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

2. (8 pts) Find $\dfrac{\partial u}{\partial s}$ 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
$$T(x,y) = e^{-x^2 y}.$$
   (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
$$D = \{(x,y) \mid x^2 + y^2 \le 4\}.$$

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
$$(1 + y^2 + xy^2)\mathbf{i} + (x^2 y + y + 2xy + 1)\mathbf{j}$$
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 Ω that gives rise to the repeated integral $\displaystyle\int_0^1 \int_{\sqrt{x}}^1 \sin\left(\frac{y^3+1}{2}\right) dydx$, change the order of integration, then evaluate.

9. (10+10 pts)
   (a) Rewrite $\displaystyle\int_0^2 \int_0^{\sqrt{2x-x^2}} x\,dydx$ 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 $\lambda(x,y,z) = x^2 y^2 z^2 + 1$.

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 $x^2 + y^2 + z^2 = 1$.