Math 3013.69033
Final Exam for Students Outside the US
8:00pm – 10:00pm, December 10, 2020

Name:______________________________

1. Give the definitions of the following linear algebraic concepts:

(a) (5 pts) a **subspace** of a vector space V.

(b) (5 pts) a **basis** for a subspace W of a vector space V

(c) (5 pts) a set of **linearly independent** vectors

(d) (5 pts) a **linear transformation** between two vector spaces V and W.

2. For each of the following augmented matrices, describe the solution space of the corresponding linear system. (Determine if there are solutions; and, if there are solutions, how many free parameters are needed to describe the general solution.)

(a) (5 pts) $\left[\begin{array}{cccc|c} 1 & 0 & 2 & 1 & 1 \\ 0 & 1 & 0 & 1 & 2 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \end{array}\right]$

(b) (5 pts) $\left[\begin{array}{cccc|c} 1 & 0 & 4 & 2 & 1 \\ 0 & 2 & 0 & 3 & 2 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{array}\right]$

(c) (5 pts) $\left[\begin{array}{ccc|c} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 0 \end{array}\right]$

3. (10 pts) Compute the inverse of $\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -2 & 0 \\ 0 & 2 & 1 \end{bmatrix}$

4. (10 pts) Let $W = \{[x, y] \in \mathbb{R}^2 \mid x + y = 0 \in \mathbb{R}\}$. Prove or disprove that W is a subspace of $\mathbb{R}^2$.

5. Consider the vectors $\{[1, -1, -1, 1], [2, -1, -2, 0], [1, 0, -1, -1], [3, -2, -3, 1]\} \in \mathbb{R}^4$

(a) (10 pts) Determine if these vectors are linearly independent.

(b) (5 pts) What is the dimension of the subspace generated by these vectors (i.e. the subspace spanned by these vectors)?

6. Consider the following linear transformation: $T : \mathbb{R}^3 \to \mathbb{R}^2 : T\left([x_1, x_2.x_3]\right) = [x_2 - x_1\,,\, x_1 - x_2]$.

(a) (10 pts) Find a matrix that represents T.

(b) (10 pts) Find a basis for the kernel of T (i.e. the set of vectors $\mathbf{x}$ such that $T(\mathbf{x}) = \mathbf{0}$).

7. (a) (15 pts) Find the eigenvalues and the eigenvectors of the following matrix : $\mathbf{A} = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 2 \end{bmatrix}$

(b) (5 pts) What are the algebraic multiplicities and geometric multiplicities of the eigenvalues of $\mathbf{A}$?

(c) (5 pts) Is this matrix diagonalizable?

8. (10 pts) Let $\mathbf{A}$ be the matrix $\begin{bmatrix} 3 & 1 \\ 1 & 3 \end{bmatrix}$. Find a 2×2 matrix $\mathbf{C}$ and a diagonal matrix $\mathbf{D}$ such that $\mathbf{C}^{-1}\mathbf{A}\mathbf{C} = \mathbf{D}$.

9. (10 pts) Find an orthonormal basis for the subspace W generated by the vectors $\mathbf{v}_1 = [1, -1, 0]$ and $\mathbf{v}_2 = [1, 0, 1]$

10. (15 pts)Let $\mathbf{v} = [2, 1, 0]$ and let $W = span\,([1\ , 1, 0]\,,\ [1, 0, 1])$. Find the orthogonal decomposition $\mathbf{v} = \mathbf{v}_W + \mathbf{v}_\perp$ of $\mathbf{v}$ with respect to the subspace W.