2}}, y' = \frac{x-y}{\sqrt{2}}$. The relation between the area elements $dx'dy'$ and $dxdy$ is given by $dx'dy' = j\,dxdy$. The value of j is.

[IIT-JAM 2015]

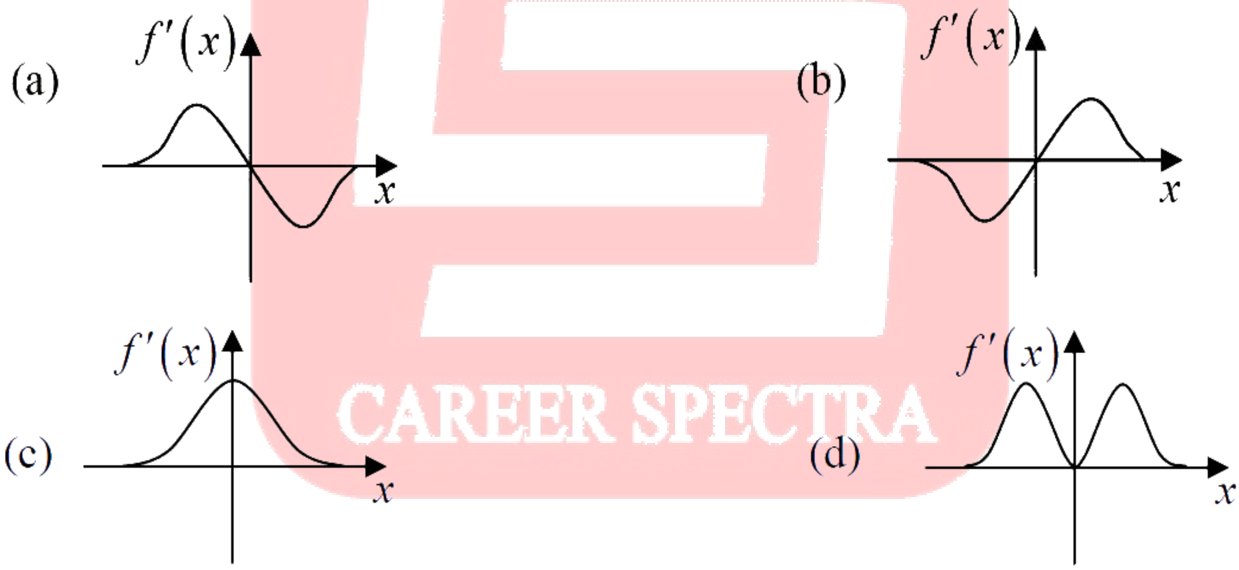
(a) 2 (b) 1 (c) -1 (d) - 2

49. For the given set of equations x + y =1, y +z =1, x + z = 1, which one of the following statements is correct? **[IIT-JAM 2016]**

(a) Equations are inconsistent
(b) Equations are consistent and a single non-trivial solution exists
(c) Equations are consistent and many solutions exist
(d) Equations are consistent and only a trivial solution exists.

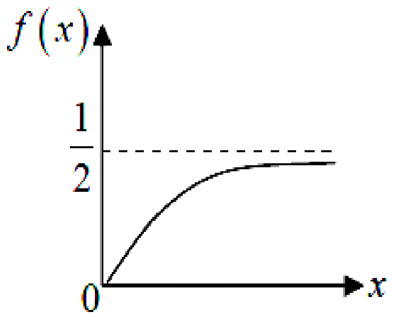
50. Consider a function $f(x, y) = x^3 + y^3$, where y represents a parabolic curve $x^2 + 1$. The total derivative of f with respect to x , at x = 1 is………………….
[IIT-JAM 2016]

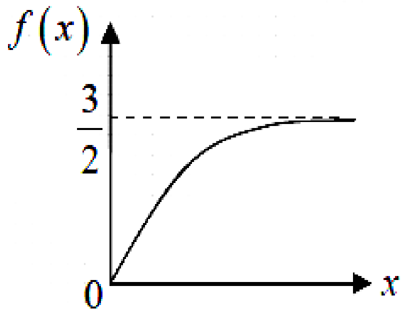
51. Which one of the following graphs represents the derivative $f'(x) = \frac{df}{dx}$ of the function $f(x) = \frac{1}{1+x^2}$ most closely (graphs are schematic and not drawn to scale)?
[IIT-JAM 2017]

