1. For each of the following equations, determine if there is a closely matching graph below. If there is, report its letter. If there is not, write NO MATCH.   *(8 points)*

   (a) $\mathbf{r}(t) = \langle \sin t, \cos t, \sin(5t) \rangle$ . . . .   _____

   (b) $\mathbf{r}(t) = \langle \cos t, \sin t, 1/t \rangle$ . . . .   _____

   (c) $\mathbf{r}(t) = \langle t^3, t^2, t \rangle$ . . . .   _____

   (d) $\mathbf{r}(t) = \langle t, \sin t, \cos t \rangle$ . . . .   _____

---
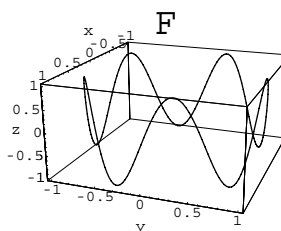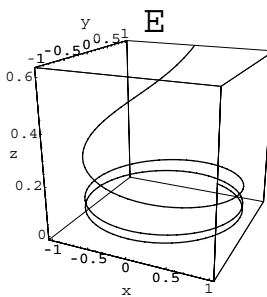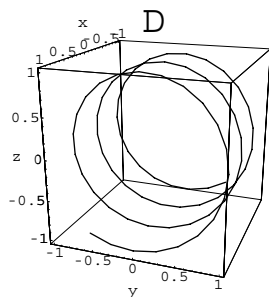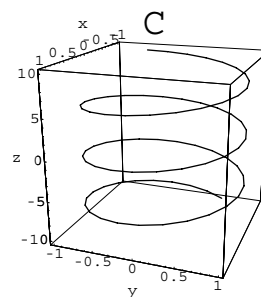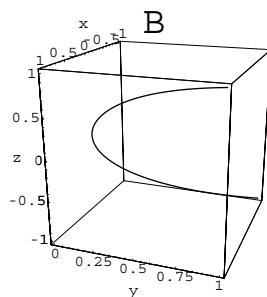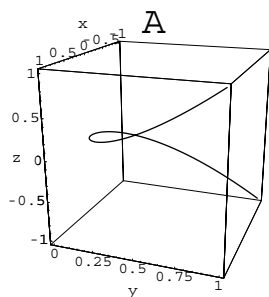
2. For the circular helix $\mathbf{r}(t) = \langle \cos(t), \sin(t), 5t \rangle$, calculate and simplify   *(12 points)*

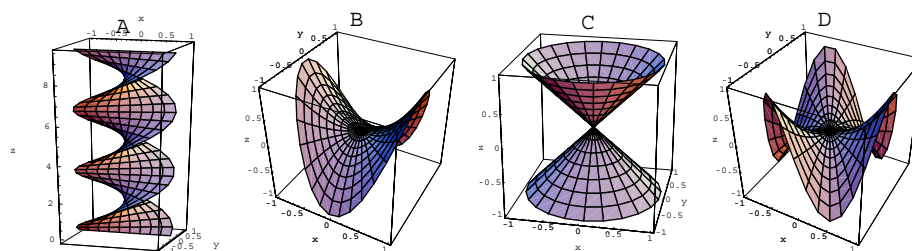   (a) $\mathbf{T}$(t)

   _____

   (b) $\mathbf{N}(t)$

   _____

   (c) the curvature at any point.

3. If a particle is moving along in space with $\mathbf{r}(t)$ as its position vector, if $\mathbf{r}'(0) = \langle 2, 1, 2 \rangle$, and if $\mathbf{r}''(0) = \langle 1, -1, 1 \rangle$, calculate the tangential and normal components of acceleration when $t = 0$. Is the speed of the particle increasing or decreasing at that point? *(10 points)*

4. For each of the following equations, determine if there is a closely matching graph. If there is, report its Letter. If there is not, write NO MATCH. *(8 points)*

