Problem 1: \(PQ = (6, 5, 0)\) \(\frac{Ps}{PQ} = -2\) \(\frac{Pt}{PQ} = 3\) 

Since \(\overrightarrow{PQ} = -2 \cdot \overrightarrow{Ps}\) and \(\overrightarrow{PQ} = 3 \cdot \overrightarrow{Pt}\), all four points are collinear.

2. \(\overrightarrow{AB} = (0, -4, 2)\) \(\overrightarrow{BC} = (1, 4, 2)\) \(\overrightarrow{AC} = (1, 0, 2)\) \(\overrightarrow{BD} = (2, 6, 1)\)

A, B, C are not collinear
A, B, D are not collinear
A, C, D are not collinear
B, C, D are not collinear

Problem 2:
1. \(\overrightarrow{v} \times (\overrightarrow{a} + \overrightarrow{w}) = 4\)
2. Undefined
3. \(\overrightarrow{v} \times \overrightarrow{u} = (-2, -3, 4)\)
4. \((\overrightarrow{v} \times \overrightarrow{u}) \cdot \overrightarrow{w} = \overrightarrow{w} \cdot \overrightarrow{u} \cdot \overrightarrow{w} = \overrightarrow{w}\)

Problem 3.
\[
\begin{align*}
\overrightarrow{w} \cdot \overrightarrow{v} &= -22 \\
\overrightarrow{w} \cdot \overrightarrow{w} &= 2 \sqrt{51} \\
\overrightarrow{v} \cdot \overrightarrow{v} &= 2 \sqrt{51} \\
\overrightarrow{u} \cdot \overrightarrow{v} &= 0 \\
\overrightarrow{w} \cdot \overrightarrow{w} &= 14 \\
\overrightarrow{u} \cdot \overrightarrow{w} &= 14 \\
\overrightarrow{u} \cdot \overrightarrow{v} &= 14 \\
\end{align*}
\]

Problem 4. 
\[
\text{proj}_u \overrightarrow{v} = \frac{\overrightarrow{v} \cdot \overrightarrow{u}}{||\overrightarrow{u}||^2} \overrightarrow{u} = \frac{-2}{30} (1, 5, 2) = \left(-\frac{1}{15}, -\frac{1}{3}, -\frac{2}{15}\right)
\]

Component of \(\overrightarrow{v}\) perpendicular to \(\overrightarrow{u}\) = \(\overrightarrow{v} - \text{proj}_u \overrightarrow{v} = \left(1, 5, 2\right) - \left(-\frac{1}{15}, -\frac{1}{3}, -\frac{2}{15}\right) = \left(\frac{16}{15}, \frac{14}{3}, \frac{32}{15}\right)\)

Problem 5. \(\overrightarrow{PQ} = (-3, 1, -1)\) \(\overrightarrow{PR} = (2, -3, -1)\) \(\overrightarrow{PQ} \times \overrightarrow{PR} = (-4, -5, 7)\)

\(\overrightarrow{PQ} \times \overrightarrow{PR}\) is orthogonal to \(\overrightarrow{PQ}\) and \(\overrightarrow{PR}\), and so \(S\) lies in the plane defined by \(\overrightarrow{PQ}\) and \(\overrightarrow{PR}\).

2. \(\overrightarrow{AB} = (-3, 3, 0)\) \(\overrightarrow{AC} = (-1, -1, -1)\) \(\overrightarrow{AD} = (-2, 1, -2)\)

\(\overrightarrow{AB} \times \overrightarrow{AC} = (3, 3, 6)\) \((\overrightarrow{AB} \times \overrightarrow{AC}) \cdot \overrightarrow{AD} = -9 \neq 0\)

\(\overrightarrow{AB} \times \overrightarrow{AC} \neq 0\)

Therefore, \(D\) does NOT lie in the plane determined by \(\overrightarrow{AB}, \overrightarrow{AC}\).
Problem 6.1. \( \mathbf{PQ} = (-3, 1, 0) \) \( \mathbf{N}_1 = \mathbf{PQ} \times \mathbf{PR} = (-2, -6, -6) \)

\( \mathbf{PR} = (0, 2, -2) \) easiest to take \( \mathbf{N}_1 = (1, 3, 3) \)

\[
\frac{(x-1) + 3(y+1) + 3(z-1)}{x + 3y + 3z} = 1
\]

