1. (25 pts) The following equations describe the concentration and temperature changes in a reactor:

\[
\frac{dC}{dt} = \alpha (C_{in} - C) - k \exp\left(\frac{\beta}{T}\right)C^2
\]

\[
\frac{dT}{dt} = \alpha (T_{in} - T) + \gamma \exp\left(\frac{\beta}{T}\right)C^2
\]

Using the following set of parameters:

| \( \alpha \) | 2 |
| \( \beta \) | -0.02 |
| \( k \) | 1.5 |
| \( \gamma \) | 500 |

Linearize both equations with respect to \( C, C_{in}, T, T_{in} \) at the following operating point:

| \( C \) | 0.616 |
| \( T \) | 295 |
| \( C_{in} \) | 0.9 |
| \( T_{in} \) | 200 |

2. (15 pts) Suppose the pressure in a tank is described by the following equation:

\[
\frac{d^2P}{dt^2} + 4 \frac{dP}{dt} = \mu (1.2 - P)
\]

Find the range of values for \( \mu \) so that the process will be underdamped.

3. (25 pts) Obtain the characteristic equation for the process described by the following equations:

\[
2 \frac{dT}{dt} + 3P = -2(T + 0.5P) + e^{-t}
\]

\[
2P - 3 \frac{dP}{dt} = -4(T + 0.5P) - 2e^{-2t}
\]
4. (25 pts) A process is described by the following equations:

\[
\frac{dx}{dt} = z
\]

\[
\frac{dz}{dt} = -kx - mz + \eta
\]

\[x(0) = 10\]

\[z(0) = 0\]

Determine the values of \( k \), \( m \) and \( \eta \) that would yield the process response shown in Figure 1.

![Figure 1](image)

5. (10 pts) Determine the range of values of \( k \) that would stabilize the following process:

\[ (k - 2) \frac{dT}{dt} + 3T = k(T - 2.5) \]

6. (Bonus: 5 pts) For a first order process given by,

\[ 10 \frac{dq}{dt} + 5q = 50 \]

what is the value of \( q \) at \( t=2 \) if \( q(0)=0 \)?