

**C.S.E. (MAIN)**  
**MATHEMATICS — 2005**  
**PAPER-I**

**Time allowed : 3 hours**

**Maximum Marks : 300**

**INSTRUCTIONS**

*Each question is printed both in Hindi and in English.*

*Answers must be written in the medium specified in the Admission Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose. No marks will be given for the answers written in a medium other than that specified in the Admission Certificate.*

*Candidates should attempt Questions 1 and 5 which are compulsory, and any three of the remaining questions selecting at least one question from each Section.*

*Assume suitable data if considered necessary and indicate the same clearly.*

*The number of marks carried by each question is indicated at the end of the question.*

**SECTION 'A'**

**Q. 1. Attempt any five of the following :**

(a) Find the values of  $k$  for which the vectors  $(1, 1, 1, 1)$ ,  $(1, 3, -2, k)$ ,  $(2, 2k - 2, -k - 2, 3k - 1)$  and  $(3, k + 2, -3, 2k + 1)$  are linearly independent in  $\mathbf{R}^4$ . 12

(b) Let  $V$  be the vector space of polynomials in  $x$  of degree  $\leq n$  over  $\mathbf{R}$ . Prove that the set  $\{1, x, x^2, \dots, x^n\}$  is a basis for  $V$ . Extend this basis so that it becomes a basis for the set of all polynomials in  $x$ . 12

(c) Show that the function given below is not continuous at the origin : 12

$$f(x, y) = \begin{cases} 0 & \text{if } xy = 0 \\ 1 & \text{if } xy \neq 0 \end{cases}$$

(d) Let  $f : \mathbf{R}^2 \rightarrow \mathbf{R}$  be defined as

$$f(x, y) = \frac{xy}{\sqrt{(x^2 + y^2)}}, (x, y) \neq (0, 0)$$

$$f(0, 0) = 0$$

Prove that  $f_x$  and  $f_y$  exist at  $(0, 0)$ , but  $f$  is not differentiable at  $(0, 0)$ . 12

(e) If normals at the points of an ellipse whose eccentric angles are  $\alpha, \beta, \gamma$  and  $\delta$  meet in a point, then show that

$$\sin(\beta + \gamma) + \sin(\gamma + \alpha) + \sin(\alpha + \beta) = 0 \quad 12$$

(f) A square ABCD having each diagonal AC and BD of length  $2a$ , is folded along the diagonal AC so that the planes DAC and BAC are at right angle. Find the shortest distance between AB and DC. 12

**Q. 2.** (a) Let  $T$  be a linear transformation on  $\mathbf{R}^3$ , whose matrix relative to the standard basis of  $\mathbf{R}^3$  is

$$\begin{bmatrix} 2 & 1 & -1 \\ 1 & 2 & 2 \\ 3 & 3 & 4 \end{bmatrix}$$

Find the matrix of  $T$  relative to the basis.

$$\mathcal{B} = \{(1, 1, 1), (1, 1, 0), (0, 1, 1)\}$$

(b) Find the inverse of the matrix given below using elementary row operations only : 15

$$\begin{bmatrix} 2 & 0 & -1 \\ 5 & 1 & 0 \\ 0 & 1 & 3 \end{bmatrix}$$

(c) If  $S$  is a skew-Hermitian matrix, then show that  $A = (I + S)(I - S)^{-1}$  is a unitary matrix. Also show that every unitary matrix can be expressed in the above form provided  $-1$  is not an eigenvalue of  $A$ . 15

(d) Reduce the quadratic form

$$6x_1^2 + 3x_2^2 + 3x_3^2 - 4x_1x_2 - 2x_2x_3 + 4x_3x_1$$

to the sum of squares. Also find the corresponding linear transformation, index and signature. 15

**Q. 3.** (a) If  $u = x + y + z$ ,  $uv = y + z$  and  $uvw = z$ , then find

$$\frac{\partial(x, y, z)}{\partial(u, v, w)}$$

15

(b) Evaluate

$$\int_0^1 \frac{x^{m-1} + x^{n-1}}{(1+x)^{m+n}} dx$$

in terms of Beta function. 15

(c) Evaluate  $\iiint_V z dV$ , where  $V$  is the volume bounded below

by the cone  $x^2 + y^2 = z^2$  and above by the sphere  $x^2 + y^2 + z^2 = 1$ , lying on the positive side of the  $y$ -axis. 15

(d) Find the  $x$ -coordinate of the centre of gravity of the solid lying inside the cylinder  $x^2 + y^2 = 2ax$ , between the plane  $z = 0$  and the paraboloid  $x^2 + y^2 = az$ .

