1. Let \( z = f(x, y) = x^3y - y \ln x \)
   a) Find \( f_x \) and \( f_y \)
   b) Show that \( f_{xy} = f_{yx} \)
   c) Suppose we switch to polar coordinates so that \( x = r \cos \theta \), \( y = r \sin \theta \). Find \( \frac{\partial z}{\partial r} \) when \( r = 1 \), \( \theta = \pi/4 \)

2. Consider \( f(x, y) = -x^3 + 4xy - 2y^2 + 1 \)
   a) Find \( \nabla f(x, y) \)
   b) Find the directional derivative of \( f(x, y) \) at the point \((1, 0)\) in the direction toward \((2, 2)\).
   c) Find all critical points of \( f(x, y) \) and classify them using the 2nd partials test.

3. Evaluate each iterated integral:
   a) \( \int_0^{\pi/2} \int_0^1 \frac{1}{e^x \ln y} \, dy \, dx \)
   b) \( \int_0^3 \int_0^{\sqrt{9-x^2}} (x^2 + y^2)^{3/2} \, dy \, dx \)

4. Evaluate the line integral:
   \( \int_C F \cdot T \, ds \), where \( C \) is given by:
   \( x = t \quad 0 \leq t \leq 2 \)
   \( y = \frac{3}{2} (t^2 - t) \)
   and \( F = \langle ye^{xy}, xe^{xy} \rangle \)

5. Evaluate the line integral \( \int_C y^3 \, dx + (x^3 + 3xy^2) \, dy \)
   where \( C \) is the closed path shown:

   ![Diagram of closed path]

6. Consider \( A = \begin{pmatrix} -1 & 1 & -1 \\ 2 & 1 & 0 \\ 3 & 0 & 1 \end{pmatrix} \)
   a) Characterize \( N(A) \).
   b) Compute the rank and nullity of \( A \).
   c) Find all eigenvalues of \( A \).
   d) Is \( A \) diagonalizable?
   e) Is \( A \) defective?

5. Consider the vectors \( \vec{u} = \begin{pmatrix} 1 \\ -2 \\ -1 \end{pmatrix} \)
   \( \vec{v} = \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} \)
   \( \vec{e}_1 = \begin{pmatrix} 4 \\ -1 \\ 5 \end{pmatrix} \)
   \( \vec{e}_2 = \begin{pmatrix} 0 \\ 4 \end{pmatrix} \)
   a) Does \( \{ \vec{u}, \vec{v}, \vec{w}, \vec{e}_1, \vec{e}_2 \} \) span \( \mathbb{R}^4 \)?
   b) Find a basis for \( \text{sp} \{ \vec{u}, \vec{v}, \vec{w}, \vec{e}_1, \vec{e}_2 \} \)

7. Consider the matrix \( A = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \)
   a) Find a nonsingular matrix \( S \) such that \( S^{-1}AS \) is diagonal.
   Verify by direct computation that \( S^{-1}AS \) is diagonal.
   b) Compute \( A^5 \)