1. The two curves $\mathbf{r}_1(t) = \langle 2, t, t^2 - 4\rangle$ and $\mathbf{r}_2(s) = \langle s, 3, 9 - s^2\rangle$ both lie on a surface S and intersect at some point P.

   (a) Find their point of intersection.

   (b) Find the angle between the tangent vectors of the curves at the point of intersection.

   (c) Find the equation of the tangent plane to S at the given point.

2. Does the limit

$$\lim_{(x,y)\to(1,0)} \frac{xy - y}{(x-1)^2 + y^2}$$

   exist? If so, what is its value?

3. Consider two helixes, one parametrized as $\mathbf{r}_1(t) = \langle \cos t, \sin t, t\rangle$ and the other as $\mathbf{r}_2(s) = \langle \cos s, \sin s, s^2\rangle$. Particles move along the curves both starting out from $(1, 0, 0)$ at $s = t = 0$.

   (a) The particle on which curve starts out faster and why?

   (b) Eventually the other particle travels faster, but there is a moment when each particle has traveled exactly the same distance. Write an expression which — if solved — would reveal the time. Do not attempt to solve for the time.

4. The functions $\mathbf{r}_1(t) = \langle \cos t, \sin t, t\rangle$ and $\mathbf{r}_2(t) = \langle 1 + t, t^2, t^3\rangle$ are parametrizations of two curves that intersect when $t = 0$.

   (a) Determine the angle of intersection between the two curves at the point of intersection.

   (b) Assuming that particles on these curves are moving with the same parameter t, is there another point in time (positive or negative) where these curves will intersect? Hint: it would help to think about the curves geometrically before making any algebraic argument.

5. Find the points on the hyperboloid $x^2 + 4y^2 - z^2 = 4$ where the tangent plane is parallel to $2x + 2y + z = 5$.

6. (30) [Multiple choice] (No partial credit) **Circle the correct answer.**

   (a) A bug is crawling straight up the side of a cylinder of radius 2 feet whose equation is $x^2 + y^2 = 4$. The cylinder is rotating counterclockwise at a rate of one rotation per second. If the bug's total speed is 5π feet per second, which vector equation describes the bug's path through space?

A. $\langle 2\pi\cos(t), 2\pi\sin(t), 3\pi t\rangle$

B. $\langle 2\pi\cos(t), 2\pi\sin(t), 5\pi t\rangle$

C. $\langle 2\cos(2\pi t), 2\sin(2\pi t), 3\pi t\rangle$

D. $\langle 2\cos(2\pi t), 2\sin(2\pi t), 5\pi t\rangle$

E. $\langle 3\cos(2\pi t), 3\sin(2\pi t), 3\pi t\rangle$