1. [APPM 2350 Exam (19 pts)] A bee leaves its hive located at the point $A(1,2,3)$ and flies in a straight line to a sunflower located at point $B(-1,4,7)$. From there it flies in a straight line to a daisy at point $C(2,-5,-1)$ and returns on a straight path back to the hive.

   (a) (2 pts) How far is the sunflower from the hive?

   (b) (5 pts) Find the area of the triangular region inside the bee's path.

   (c) (6 pts) Find the equation of the plane containing the bee's path. Write your answer in the form $ax + by + cz = d$.

   (d) (3 pts) The queen bee leaves the hive and crawls along a straight branch to point D at the origin. Find the volume of the parallelepiped formed by the queen bee's path, and the bee's path from the hive to the sunflower and from the hive to the daisy.

   (e) (3 pts) Is the angle between the queen bee's path and the path from the sunflower to the daisy acute or obtuse (greater than $\pi/2$ radians)? Justify your answer.

2. [APPM 2350 Exam (26 pts)] A particle moves along the path parameterized by $\mathbf{r}(t) = 2t^2\,\mathbf{i} + 6\,\mathbf{j} + \frac{4}{3}t^3\,\mathbf{k}$, $t \geq 0$.

   (a) (13 pts) When $t = \sqrt{3}$ find the following. Simplify your answers.

      i. (3 pts) Where is the particle?

      ii. (5 pts) How fast is the particle moving?

      iii. (5 pts) Find a unit vector in the direction of motion of the particle.

   (b) (3 pts) When does the particle reach the point $(18, 6, 36)$?

   (c) (8 pts) How far did the particle travel moving from the point with position vector $6\,\mathbf{j}$ to the point where $t = \sqrt{2}$.

   (d) (2 pts) Find the binormal vector $\mathbf{B}$. Hint: Do not spend time computing $\mathbf{T}$ and $\mathbf{N}$. Instead, just visualize the path.

3. [APPM 2350 Exam (28 pts)] The following problems are not related.

   (a) (8 pts) Find the equation of the surface consisting of all points that are equidistant from the point $(-1,1,2)$ and the plane $y = -1$. Is this one of the quadric surfaces? If so, identify it.

   (b) (12 pts) Consider the equation $x^2 + z^2 - 4x - 2y - 2z = y^2 - c$.

      i. (5 pts) For what value of c will the equation describe a cone?

      ii. (3 pts) For the value of c found in part (i), find the vertex of the cone.

      iii. (4 pts) For the value of c found in part (i), find the trace of the surface in the plane $y = 2$, giving its equation and a geometrical description in words.

   (c) (8 pts) Consider the plane passing through the point $(-1,1,-14)$ with normal vector $-\mathbf{i} + 2\,\mathbf{j} + 3\,\mathbf{k}$. Find the point where the line with symmetric equations $\dfrac{x-1}{-2} = \dfrac{y+2}{3} = z + 4$ intersects the plane.

4. [APPM 2350 Exam (27 pts)] The following problems are not related.

   (a) (9 pts) Let $\mathbf{r}(t) = \left\langle \sqrt{t+1}, \cos t, t^4 - 8t^2 \right\rangle$, $t > -1$.

      i. (6 pts) Find all values of t where the path is parallel to the xy-plane.

      ii. (3 pts) Is the path ever parallel to the yz-plane? Justify your answer.

   (b) (8 pts) An object moving with velocity $\mathbf{v}(t) = (t+2)\,\mathbf{i} + t^2\,\mathbf{j} + e^{-t/3}\mathbf{k}$ passes through the point $(4,0,-2)$ at time $t = 0$. Find the vector-valued function describing the position of the object at any time t.

   (c) (10 pts) Let $\mathbf{r}(t) = (1+t)\,\mathbf{i} + \left(t^2 - 2t\right)\mathbf{j} + 0\,\mathbf{k}$, $-\infty < t < \infty$.

      i. (5 pts) Find the curvature of the path when $t = 1$.

      ii. (5 pts) Find the point(s) on the path where the acceleration vector consists of only a normal component, and compute the magnitude of the normal component of the acceleration at that(those) point(s).