1. Given the points $P(2, 0, 0)$, $Q(0, 4, 1)$ and $R(3, 3, 0)$ in space.
   (a) (10 points) Find the vector $\mathbf{V} = 2(\overrightarrow{PQ} - \overrightarrow{QR})$.
   (b) (10 points) Find the vector of length 6 in the direction opposite to $\overrightarrow{PR}$.

2. Given the points $P(1, 2, 3)$, $Q(0, 2, 5)$ and $R(4, 3, 4)$ in space,
   (a) (10 points) Find the area of the triangle $\triangle PQR$ using a cross product.
   (b) (10 points) Find the cosine of vertex angles at $P$, $Q$ and $R$.

3. Given the points $P(1, 0, 1)$, $Q(2, 0, 0)$ and $R(-1, 1, 0)$ in space,
   (a) (5 points) Ind an equation of a plane through the points $P$, $Q$, and $R$.
   (b) (5 points) Where does the line $x = 1 + 2t$, $y = 2 + t$, $z = -1 - t$ intersect the plane that contains $P$, $Q$, and $R$?
   (c) (10 points) Find a parametric representation of the line of intersection of the plane $3x - 6y + 2z = 4$ and the plane that contains $P$, $Q$, and $R$.

4. Sketch each of the following surfaces and find their intersection points (if any) with the coordinate $(x, y$ and $z$) axes,
   (a) (5 points) $z = y^2 - 1$.
   (b) (10 points) $z = 8 - x^2 - y^2$.

5. The position vector of a particle moving through space is
   \[ \mathbf{r}(t) = (t - \sin t) \mathbf{i} + (1 - \cos t) \mathbf{j} + t \mathbf{k}, \quad t \geq 0. \]
   (a) (5 points) Find the velocity and acceleration vectors and the speed as a function of $t$.
   (b) (5 points) Find the parametric equation of the tangent line to the curve described by the particle at $t = \pi/4$.
   (c) (10 points) Find the time(s) (if any) when the particle’s acceleration vector is orthogonal to its velocity vector.