**Q. 4.** (a) A plane is drawn through the line  $x + y = 1, z = 0$  to

make an angle  $\sin^{-1} \left( \frac{1}{3} \right)$  with the plane  $x + y + z = 5$ . Show that two such planes can be drawn. Find their equations and the angle between them. 15

(b) Show that the locus of the centres of spheres of a co-axial system is a straight line. 15

(c) Obtain the equation of a right circular cylinder on the circle through the points  $(a, 0, 0)$ ,  $(0, b, 0)$  and  $(0, 0, c)$  as the guiding curve. 15

(d) Reduce the following equation to canonical form and determine which surface is represented by it : 15

$$2x^2 - 7y^2 + 2z^2 - 10yz - 8zx - 10xy + 6x + 12y - 6z + 2 = 0$$

### SECTION 'B'

**Q. 5. Attempt any five of the following :**

(a) Find the orthogonal trajectory of a system of co-axial circles  $x^2 + y^2 + 2gx + c = 0$ , where  $g$  is the parameter. 12

(b) Solve :

$$xy \frac{dy}{dx} = \sqrt{(x^2 - y^2 - x^2y^2 - 1)}$$

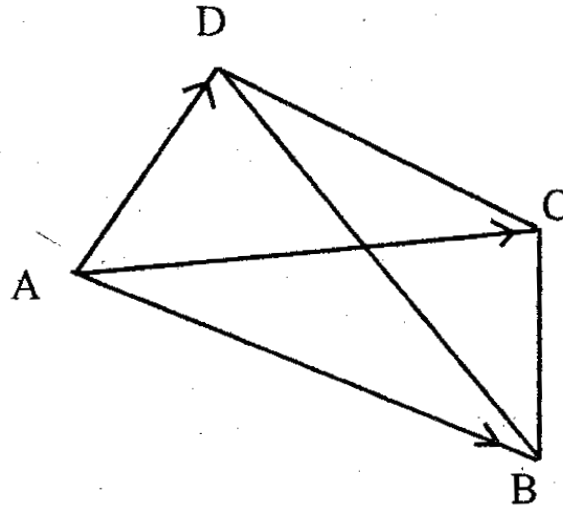
(c) A body of mass  $(m_1 + m_2)$  moving in a straight line is split into two parts of masses  $m_1$  and  $m_2$  by an internal explosion which generates kinetic energy  $E$ . If after the explosion, the two parts move in the same line as before, find their relative velocity. 12

(d) If a number of concurrent forces be represented in magnitude and direction by the sides of a closed polygon, taken in order, then show that these forces are in equilibrium. 12

(e) Show that the volume of the tetrahedron ABCD is  $\frac{1}{6} (\vec{AB} \times \vec{AC}) \cdot \vec{AD}$ . Hence, find the volume of the tetrahedron with

vertices  $(2, 2, 2)$ ,  $(2, 0, 0)$ ,  $(0, 2, 0)$  and  $(0, 0, 2)$ .

12



(f) Prove that the curl of a vector field is independent of the choice of coordinates. 12

Q. 6. (a) Solve the differential equation : 15

$$[(x+1)^4 D^3 + 2(x+1)^3 D^2 - (x+1)^2 D + (x+1)] y = \frac{1}{x+1}$$

(b) Solve the differential equation

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

where  $p = \frac{dy}{dx}$ , by reducing it to Clairaut's form by using suitable substitution. 15

(c) Solve the differential equation

$(\sin x - x \cos x) y'' - x \sin x y' + y \sin x = 0$  given that  $y = \sin x$  is a solution of this equation. 15

(d) Solve the differential equation

$$x^2 y'' - 2xy' + 2y = x \log x, x > 0$$

by variation of parameters. 15

Q. 7. (a) A particle is projected along the inner side of a smooth vertical circle of radius  $a$  so that its velocity at the lowest point is  $u$ . Show that if  $2ag < u^2 < 5ag$ , the particle will leave the circle before arriving at the highest point and will describe a pa-



parabola whose latus rectum is  $\frac{2(u^2 - 2ga)^3}{27g^3a^2}$  15

(b) Two particles connected by a fine string are constrained to move in a fine cycloidal tube in a vertical plane. The axis of the cycloid is vertical with vertex upwards. Prove that the tension in the string is constant throughout the motion. 15

(c) Two equal uniform rods AB and AC, of length  $a$  each, are freely joined at A, and are placed symmetrically over two smooth pegs on the same horizontal level at a distance  $c$  apart ( $3c < 2a$ ). A weight equal to that of a rod, is suspended from the joint A. In the position of equilibrium, find the inclination of either rod with the horizontal by the principle of virtual work. 15

(d) A rectangular lamina of length  $2a$  and breadth  $2b$  is completely immersed in a vertical plane, in a fluid, so that its centre is at a depth  $h$  and the side  $2a$  makes an angle  $\alpha$  with the horizontal. Find the position of the centre of pressure. 15

**Q. 8.** (a) The parametric equation of a circular helix is

$$\mathbf{r} = a \cos u \hat{i} + a \sin u \hat{j} + cu \hat{k}$$

where  $c$  is a constant and  $u$  is a parameter. Find the unit tangent vector  $\hat{t}$  at the point  $u$  and the arc length measured from  $u = 0$ .

Also find  $\frac{d\hat{t}}{ds}$ , where  $s$  is the arc length. 15

(b) Show that

$$\text{curl} \left( \mathbf{k} \times \text{grad} \frac{1}{r} \right) + \text{grad} \left( \mathbf{k} \cdot \text{grad} \frac{1}{r} \right) = 0$$

where  $r$  is the distance from the origin and  $\mathbf{k}$  is the unit vector in the direction OZ. 15

(c) Find the curvature and the torsion of the space curve

$$x = a(3u - u^3)$$

$$y = 3au^2$$

$$z = a(3u + u^3)$$

(d) Evaluate

15

$$\oiint_S (x^3 dy dz + x^2 y dz dx + x^2 z dx dy)$$

by Gauss divergence theorem, where S is the surface of the cylinder  $x^2 + y^2 = a^2$  bounded by  $z = 0$  and  $z = b$ .

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