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3 (Sem-5/CBCS) MAT HC 2

2023

MATHEMATICS

(Honours Core)

Paper : MAT-HC-5026

(Linear Algebra)

Full Marks : 80

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions as directed :

1×10=10

(a) Let $A = \begin{pmatrix} 1 & -3 & -2 \\ -5 & 9 & 1 \end{pmatrix}$ and $\vec{u} = \begin{bmatrix} 5 \\ 3 \\ -2 \end{bmatrix}$.

Check whether \vec{u} is in null space of A.

(b) Define subspace of a vector space.

(c) Give reason why \mathbb{R}^2 is not a subspace of \mathbb{R}^3 .

Contd.

(d) State whether the following statement is true **or** false :

"If dimension of a vector space V is $p > 0$ and S is a linearly dependent subset of V , then S contains more than p elements."

(e) If \vec{x} is an eigenvector of A corresponding to the eigenvalue λ then what is $A^3\vec{x}$?

(f) When two square matrices A and B are said to be similar ?

(g) If $\vec{v} = (1 \ -2 \ 2 \ 4)$ then find $\|\vec{v}\|$.

(h) Find a unit vector in the direction of

$$\vec{u} = \begin{bmatrix} 8/3 \\ 2 \end{bmatrix}.$$

(i) Under what condition two vectors \vec{u} and \vec{v} are orthogonal to each other ?

(j) Define orthogonal complement of vectors.

2. Answer the following questions :

2×5=10

(a) Show that the set $W = \left\{ \begin{bmatrix} x \\ y \end{bmatrix} : xy \geq 0 \right\}$ is

not a subspace of \mathbb{R}^2 .

(b) Let $\bar{b}_1 = \begin{bmatrix} 2 \\ 1 \end{bmatrix}$, $\bar{b}_2 = \begin{bmatrix} -1 \\ 1 \end{bmatrix}$, $\bar{x} = \begin{bmatrix} 4 \\ 5 \end{bmatrix}$ and

$\beta = \{b_1, b_2\}$. Find the coordinate vector $[x]_\beta$ of \bar{x} relative to β .

(c) Find the eigenvalues of $A = \begin{bmatrix} 2 & 3 \\ 3 & -6 \end{bmatrix}$.

(d) Let P_2 be the vector space of all polynomials of degree less than equal to 2. Consider the linear transformation

$T: P_2 \rightarrow P_2$ defined by

$T(a_0 + a_1t + a_2t^2) = a_1 + 2a_2t$. Find the matrix representation $[T]_\beta$ of T with respect to the base $\beta = \{1, t, t^2\}$.

(e) Show that the matrix $A = \begin{bmatrix} 1 & 2 \\ \sqrt{2} & 3 \\ 1 & -2 \\ \sqrt{2} & 3 \\ 0 & \frac{1}{3} \end{bmatrix}$

has orthogonal columns.

3. Answer **any four** questions : $5 \times 4 = 20$

(a) Let $S = \{v_1, v_2, \dots, v_p\}$ be a set in the vector space V and $H = \text{span}(S)$. Now if one of the vector in S , say v_k , is linear combination of the other vectors in S , then show that S is linearly dependent and the subset of $S_1 = S - \{v_k\}$ still span H . $2+3=5$

(b) Show that the set of all eigenvectors corresponding to the distinct eigenvalues of a $n \times n$ matrix A is linearly independent.

(c) Let W be a subspace of the vector space V and S is a linearly independent subset of W . Show that S can be extended, if necessary, to form a basis for W and $\dim W \leq \dim V$.

(d) If $A = \begin{bmatrix} 1 & 3 & 3 \\ -3 & -5 & -3 \\ 3 & 3 & 1 \end{bmatrix}$. Find an

invertible matrix P and a diagonal matrix D such that $A = PDP^{-1}$.

(e) If $\bar{y} = \begin{bmatrix} 2 \\ 3 \end{bmatrix}$ and $\bar{u} = \begin{bmatrix} 4 \\ -7 \end{bmatrix}$ then find the orthogonal projection of \bar{y} onto \bar{u} and write \bar{y} as the sum of two orthogonal vectors, one in $\text{span}\{\bar{u}\}$ and the other orthogonal to \bar{u} .

