1. How much work is done to push a box up an incline from (2, 1) to (4, 2) by the force $\vec{F} = (3, 2)$?
   a. 65
   b. $\sqrt{65}$
   c. $2\sqrt{65}$
   d. 64
   e. 8

2. The graph of $2x^2 + 4x + 3y - 3z^2 - 6z = 4$ is a
   a. hyperboloid of 1-sheet
   b. hyperboloid of 2-sheets
   c. elliptic paraboloid
   d. hyperbolic paraboloid
   e. cone

3. Find the tangential acceleration, $a_T$, or the curve $\vec{r}(t) = (t^2, \frac{4}{3}t^3, t^4)$. HINT: Perfect square.
   a. $2 - 12t^2$
   b. $2 + 12t^2$
   c. $2t - 4t^3$
   d. $2t + 4t^3$
   e. $2 + 16t^2
4. Find the equation of the plane through the points $(1,2,3)$, $(2,4,2)$ and $(-1,2,4)$. Its $z$-intercept is

- a. 1
- b. 2
- c. 4
- d. 8
- e. 16

5. Find the plane tangent to the graph of the function $z = 2x^2y$ at the point $(x,y) = (3,2)$. Its $z$-intercept is

- a. $-72$
- b. $-36$
- c. 0
- d. 36
- e. 72

6. Find the plane tangent to the level set of the function $F(x,y,z) = 2x^2yz^3$ at the point $(x,y,z) = (3,2,1)$. Its $z$-intercept is

- a. 1
- b. 2
- c. 3
- d. 108
- e. 216
7. The volume of a cone is \( V = \frac{1}{3}\pi r^2h \).
If the radius \( r \) is currently 3 cm and decreasing at 2 cm/sec
while the height \( h \) is currently 4 cm and increasing at 1 cm/sec,
is the volume increasing or decreasing and at what rate?

a. increasing at 19\( \pi \) cm\(^3\)/sec
b. increasing at 13\( \pi \) cm\(^3\)/sec
c. neither increasing nor decreasing
d. decreasing at 13\( \pi \) cm\(^3\)/sec
e. decreasing at 19\( \pi \) cm\(^3\)/sec

8. Duke Skywater is traveling in the Millenium Eagle through a dangerous galactic politon field whose density is \( \rho = 2x^2yz^3 \). If Duke’s current position and velocity are \( \vec{r} = (3, 2, 1) \) and \( \vec{v} = (0.25, 0.5, -0.25) \), what is the current time rate of change of the politon field as seen by Duke?

a. -12
b. -120
c. 12
d. 120
e. 12,564

9. Duke Skywater is traveling in the Millenium Eagle through a dangerous galactic politon field whose density is \( \rho = 2x^2yz^3 \). If Duke’s current position is \( \vec{r} = (3, 2, 1) \), in what unit vector direction should he travel to reduce the politon field as fast as possible?

a. \( \frac{1}{\sqrt{349}}(4, 3, 18) \)
b. \( \frac{1}{\sqrt{349}}(4, -3, 18) \)
c. \( \frac{1}{\sqrt{349}}(-4, -3, -18) \)
d. \( \frac{1}{\sqrt{349}}(-4, 3, -18) \)
10. Compute \( \int \vec{F} \cdot d\vec{s} \) where \( \vec{F} = (2x + 2y, 2x + 2y) \) along the curve \( \vec{r}(t) = (4\sqrt{2} \cos(t), 4\sqrt{2} \sin(t)) \) for \(-\frac{\pi}{4} \leq t \leq \frac{\pi}{4}\). 
HINT: Find a scalar potential.

a. 2\( \pi \)

b. 4\( \pi \)

c. 8\( \pi \)

d. 4(\( \pi \))^2

e. 8(\( \pi \))^2

11. Compute \( \oint \vec{F} \cdot d\vec{s} \) for \( \vec{F} = (x - y, x + y) \) counterclockwise around the one leaf of the 3 leaf rose \( r = \cos(3\theta) \) with \( x \geq 0 \). 
HINT: Use Green's Theorem.

