Midterm 3 Review - Math 243

1. Find all equilibrium solutions for the following nonlinear system.

$$\frac{dx}{dt} = xy - 4x$$
$$\frac{dy}{dt} = y - x^2 + 5$$

2. Consider the non-homogeneous linear system

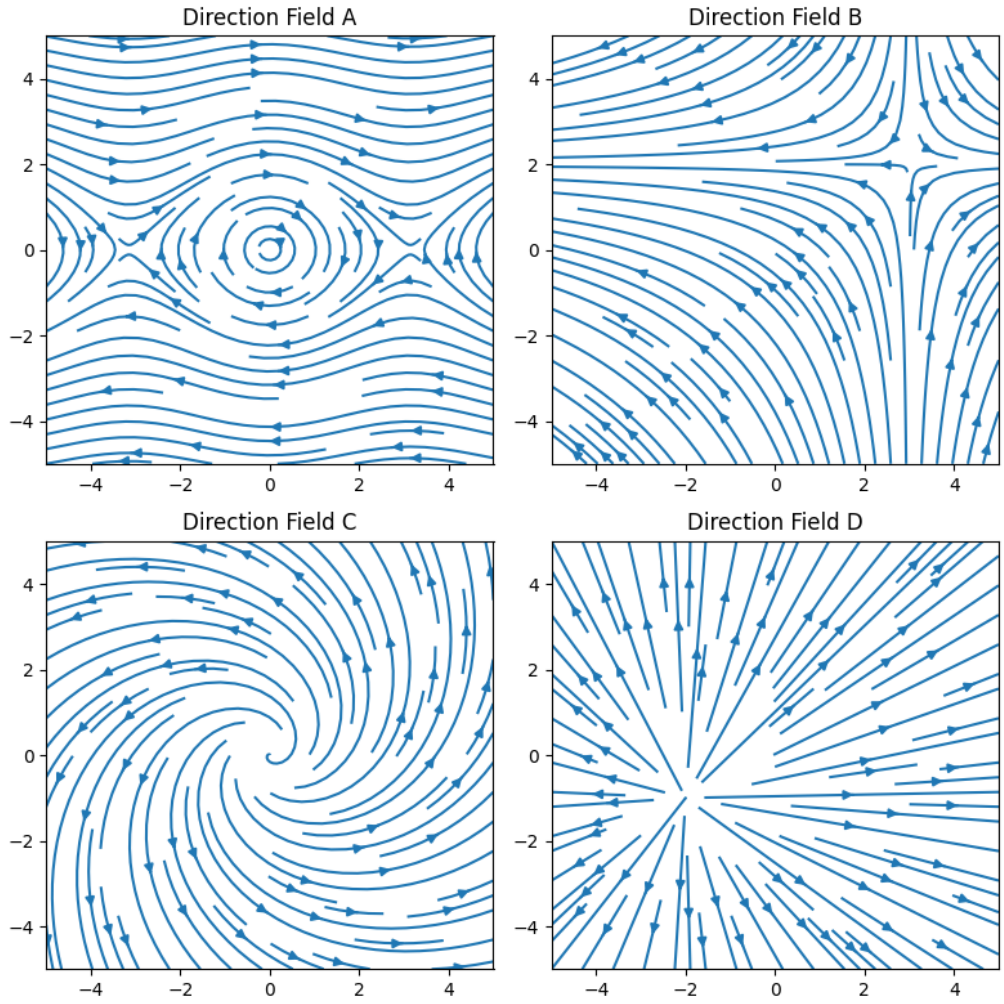
$$\frac{d\mathbf{y}}{dt} = A\mathbf{y} + \mathbf{b}, \text{ where } A = \begin{bmatrix} 1 & 3 \\ -1 & 1 \end{bmatrix} \text{ and } \mathbf{b} = \begin{bmatrix} -6 \\ 2 \end{bmatrix}.$$

   (a) Find the equilibrium point for the system.

   (b) Find the general solution to the system above. Hint, the eigenvectors and eigenvalues of A are $\lambda_1 = 1 - \sqrt{3}i$ with $\mathbf{v}_1 = \begin{bmatrix} \sqrt{3}i \\ 1 \end{bmatrix}$ and $\lambda_2 = 1 + \sqrt{3}i$ with $\mathbf{v}_2 = \begin{bmatrix} -\sqrt{3}i \\ 1 \end{bmatrix}$.

   (c) If we replace the constant vector $\mathbf{b}$ above with the vector-valued function $\mathbf{b}(t) = \begin{bmatrix} -6e^{-t} \\ 2e^{-t} \end{bmatrix}$, then what would make a good guess for a particular solution $\mathbf{y}_p$ for this new system?

3. Which of the following phase-portraits could show a Hamiltonian system? There might be more than one correct option.



4. Find a Hamiltonian function for the system

$$x' = 3y^2 + \cos x,$$
$$y' = 2x + y \sin x.$$

5. Consider the following forced harmonic oscillator.

$$y'' + 3y' + 2y = \cos 2t$$

(a) What is the complexification of this differential equation?

(b) Find a particular solution for this differential equation.

(c) Find the general solution for this differential equation.

(d) If this system represents a harmonic oscillator, is it overdamped or underdamped? How can you tell?

6. Consider the system

$$\frac{dx}{dt} = x^2 - y$$
$$\frac{dy}{dt} = x^2 - 1$$

(a) Find all equilibria.

(b) Use linearization (i.e., the Jacobian matrix) to classify each equilibrium point.

7. Consider the system

$$\frac{dx}{dt} = x\cos(xy)$$
$$\frac{dy}{dt} = -y\cos(xy)$$

(a) Show that the quantity $H(x, y) = \sin(xy)$ is a Hamiltonian function for the system.

(b) Sketch the level sets for this system. Hint: The level sets occur when xy is a constant. What does the graph of $xy = c$ look like?

(c) Sketch the solution curve that passes through the point $(1, \pi)$. Be sure to indicate the direction of the solution.

8. Find general solutions to the following non-homogeneous equations.

(a) $y'' - y' - 6 = e^{4t}$

(b) $y'' - y' - 6 = e^{2t}$

(c) $y'' + 4y = \cos(2t)$

(d) $y'' + 2y' + 6y = 3t + 2$