1. The position of a particle at time t seconds is given by $\mathbf{r}(t) = \langle 3\cos t, 3\sin t, 4t\rangle$. Show directly that the velocity and acceleration vectors are always perpendicular. What does this tell you about the speed? At what rate is the particle changing direction? What is the curvature of the path?

2. The position of a particle at time t seconds is given by $\mathbf{r}(t) = \langle t, t^2, t^3\rangle$.
a. Determine the tangential and normal components of the acceleration at time $t = 1$ second.
b. Determine the rate at which the speed of the particle is changing at time $t = 1$ second.
c. Determine the rate at which the particle is changing direction at time $t = 1$ second.

3. A particle moves along the parabola $y = x^2$ with a constant speed. Roughly sketch possible acceleration vectors for the particle as it passes the points $(-2, 4)$, $(-1, 1)$, $(0, 0)$, $(1, 1)$, and $(2, 4)$.

4. A particle moves along the curve $y = \sin x$. Is it possible that the acceleration of the particle is always zero? Is it possible that the acceleration is sometimes zero? Is it possible that the acceleration is never zero? Explain.

5. The axis of rotation of a rigid object is a line through the points $(2, 0, 1)$ and $(4, 2, 0)$. At some instant the object is rotating counter-clockwise (when viewed from the point $(4, 2, 0)$ looking toward the point $(2, 0, 1)$) at the rate of 6 rev/sec and this rate is decreasing at the rate of 2 rev/sec/sec.

a. Determine the acceleration of the point P on the object if it is at the point $(3, -1, 5)$ at the instant considered.
b. Determine the rate at which the speed of P is changing at this instant.
c. Determine the rate at which P is changing direction at this instant.

6a. A small object is thrown near the surface of the earth. As it falls, the only force acting on the object is the force of gravity. Let $\mathbf{v}(t)$ denote the velocity of the object and let $h(t)$ denote its height t seconds after being released. Let $E(t) = \frac{1}{2}\mathbf{v}(\mathbf{t})\cdot\mathbf{v}(\mathbf{t}) + gh(t)$. Find $E'(t)$ and simplify your answer as much as possible. What can you conclude about the function $E(t)$?

b. Repeat part a) for the situation where a small bead slides along a frictionless wire. Assume that the only forces acting on the bead are the gravitational force and the force of the wire on the bead (which is normal to the wire at all times). You may assume the wire lies in a vertical plane.

c. A frictionless wire in a vertical plane is bent in the shape of the curve $\mathbf{r}(\theta) = \langle x(\theta), y(\theta)\rangle$. A small bead is released from rest at the point on the curve corresponding to $\theta = \theta_0$. Find an expression that gives the time it takes the particle to reach the point corresponding to $\theta = \theta_1$.