1. Find the velocity, speed and acceleration at time $t$ of the particle whose position is $\vec{r}(t)$. Describe the path of the particle.
   a) $\vec{r}(t) = a \cos t \hat{i} + a \sin t \hat{j} + ct \hat{k}$
   b) $\vec{r}(t) = a \cos t \sin t \hat{i} + a \sin^2 t \hat{j} + a \cos t \hat{k}$

2. A projectile falling under the influence of gravity and slowed by air resistance proportional to its speed has position satisfying
   \[ \frac{d^2 \vec{r}}{dt^2} = -g \hat{k} - \alpha \frac{d\vec{r}}{dt} \]
   where $\alpha$ is a positive constant. If $\vec{r} = \vec{r}_0$ and $\frac{d\vec{r}}{dt} = \vec{v}_0$ at time $t = 0$, find $\vec{r}(t)$. (Hint: consider $\vec{u}(t) = e^{\alpha t} \frac{d\vec{r}}{dt}(t)$.)

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
   \[ \vec{r}(t) = a \cos^3 t \hat{i} + a \sin^3 t \hat{j} + b \cos 2t \hat{k}, \quad 0 \leq t \leq \frac{\pi}{2} \]
   with the same orientation, in terms of arc length measured from the point where $t = 0$.

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. Show that, if the position and velocity vectors of a moving particle are always perpendicular, then the path of the particle lies on a sphere.