1. A quantity $Q$ depends upon $x$ and $y$ according to

$$Q = x \left( x^2 + 4y \right)^{\frac{1}{2}}.$$ 

Both $x$ and $y$ are changing with the time $t$ and, at a certain instant, you know that $x = 3$, $y = 4$, $\frac{dx}{dt} = -1$ and $\frac{dy}{dt} = 4$.

Use the chain rule to calculate $\frac{dQ}{dt}$ at this instant.
2. Let \( f(x, y) = x^3y - 12xy + y^2 \).

a) Find the gradient vector field of \( f(x, y) \)

\[ \nabla f = \]

b) Find the directional derivative of \( f(x, y) \) at \((x, y) = (1, 2)\) in the direction of the vector \( a = 3i - 4j \).

c) Find the value of the largest directional derivative of \( f(x, y) \)
at the point \((x, y) = (1, 2)\)

d) Find a unit vector which points in the direction that gives the largest directional derivative for \( f(x, y) \) at the point \((x, y) = (1, 2)\).
3. Find the equation of the tangent plane to the surface

\[ z = \exp(-x^2 - y^2) \]

at the point determined by \( x = 1 \) and \( y = -2 \).
(25) 4. Let $f(x,y) = x^3y - 12xy + y^2$. Find all the critical points of $f(x,y)$ and then apply the 2nd partials test to each critical point to determine the local max points, local min points and saddle points.
5. Use the method of Lagrange Multipliers to find the largest value and the smallest value of $f(x,y) = x^2 + 2y^2 - 4y$ on the circle $x^2 + y^2 = 16$. 
(10) 6. Use a double integral to calculate the volume of the 3D-region which is under \( z = 5x + 2y \) and above the region in the 1st quadrant of the xy-plane that is bounded by \( x = y^2, x = 4, y = 0 \).