(f) If $W = \text{span}\{x_1, x_2\}$ where $x_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$,

$x_2 = \begin{bmatrix} 1 \\ 3 \\ -2 \\ 3 \end{bmatrix}$, find an orthogonal basis for

W .

Answer **either** (a) **or** (b) from each of the following questions : $10 \times 4 = 40$

4. (a) Find a spanning set for the null space of the matrix :

$$A = \begin{bmatrix} -3 & 6 & -1 & 1 & -7 \\ 1 & -2 & 2 & 3 & -1 \\ 2 & -4 & 5 & 8 & -4 \end{bmatrix}$$

Is this spanning set linearly independent?

$8 + 2 = 10$

- (b) (i) If a vector space V has a basis of n vectors, then show that every basis of V must consist of exactly n vectors. 4
- (ii) Find a basis for column space of the following matrix : 6

$$B = \begin{bmatrix} 1 & 4 & 0 & 2 & -1 \\ 3 & 12 & 1 & 5 & 5 \\ 2 & 8 & 1 & 3 & 2 \\ 5 & 20 & 2 & 8 & 8 \end{bmatrix}$$

5. (a) Define eigenvalue and eigenvector of a matrix. Find the eigenvalues and corresponding eigenvectors of the

matrix $\begin{bmatrix} 2 & 3 \\ 3 & -6 \end{bmatrix}$. 2+8=10

- (b) Let T be a linear operator on a finite dimensional vector space V and let W denote the T -cyclic subspace of V generated by a non-zero vector $v \in V$. If $\dim(W) = k$ then show that

- (i) $\{v, T(v), T^2(v), \dots, T^{k-1}(v)\}$ is a basis for W .

(ii) If

$$a_0v + a_1T(v) + \dots + a_{k-1}T^{k-1}(v) + T^k(v) = 0,$$

then the characteristic polynomial of T_w is

$$f(t) = (-1)^k (a_0 + a_1t + \dots + a_{k-1}t^{k-1} + t^k).$$

$$6+4=10$$

6. (a) (i) Define orthogonal set of vectors.

Let $S = \{\bar{u}_1, \bar{u}_2, \dots, \bar{u}_p\}$ is an

orthogonal set of non-zero vectors in \mathbb{R}^n , then show that S is linearly independent. $1+4=5$

(ii) For any symmetric matrix show that any two eigenvectors from different eigenspaces are orthogonal. 5

(b) Define inner product space. Show that the following is an inner product in \mathbb{R}^2

$$\langle u, v \rangle = 4u_1v_1 + 5u_2v_2$$

Where $u = (u_1, u_2), v = (v_1, v_2) \in \mathbb{R}^2$

Also, show that in any inner product space V ,

$$|\langle u, v \rangle| \leq \|u\| \cdot \|v\|, \quad \forall u, v \in V.$$

$$2+4+4=10$$

7. (a) (i) Consider the bases $\beta = \{b_1, b_2\}$ and $\gamma = \{c_1, c_2\}$ for \mathbb{R}^2 where

$$b_1 = \begin{bmatrix} 1 \\ -3 \end{bmatrix}, \quad b_2 = \begin{bmatrix} -2 \\ 4 \end{bmatrix}, \quad c_1 = \begin{bmatrix} -7 \\ 9 \end{bmatrix}$$

and $c_2 = \begin{bmatrix} -5 \\ 7 \end{bmatrix}$, find the change

of coordinate matrix from γ to β and from β to γ . 5

(ii) Compute A^{10} where

$$A = \begin{bmatrix} 4 & -3 \\ 2 & -1 \end{bmatrix}. \quad 5$$

(b) State Cayley-Hamilton theorem for matrices. Verify the theorem for the

matrix $M = \begin{bmatrix} 3 & 1 \\ -1 & 2 \end{bmatrix}$ and hence find M^{-1} .