1. Find the velocity, speed and acceleration at time $t$ of the particle whose position is

$$\mathbf{r}(t) = a \cos t \hat{i} + a \sin t \hat{j} + ct \hat{k}$$

Describe the path of the particle.

2. A projectile falling under the influence of gravity and slowed by air resistance proportional to its speed has position satisfying

$$\frac{d^2 \mathbf{r}}{dt^2} = -g \hat{k} - \alpha \frac{d \mathbf{r}}{dt}$$

where $\alpha$ is a positive constant. If $\mathbf{r} = \mathbf{r}_0$ and $\frac{d \mathbf{r}}{dt} = \mathbf{v}_0$ at time $t = 0$, find $\mathbf{r}(t)$. (Hint: Define $u(t) = e^{\alpha t} \frac{d \mathbf{r}}{dt}(t)$ and substitute $\frac{d \mathbf{r}}{dt}(t) = e^{-\alpha t} u(t)$ into the given differential equation to find a differential equation for $u$.)

3. Find the specified parametrization of the first quadrant part of the circle $x^2 + y^2 = a^2$.
   (a) In terms of the $y$ coordinate.
   (b) In terms of the angle between the tangent line and the positive $x$–axis.
   (c) In terms of the arc length from $(0, a)$.

4. Find the length of the parametric curve

$$x = a \cos t \sin t \quad y = a \sin^2 t \quad z = bt$$

between $t = 0$ and $t = T > 0$.

5. Reparametrize the curve

$$\mathbf{r}(t) = a \cos^3 t \hat{i} + a \sin^3 t \hat{j} + b \cos 2t \hat{k}, \quad 0 \leq t \leq \frac{\pi}{2}$$

with the same orientation, in terms of arc length measured from the point where $t = 0$. You may use the formulae

$$\sin(2t) = 2 \sin t \cos t \quad 1 - \cos(2t) = 2 \sin^2(t)$$

to simplify the computations.

6. The plane $z = 2x + 3y$ intersects the cylinder $x^2 + y^2 = 9$ in an ellipse. Find a parametrization of the ellipse. Express the circumference of this ellipse as an integral. You need not evaluate the integral.

7. A wire of total length 1000 cm is formed into a flexible coil that is a circular helix. If there are 10 turns to each centimeter of height and the radius of the helix is 3 cm, how tall is the coil?

8. You are lost in a desert during the night. There is a road as indicated in the figure on the next page. Your position is $(100, 190)$. A car is approaching from the left with headlights that have range 70m. Will the driver be able to see you?