2. \( \mathbf{AB} = (3, -4, -1) \) \( \mathbf{N}_2 = \mathbf{AB} \times \mathbf{AC} = (6, 3, 0) \)

\( \mathbf{AC} = (1, -2, -2) \) easiest to take \( \mathbf{N}_2 = (2, 1, 0) \)

\[
2(x+2) + (y-3) = 0 \quad 2x + y = -1
\]

3. \( \cos \theta = \frac{\mathbf{N}_1 \cdot \mathbf{N}_2}{\|\mathbf{N}_1\| \|\mathbf{N}_2\|} = \frac{5}{\sqrt{19} \sqrt{5}} = \frac{\sqrt{95}}{19} \)

4. \( \mathbf{AQ} = (0, -3, -1) \) \( \text{dist}(Q, K) = \|\text{proj}_{\mathbf{N}_2} \mathbf{AQ}\| \)

\[
= \frac{|\mathbf{AQ} \cdot \mathbf{N}_2|}{\|\mathbf{N}_2\|} = \frac{|-3|}{\sqrt{5}} = \frac{3\sqrt{5}}{5}
\]

Problem 7. \( \mathbf{u} = \mathbf{PQ} = (-2, 3, -3) \)

\[
x = 1 - 2t \\
y = 1 + 3t \\
z = -3t
\]

\[
\text{dist}(S, \text{line}) = \|\text{component of } \mathbf{PS} \text{ which is } \| \mathbf{u} \| \\
= \| \mathbf{PS} - \text{proj}_{\mathbf{u}} \mathbf{PS} \| = \| (3, 5, 4) - \left( \frac{\mathbf{PS} \cdot \mathbf{u}}{\|\mathbf{u}\|^2} \right) \mathbf{u} \| \\
= \| (3, 5, 4) - \frac{3}{22} (-2, 3, -3) \| = \| (\frac{20}{22}, \frac{11}{22}, \frac{7}{22}) \| \\
= \frac{\sqrt{29002}}{22}
\]
Problem 9.1. \((x-1)^2 - (y+2)^2 = z+1\)

2. \(\frac{(x-1)^2}{3} + \frac{(y+2)^2}{2} - \frac{(z-1)^2}{2} = 1\)

3. \(-\frac{(x+1)^2}{3} + \frac{(y-1)^2}{3} + \frac{(z-1)^2}{3} = 1\)

Problem 10.

1. \(y^2 + z^2 = (\ln x)^2\)

2. \(x^2 + z^2 = e^{2y}\)

Problem 112. \(\vec{F}(t) = \int \vec{a}(t) \, dt\)

\[
\vec{F}(t) = \int \vec{a}(t) \, dt = (-\cos(t) + C_1, \frac{1}{2} \sin(2t) + C_2, 2 \sin(t + \frac{\pi}{4}) + C_3)
\]

\[-\cos(0) + C_1 = 1 \Rightarrow C_1 = 1, \quad C_2 = \frac{1}{2}, \quad C_3 = \frac{\pi}{2}\]

\[
\vec{F}(t) = (1 - \cos(t), \frac{1}{2} \sin(2t) - 2e^{2t}, 2 \sin(t + \frac{\pi}{4}) + \frac{\pi}{2})
\]

Problem 11.

1. Cylindrical: \(x = r \cos \theta\), \(y = r \sin \theta\), \(z = z\)

\(r^2 - \cos^2 \theta - \sin^2 \theta = 1\)

2. Spherical: \(x = \rho \sin \phi \cos \theta\), \(y = \rho \sin \phi \sin \theta\), \(z = \rho \cos \phi\)

\(\rho^2 \sin^2 \phi \cos^2 \theta - \rho^2 \sin^2 \phi \sin^2 \theta = 1\)

\(\rho^2 = \cos^2 \phi \sec \theta\)

Problem 13. \(F(t) = (1, -4t, -2t)\)

\(\vec{F}''(t) = (0, -4, -2)\)

\(\vec{F}'(t) = (1, -4t, -2t)\)

\(\vec{F}(t) = (1, -4t, -2t)\)

\(\hat{n}(t) = \frac{1}{\sqrt{105}}(10, 4, 2)\)

\(\hat{n}(t) = \frac{1}{\sqrt{105}}(10, 4, 2)\)