Q1. Given the second-order process that describes the dynamics of reactor temperature:

\[ T(s) = \frac{k_p(\tau_1 s + 1)}{(\tau_1 s + 1)(\tau_2 s + 1)} F(s) \]

(a) Find the time-domain temperature response to a step change in \( F \) at \( t = 0 \) of magnitude of 1.
(b) If \( k_p = 1 \) °C/Lpm, \( \tau_1 = 3 \) min, \( \tau_2 = 15 \) min and \( \tau = 20 \) min, find the peak temperature and the time that it occurs.

Q2. Consider the following process transfer function:

\[ y(s) = \frac{1}{(s-1)(s+2)} u(s) \]

(a) Is the open-loop system stable and why?
(b) Find the range of \( k_c \) for a P-only controller that will stabilize the system assuming negligible dynamics for the control valve and measuring device.
(c) Let \( k_c = 2 \) and assume the measuring device has a first-order dynamics with gain \( k_m = 2 \) and unknown time constant \( \tau_m \). Find the maximum value of \( \tau_m \) which is allowed before the system becomes unstable.

Q3. A pressurized tank dynamics is modeled by the following transfer function:

\[ G_p(s) = \frac{4s + 1}{(2s + 1)(s + 1)} \]
Assume the dynamic behavior of the pressure sensor and the control valve are characterized by the following:

\[
G_m(s) = \frac{1}{0.2s + 1} \quad G_v(s) = \frac{1}{0.1s + 1}
\]

For P-only controller, find the ultimate controller gain and ultimate period.

**Q4.** Given \( G_p = \frac{1}{s-1} \); \( G_m = G_v = 1 \), and \( G_c = k_c (1 + \frac{1}{\tau cs}) \) find the value of the integral time that makes the closed-loop response over-damped when \( k_c = 2 \).

Useful data

<table>
<thead>
<tr>
<th>( f(t) )</th>
<th>( F(s) )</th>
<th>decay ratio</th>
<th>Period</th>
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<td>( \exp\left(-\frac{2\pi \xi}{\sqrt{1 - \xi^2}}\right) )</td>
<td>( \frac{2\pi \tau}{\sqrt{1 - \xi^2}} )</td>
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<tr>
<td>( \sin wt )</td>
<td>( w/(s^2+w^2) )</td>
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<tr>
<td>( \cos wt )</td>
<td>( s/(s^2+w^2) )</td>
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