Place all books, papers and calculators under your desk. Write your name and section number on your blue book . In a column number one to four. Box your answers and show all your work. Good Luck!

1. (a) 5 pts. Find 3 complex numbers that satisfy $z^3 = i$.

   (b) 5 pts. Find 2 unit vectors that make an angle of $\pi/6$ with $\vec{\jmath}$.

   (c) 5 pts. Find the equation of a plane perpendicular to $2\vec{\imath} + \vec{\jmath} - \vec{k}$ passing through $(1, 2, 3)$.

   (d) 5 pts. $P = (2, -1, 0)$, $Q = (-1, 0, 3)$, $R = (2, 1, 1)$ are vertices of a parallelogram. If S is the $4th$ vertex opposite P, find S.

2. (a) 10 pts. Let $f(x, y) = x^2 e^y + \cos(xy)$. Let $x(t) = \sqrt{t}$, $y = t^2$. Compute f_x f_y, f_{xy}. Use the chain rule to find $\frac{df}{dt}$.

   (b) 10 pts. A function $g(x, y)$ has directional derivative $2\sqrt{2}$ at (1,2) in the direction of $\vec{\imath} + \vec{\jmath}$ and directional derivative 2 in the direction of $\vec{\imath} + 2\jmath$. What is $\vec{\nabla} g(1, 2)$? Check your answer.

3. 20 pts. Find all critical points, local maxima, minima and saddle points of $f(x, y) = xy - x^2 - y^2 - 2x - 2y + 4$.

4. (a) 10 pts. Use Lagrange multipliers to find the maxima and minima of the function $f(x, y) = xy$ subject to the constraint $x^2 + y^2 = 1$. Find the points where maximum and minimum occur and also the maximum and minimum values of f.

   (b) 10 pts. Sketch level curves of f and the graph of $x^2 + y^2 = 1$.