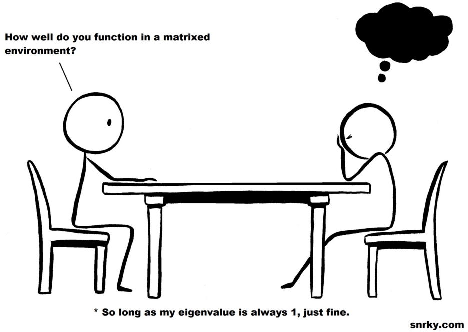
MATH 226 Differential Equations



Class 11: October 5, 2022

Assignment 8

Notes on Sample Exam 1

Project 1 Peer and Self Evaluations

Announcements

- First Team Projects Due Tomorrow
- Exam 1
  - Wenesday, October 12
  - 7 PM - ? (No Time Limit)
  - No Calculators, Books, Notes, Smart Phones, etc.
  - Focus on Material in Chapters 1 and 2

Today's Topics

Introduction To Systems of First Order Differential Equations

Lotka – Volterra Predator Prey Model

$$x(t) = \text{Population of Prey}$$
$$y(t) = \text{Population of Predator}$$

$$x' = ax - bxy$$

$$y' = mxy - ny$$

where a, b, m, n are positive constants.

Richardson Arms Race Model

$$x(t) = \text{Arms Expenditure of Blue Nation}$$
$$y(t) = \text{Arms Expenditure of Red Nation}$$

$$x' = ay - mx + r$$

$$y' = bx - ny + s$$

where a, b, m, n are positive constants while r and s are constants.

Kermack – McKendrick Epidemic Model

(1927 – 1939)

$$\boxed{\text{Susceptibles}} \rightarrow \boxed{\text{Infectives}} \rightarrow \boxed{\text{Removeds}}$$

S = Number of Susceptibles
I = Number of Infectives
R = Number of Recovereds

$$S' = -\beta S I$$

$$I' = \beta S I - r I$$

$$R' = r I$$

Home Heating Model

$x(t)$ = Temperature of the Ground Floor
$y(t)$ = Temperature of Upper Floor
k = coefficient of thermal conductivity
k_1 = Thermal Conductivity of Floor on Ground Level
k_2 = Thermal Conductivity of Ceiling on Ground Level
k_3 = Thermal Conductivity of Walls on Ground Level
k_4 = Thermal Conductivity of Walls on Upper Floor and Roof
T_e = Temperature of Surrounding Environment

$$x' = -(k_1 + k_2 + k_3)x + k_2 y + k_1 T_g + k_3 T_e(t) + f(t)$$
$$y' = k_2 x - (k_2 + k_4)y + k_4 T_e(t)$$

where $f(t)$ describes the heat source located on the ground floor.

Terrorism

$x =$ Number of Terrorists at time t
$y =$ Number of Individuals Who Can Be Influenced By Terrorist Propaganda and Counter – Terrorist Influence.
$z =$ Number of Individuals Resistant To Terrorist Propaganda

$$x' = ay - bx^2 + (c - 1)$$
$$y' = -axy - cx^2y + fx + gy$$
$$z' = ex^2y - hx + mz$$

Our Focus: Linear Models

$$x' = a(t)x + b(t)y + f(t),\ y' = c(t)x + d(t)y + g(t)$$

Narrow Focus First to **Homogeneous Systems**

$$x' = a(t)x + b(t)y,\ y' = c(t)x + d(t)y$$

Initial Concern: **Homogeneous Systems of 2 First Order Differential Equations With Constant Coefficients**

$$x' = ax + by,\ y' = cx + dy$$

has form **X'** $=$ A **X** where **X** $= \begin{bmatrix} x(t) \\ y(y) \end{bmatrix}$

Ideas and Tools From Linear Algebra Are Essential To This Study

Initial Concern: **Homogeneous Systems of 2 First Order Differential Equations With Constant Coefficients**

$$x' = ax + by,\ y' = cx + dy$$

$$\begin{bmatrix} x \\ y \end{bmatrix}' = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$\mathbf{X'} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \mathbf{X}$$

Ideas and Tools From Linear Algebra Are Essential To This Study

Start With System of Linear **ALGEBRAIC** Equations

Two Linear Equations in 2 Unknowns

$$3x + 4y = 18$$

$$5x - 2y = 4$$

Geometric Nature of Possible Solutions

1 Solution   No Solutions   Infinitely Many Solutions

Matrix Representation

$$\begin{bmatrix} 3 & 4 \\ 5 & -2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 18 \\ 4 \end{bmatrix}$$

$$A \quad \mathbf{X} = \mathbf{b}$$

Reduce A to Row Echelon Form

Example

$$3x_1 + 5x_2 - 4x_3 = 0$$

$$-3x_1 - 2x_2 + 4x_3 = 0$$

$$6x_1 + x_2 - 8x_3 = 0$$

$$\begin{bmatrix} 3 & 5 & -4 & | & 0 \\ -3 & -2 & 4 & | & 0 \\ 6 & 1 & -8 & | & 0 \end{bmatrix} \Rightarrow \begin{bmatrix} 1 & 0 & -4/3 & | & 0 \\ 0 & 1 & 0 & | & 0 \\ 0 & 0 & 0 & | & 0 \end{bmatrix}$$

$$x_2 = 0$$
$$x_1 = \frac{4}{3}x_3 \rightarrow x_3 = \frac{3}{4}x_1$$

$$\mathbf{X} = \begin{bmatrix} a \\ 0 \\ \frac{3}{4}a \end{bmatrix}, a \text{ any value}$$

One Dimensional Set of Solutions

EIGENVALUES AND EIGENVECTORS

$$A \quad n \times n \quad \text{[Square Matrix]}$$
$$\vec{x} \quad n \times 1 \quad \text{[Element of } R^n \text{]}$$

Then $A\vec{x}$ is another vector in R^n.

Is there a **nonzero** vector $\vec{v}$ and a constant λ such that

$$A\vec{v} = \lambda\vec{v}?$$

The equation $A\vec{v} = \lambda\vec{v}$ is equivalent to

$$A\vec{v} - \lambda\vec{v} = \vec{0}$$

or $(A - \lambda I)\vec{v} = \vec{0}$

which is a system of homogeneous equations.

The system has nontrivial solution if and only if $(A - \lambda I)$ is Non-Invertible.

$$\Rightarrow det(A - \lambda I) = 0.$$