INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics & Control
Assignment 3

Due: Friday, March 06, 2020

Exercise

1. A process is given by the transfer function $G(s) = \dfrac{10(s-4)}{s^2+7s+10}e^{-3s}$. For this process,
   (a) Compute the impulse and step response of the system. Sketch these responses by hand.
   (b) Determine the large-time response of the process to an input $u(t) = 2\sin(4t) + \cos(0.1t)$
   (c) Construct the Bode plot by hand. Show the working details neatly.
   (d) Determine the LTI system that has the same magnitude at all frequencies but the lowest phase.
   (e) Verify your answers to all parts using MATLAB.

2. The dynamic behavior of the liquid level in a leg of a manometer tube, responding to a change in pressure, is given by

$$\frac{d^2h'}{dt^2} + \frac{6\mu}{R^2\rho}\frac{dh'}{dt} + \frac{3}{2}\frac{g}{L}h' = \frac{3}{4\rho L}p'(t)$$

   where $h(t)$ is the level of fluid measured with respect to the initial steady-state value, $p(t)$ is the pressure change, and R, L, g, ρ, and μ are constants.
   (a) Rearrange this equation into standard gain-time constant form and find expressions for K, τ, ζ in terms of the physical constants.
   (b) For what values of the physical constants does the manometer response oscillate?
   (c) How would you change the length L of the manometer leg so as to make the response more oscillatory, or less? Repeat the analysis for an increase in μ (viscosity).

3. The transfer function that relates the change in blood pressure y to change in u the infusion rate of a drug (sodium nitroprusside) is given by

$$G_p(s) = \frac{Ke^{-\theta_1 s}(1+\alpha e^{-\theta_2 s})}{\tau s + 1}$$

   The two time delays result from the blood recirculation that occurs in the body, and α is the recirculation coefficient. The following parameter values are available:

$$K = -1.0\frac{\text{mm Hg}}{ml/h},$$
$$\alpha = 0.4, \theta_1 = 30 \text{ s}, \theta_2 = 45 \text{ s}, \text{and } \tau = 40 \text{ s}$$

   Use Simulink to construct the block diagram and simulate the blood pressure response to a unit step change ($u = 1$) in sodium nitroprusside infusion rate. Is it similar to other responses discusses in class ?