1.) Let \( f(x) = (2x, e^{3x-3}) \). Let \( g(x, y) = \sqrt{x^2y - 4} \). Use the chain rule to calculate \( D(f \circ g)(1, 4) \) and \( D(g \circ f)(1) \).
Evaluate the following integral by transforming this integral in Cartesian coordinates to one in polar coordinates. Sketch the region of integration for the integral in Cartesian coordinates and the region of integration for the integral in polar coordinates.

\[
\int_{-2}^{2} \int_{0}^{\sqrt{4-x^2}} e^{-(x^2+y^2)} \, dy \, dx = \text{______________________________}.
\]
3.) Let $S$ denote the surface of the cylinder $x^2 + y^2 = 9, -1 \leq z \leq 1$.

A parametrization of $S$ is ________________________________

Use this parametrization to calculate $\int \int_S 1dS = \____________$.

The surface area of $S$ is ____________.
4.) Use a Lagrange multiplier to find the largest sphere centered at the origin that can be inscribed in the ellipsoid $3x^2 + 2y^2 + z^2 = 6$. 
A.) Find the following limit if it exists. If it doesn’t exist, state why you know it doesn’t exist.

\[ \lim_{(x,y) \to (0,0)} \frac{xy - 2x^2}{x^2 + y^2} \]
B.) Let \( \mathbf{a}, \mathbf{b}, \mathbf{c} \in \mathbb{R}^n \).

Is the scalar product associative (i.e., does \( \mathbf{a} \cdot (\mathbf{b} \cdot \mathbf{c}) = (\mathbf{a} \cdot \mathbf{b}) \cdot \mathbf{c} \))?

Is the cross product associative (i.e., does \( \mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = (\mathbf{a} \times \mathbf{b}) \times \mathbf{c} \))?

Prove that \( \mathbf{a} \cdot (\mathbf{b} + \mathbf{c}) = \mathbf{a} \cdot \mathbf{b} + \mathbf{a} \cdot \mathbf{b} \).
C.) Show that the vector field \( \mathbf{F}(x, y) = (y^2 + 2x + 4)i + (2xy + 4y - 5)j \) is conservative.

Find a scalar potential function for \( \mathbf{F} \)

Evaluate \( \int_X \mathbf{F} \cdot ds \) along the path \( x : [2, 5] \rightarrow \mathbb{R}^2, \ x(t) = (t\sqrt{t^2 + 1}, 2t^2 + 3) \)
D.) Find the arclength parameter $s = s(t)$ for the path $\mathbf{x}(t) = (t^3, t^2)$, $0 \leq t \leq 10$

The length of this path is ______________.

Express the original parameter $t$ in terms of $s$: ________________________.

Reparametrize $\mathbf{x}$ in terms of $s$: 
E.) Let $f(x, y, z) = x^2 \sin(yz)$. Calculate the directional derivative of $f$ at $a = (3, 0, 2)$ in the direction parallel to the vector $(3, 4, 0)$. 
F.) Let \( \mathbf{x}(t) = (\ln(t), 2t, e^{3t}) \).

The velocity of this path when \( t = 1 \) is ____________

The speed of this path when \( t = 1 \) is ____________

The acceleration of this path when \( t = 1 \) is ____________

The tangential component of acceleration of this path when \( t = 1 \) is ____________

The normal component of acceleration of this path when \( t = 1 \) is ____________
G.)