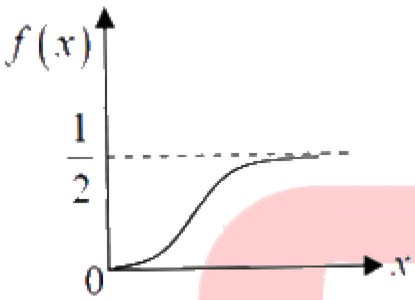


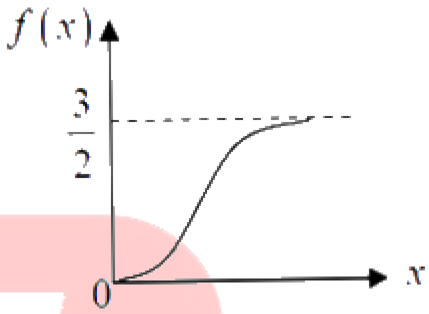
52. Consider two particles moving along the x - axis. In terms of their coordinates x_1 and x_2, their velocities are given as $\frac{dx_1}{dt} = x_2 - x_1$ and $\frac{dx_2}{dt} = x_1 - x_2$, respectively. When they start moving from their initial locations of $x_1(0) = 1$ and $x_2(0) = -1$, the time dependence of both x_1 and x_2 contains a term of the form ea t , where a is a constant. The value of a (an integer) is……………… **[IIT-JAM 2017]**

53. Which one of the following curves correctly represents (schematically) the solution for the equation $\frac{df}{dx} + 2f = 3: f(0) = 0$? **[IIT-JAM 2018]**

(a)


(b)


(c)


(d)


54. Consider the transformation to a new set of coordinates (ξ, η) from rectangular Cartesian Coordinates (x, y), where $\xi = 2x + 3y$ and $\eta = 3x - 2y$. In the (ξ, η)coordinate system, the area element dxdy is. **[IIT-JAM 2018]**

(a) $\frac{1}{13}d\xi d\eta$ (b) $\frac{2}{13}d\xi d\eta$ (c) $5d\xi d\eta$ (d) $\frac{3}{5}d\xi d\eta$

55. Let $f(x) = 3x^6 - 2x^2 - 8$. Which of the following statements is (are) true? **[IIT-JAM 2018]**

(a) The sum of all its roots is zero

(b) The product of its roots is $-\frac{8}{3}$

(c) The sum of all its roots is $\frac{2}{3}$

(d) Complex roots are conjugates of each other.

56. The function $f(x) = \frac{8x}{x^2+9}$ is continuous everywhere except at. **[IIT-JAM 2019]**

(a) $x = 0$ (b) $x = \pm 9$ (c) $x = \pm 9i$ (d) $x = \pm 3i$

57. The value of $\left|\int_0^{3+i} (\bar{z})^2 dz\right|^2$, along the line 3y = x , where z = x + iy is______ (Round off to 1 decimal places). **[IIT-JAM 2019]**

ANSWER KEY

1.	C	2.	D	3.	B	4.	C	5.	C	6.	C
7.	B	8.	A	9.	D	10.	B	11.	A,C,D	12.	A
13.	B	14.	B	15.	B	16.	A	17.	B	18.	C
19.	A	20.	B	21.	-2	22.	2	23.	D	24.	15.07
25.	B	26.	D	27.	A	28.	D	29.	A,B,C	30.	1.17
31.	C	32.	D	33.	B	34.	0.606	35.	C	36.	0.5
37.	C	38.	B	39.	A	40.	C	41.	A	42.	0.33
43.	$Ce^{-(x^2+y^2)/2}$	44.	D	45.	0.27	46.	A	47.	A	48.	C
49.	B	50.	27	51.	A	52.	2	53.	B	54.	A
55.	A,B,D	56.	D	57.	111.1						