a. \( \frac{\pi}{2} \)

b. \( \frac{\pi}{3} \)

c. \( \frac{\pi}{4} \)

d. \( \frac{\pi}{6} \)

e. \( \frac{\pi}{12} \)
12. Compute  \( \iiint \vec{F} \cdot d\vec{S} \) for  \( \vec{F} = (xy^2, yx^2, z(x^2 + y^2)) \)
over the complete surface of the solid
above the paraboloid  \( z = x^2 + y^2 \)
below the plane  \( z = 4 \), oriented outward.

a. \( \frac{64}{5} \pi \)
b. \( \frac{64}{3} \pi \)
c. \( \frac{64}{15} \pi \)
d. \( \frac{256}{15} \pi \)
e. \( \frac{256}{3} \pi \)

13. Compute  \( \iint (x^3 + xy^2) \, dx \, dy \) over the quarter circle  \( x^2 + y^2 \leq 4 \) in the first quadrant.

a. 4
b. \( \frac{8}{5} \pi \)
c. \( \frac{16}{5} \pi \)
d. \( \frac{64}{5} \pi \)
e. \( \frac{32}{5} \)
14. (15 points) The half cylinder \( x^2 + y^2 = 9 \) for \( y \geq 0 \) and \( 0 \leq z \leq 4 \) has mass surface density \( \rho = y^2 \). Find the total mass and the center of mass. Follow these steps:

Parametrize the surface:
\[
\vec{R}(\theta, z) = (\quad , \quad , \quad )
\]

Find the tangent vectors, the normal vector and its length:
\[
\vec{e}_\theta = \\
\vec{e}_z = \\
\vec{N} =
\]

\[
|\vec{N}| =
\]

Evaluate the density on the surface and compute the total mass:
\[
\rho = y^2 \quad \rho|_{\vec{R}} = \\
M =
\]

Use symmetry to determine the \( x \) and \( z \) components for the center of mass and then compute the \( y \) component of the center of mass.
\[
\bar{x} = \\
\bar{z} = \\
M_{xz} =
\]

\[
\bar{y} =
\]
15. (15 points) A rectangular box sits on the $xy$-plane with its top 4 vertices on the paraboloid $z + 2x^2 + 8y^2 = 8$. Find the dimensions and volume of the largest such box.

NOTE: Full Credit for solving by Lagrange Multipliers, Half Credit for Eliminating a Variable.
16. (20 points) Verify Stokes’ Theorem 
\[ \iint_C \nabla \times \mathbf{F} \cdot d\mathbf{S} = \oint_{\partial C} \mathbf{F} \cdot d\mathbf{s} \]
for the cone \( C \) given by \( z = \sqrt{x^2 + y^2} \) for \( z \leq 3 \) oriented down and out, and the vector field \( \mathbf{F} = (-yz, xz, z^2) \).
Note: The boundary of the cone is the circle, \( x^2 + y^2 = 9 \).
Be sure to check the orientations. Use the following steps:

a. The cone, \( C \), may be parametrized as \( \mathbf{R}(r, \theta) = (r \cos \theta, r \sin \theta, r) \)

Compute the surface integral by successively finding:
\[ \mathbf{e}_r, \mathbf{e}_\theta, \mathbf{N}, \mathbf{\nabla} \times \mathbf{F}, \mathbf{\nabla} \times \mathbf{F} \bigg|_{\mathbf{R}(r, \theta)}, \iint_C \mathbf{\nabla} \times \mathbf{F} \cdot d\mathbf{S} \]

b. Parametrize the circle, \( \partial C \), and compute the line integral by successively finding:
\[ \mathbf{r}(\theta), \mathbf{v}, \mathbf{F} \bigg|_{\mathbf{r}(\theta)}, \oint_{\partial C} \mathbf{F} \cdot d\mathbf{s} \]