

### Midterm 3 Review - Math 243

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

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

2. Consider the non-homogeneous linear system

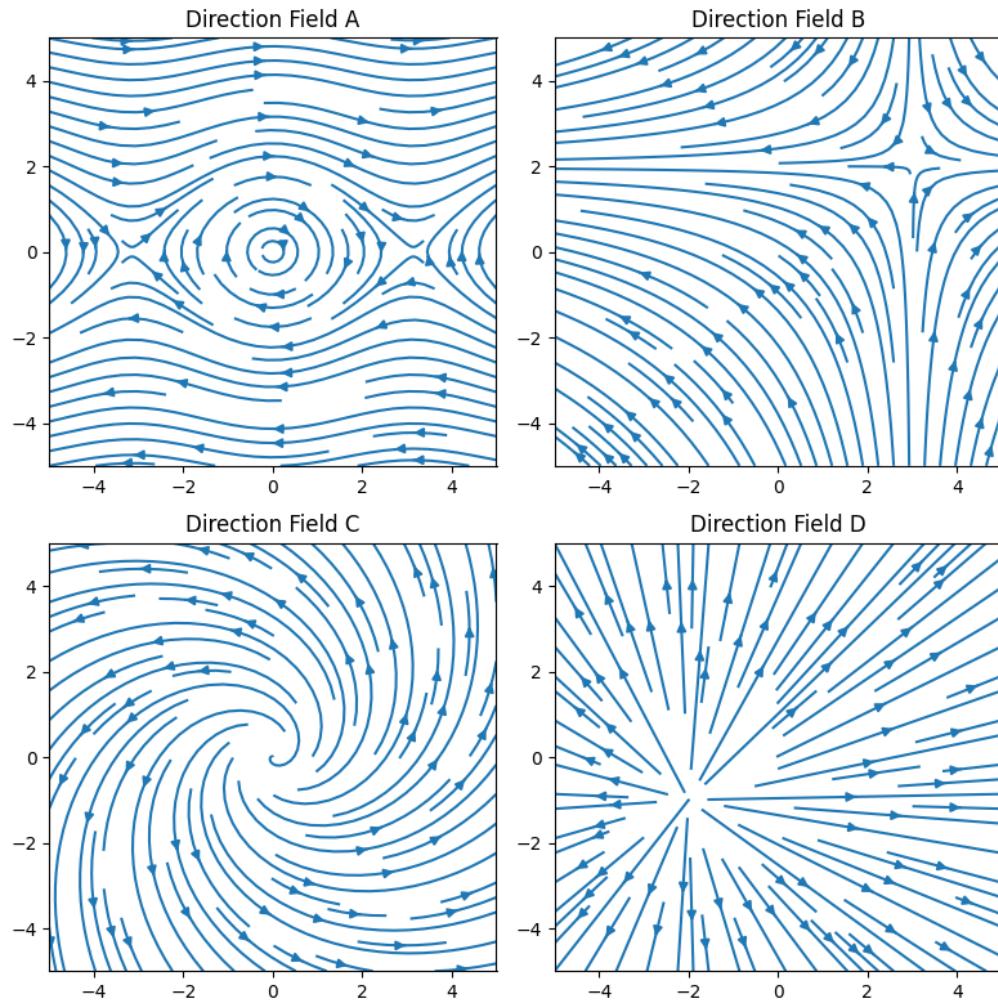
$$\frac{d\mathbf{y}}{dt} = A\mathbf{y} + \mathbf{b}, \text{ where } A = \begin{bmatrix} 1 & 3 \\ -1 & 1 \end{bmatrix} \text{ and } \mathbf{b} = \begin{bmatrix} -6 \\ 2 \end{bmatrix}.$$

- (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

$$\begin{aligned}x' &= 3y^2 + \cos x, \\y' &= 2x + y \sin x.\end{aligned}$$

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

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

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

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