   (a) $\mathbf{r}(u, v) = \langle u \cos v, u \sin v, u \rangle$ . . . . _____

   (b) $\mathbf{r}(u, v) = \langle u \cos v, u \sin v, v \rangle$ . . . . _____

   (c) $\mathbf{r}(u, v) = \langle u \cos v, u \sin v, u \cos(2v) \rangle$ . . . . _____

   (d) $\mathbf{r}(u, v) = \langle u \cos v, u \sin v, u \cos(3v) \rangle$ . . . . _____

5. Let $f(x, y) = \sqrt{25 - x^2 - y^2}$. Describe the domain of f. Plot level curves for $z = 0, 1, 2, 3, 4,$ and 5 on the set of axes. *(10 points)*
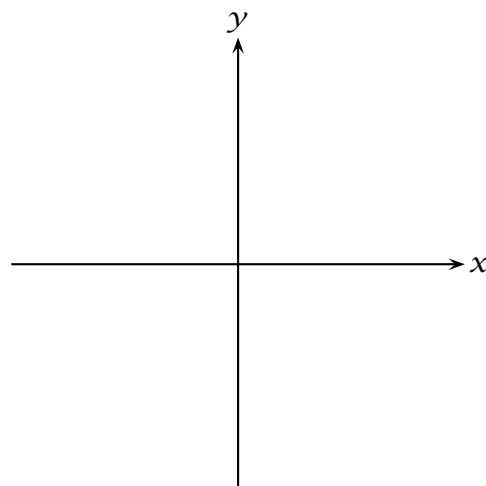
6. Evaluate the limit   *(9 points)*

$$\lim_{(x,y)\to(0,0)} \frac{xy^2}{x^2 + y^4}$$

7. A right circular cylinder has its height increasing at a constant rate of 2 millimeters per second while its radius is decreasing at a rate of 1 millimeter per second. At what rate is its volume changing if the height is 100 mm and the radius is 10 mm?   *(10 points)*

8. Let $f(x, y) = \sqrt{x^2 + y^2}$.   *(12 points)*

   (a) Calculate the gradient function for f.

   (b) Find the value of the directional derivative of f at the point $(1,1)$ going in the direction from the point $(1,1)$ to the point $(4,5)$.

9. The contour plot below shows z-levels from 1 to 15 along the right edge from bottom to top. *(12 points)*

   (a) Estimate the value of $f_x(1,1)$ and $f_y(1,1)$.

   (b) Draw the gradient vector at (1,1) on the graph so the tail of the vector is at the point (1,1).

   (c) Determine the signs of $f_{xx}(1,1)$, $f_{xy}(1,1)$, and $f_{yy}(1,1)$.
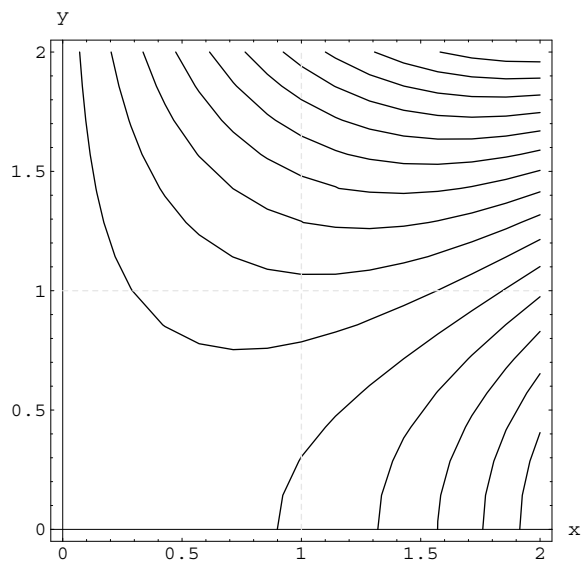
10. For the function $f(x,y) = \dfrac{1}{\sqrt{x^2 + y^2}}$ find an equation of the tangent plane to the graph of $f(x,y)$ when $x = 3$ and $y = 4$. *(9 points)*