Instructions. BE SURE TO WRITE YOUR NAME ON EACH PAGE TURNED IN. No programmable or graphical calculators. Show all working for full credit. Simplify your answers as much as possible. [Approximate point values are in square brackets, total 100 points (there are some bonus points).]

1. Tell whether the following expressions make sense or are true. For each one which does not make sense, or is not true, correct it by replacing the word or phrase in capital letters. [16]
   Example. The polar coordinates of a VECTOR IN 3-SPACE.
   Solution: Does’nt make sense. POINT IN 2-SPACE.
   (a) The SUM of two vectors is a scalar.
   (b) Given a point on a plane, and a vector PARALLEL to the plane, one can find the equation of the plane.
   (c) The circle of radius 1 center at the origin is an example of an ORIENTED CURVE.
   (d) The CURVATURE points in the direction a loose roller coaster car would fly off in.

2. Let \( \mathcal{L} \) be the line with parametric equation
\[
\begin{align*}
  x &= t \\
  y &= 1 \\
  z &= \sqrt{3}t - 5
\end{align*}
\]
and let \( \mathcal{P} \) be the plane \( 2\sqrt{3}x + 2y + 3z = 2 \). FIND:
   (a) the point of intersection of the line and the plane. [6]
   (b) a vector which is perpendicular to the line and also is parallel to the plane. [9]
   (c) the (smallest) angle \( \theta \) which the line makes with the plane at the intersection. [10]
3. Let $P$ and $Q$ be the points $(3, 1, -2)$ and $(4, -2, -1)$ respectively. Find:
   (a) the unit vector in the direction of $\overrightarrow{PQ}$, [5]
   (b) A parametrization of the line segment from $P$ to $Q$. [6]

4. Let $\overrightarrow{F}(t) = t^2 \overrightarrow{i} - 3 \overrightarrow{j} + t \overrightarrow{k}$ and $\overrightarrow{G}(t) = 10 \overrightarrow{i} + t \overrightarrow{j}$.
   (a) Find the values of $t$ so that $\overrightarrow{F}(t)$ and $\overrightarrow{G}(t)$ are perpendicular. [5]
   (b) Give a rough sketch the curve traced out by $\overrightarrow{F}(t)$. [5]
   (c) Find the curvature of the curve traced out by $\overrightarrow{F}(t)$ at the point $(2, -3, \sqrt{2})$ on the curve. [12]

5. Consider the curve consisting of the points on the plane $x + y + z = 1$ sitting above or below the circle $x^2 + y^2 = 1$.
   (a) Give a rough sketch of the plane and the curve. [7]
   (b) Complete: a parametrization of the curve is $\overrightarrow{F}(t) = (\cos t, \sin t, \text{__________})$. [5]
   (c) Find an equation for the tangent line to the curve at the point $(1, 0, 0)$. [10]
   (d) Write the length of this curve as an integral (you do not need to compute the integral). [8]