1. (a) (8 points) Find the area of the triangle $PQR$ where $P = (1,1,1)$, $Q = (1,2,3)$ and $R = (0,1,1)$.
(b) (4 points) Find an equation of the plane which passes through $P$, $Q$, and $R$.

2. The velocity vector of a moving particle at time $t$ is
$$\mathbf{v}(t) = \langle 2t \cos(t^2), -2t \sin(t^2), t^2 - 1 \rangle.$$
(a) (2 points) Find the particle’s acceleration $\mathbf{a}(t)$ as a function of $t$.
(b) (4 points) Find the particle’s position vector $\mathbf{r}(t)$ as a function of $t$ if the initial position $\mathbf{r}(0) = (1,0,1)$.
(c) (4 points) Find the total distance traveled by the particle during the time interval $1 \leq t \leq 2$.

3. (5 points) Suppose that $z = f(x,y)$ satisfies $xe^z + ze^y = x + y$. Calculate $\partial z/\partial x$ as a function of $x$, $y$, and $z$.

4. (5 points) Find all the points on the ellipsoid $\frac{x^2}{4} + \frac{y^2}{9} + \frac{z^2}{2} = 1$, where the tangent plane is parallel to $z = 1 - x - y$.

5. (a) (8 points) Let $f(x,y) = \sqrt{x^2 + y^2}$. Find an equation of the tangent plane of the graph $z = f(x,y)$ at $(3,4,5)$.
(b) (4 points) Use a linear approximation to estimate $f(3.1,4.2)$.

6. (a) (8 points) Find the directional derivative of $f(x,y,z) = zx^2 - y^2$ at $P = (1,1,1)$ in the direction of $\mathbf{v} = (-1,1,1)$. Explain if the function increases or decreases?
(b) (2 points) Find the maximum rate of increase of $f$ at $P = (1,1,1)$.

7. (12 points) Find the critical points of $f$, and determine local minimum, local maximum, and the saddle points, where $f(x,y) = x^4 - 4xy + 2y^2$.

8. (a) (2 points) Explain why $f(x,y) = x^2y + 1$ has a maximum and a minimum on the ellipse $4x^2 + 9y^2 = 36$.
(b) (8 points) Find the maximum and the minimum of $f$ subject to the constraint $4x^2 + 9y^2 = 36$. 
9. (a) (4 points) Sketch the domain of integration

\[ \int_0^1 \int_{x^2}^x \frac{\sin(\pi y)}{\sqrt{y-y}} \, dy \, dx. \]

(b) (4 points) Change the order of integration.
(c) (4 points) Evaluate the integral.

10. (12 points) Find the volume of the solid enclosed by the \( xy \)-plane, the paraboloid \( z = 4 - x^2 - y^2 \), and the cylinder \( x^2 + y^2 = 1 \).

Good luck.