1. (8 pts) Let \( f(x, y) = \frac{x^2y}{x^4 + y^2} \). Show that \( \lim_{(x, y) \to (0, 0)} f(x, y) \) does not exist.

2. (8 pts) Find \( \frac{\partial u}{\partial s} \) where \( u(x, y) = \ln(x + e^y), \ x = s \sin st, \ y = t \ln s \). Express your answer in terms of \( s \) and \( t \).

3. (15+6+6 pts) The temperature in a neighborhood of the point \((1, 1)\) is given by the function
\[ T(x, y) = e^{-x^2y}. \]
(a) Find the path followed by a heat-seeking particle that originates at the point \((1, 1)\).
(b) Find the directional derivative of \( T(x, y) \) at \((1, 1)\) toward the point \((-1, 3)\).
(c) Find an equation for the plane tangent to the surface \( z = T(x, y) \) at the point \((1, 1, \frac{1}{e})\).

4. (15 pts) Find all stationary points and all local extreme values of \( f(x, y) = 3xy - x^3 - y^3 + 2 \).

5. (15 pts) Find the absolute extreme values of \( f(x, y) = x^2 + y^2 + 3xy + 2 \) on the set
\[ D = \{(x, y) \mid x^2 + y^2 \leq 4\}. \]

6. (15 pts) Use the Lagrange multiplier method to determine the maximum value of \( f(x, y, z) = 3x - 2y + z \) on the sphere \( x^2 + y^2 + z^2 = 14 \).

7. (12 pts) Determine whether the vector function
\[ (1 + y^2 + xy^2)i + (x^2y + y + 2xy + 1)j \]
is the gradient \( \nabla f(x, y) \) of a function \( f \) everywhere defined. If so, find all such functions.

8. (15 pts) Sketch the region \( \Omega \) that gives rise to the repeated integral \( \int_0^1 \int_0^{\sqrt{x^2-x^2}} \sin \left( \frac{y^2+1}{2} \right) dy dx \), change the order of integration, then evaluate.

9. (10+10 pts)
(a) Rewrite \( \int_0^2 \int_0^{\sqrt{2x-x^2}} x dy dx \) as a repeated integral in polar coordinates. Do not evaluate the integral.
(b) Express the mass of \( T \) by a repeated integral (do not evaluate the integral), where \( T \) is the solid bounded by the planes \( z = y + 1, \ y + z = 1, \ x = 0, \ x = 1, \ z = 0 \), and its density function is \( \lambda(x, y, z) = x^2y^2z^2 + 1 \).

10. (15 pts) Use cylindrical coordinates to find the volume of the "ice cream cone" bounded below by the half-cone \( z = \sqrt{3(x^2 + y^2)} \) and above by the unit sphere \( x^2 + y^2 + z^2 = 1 \).