INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics and Control
Assignment 1

Due: Sunday, February 02, 2020 11:55 PM

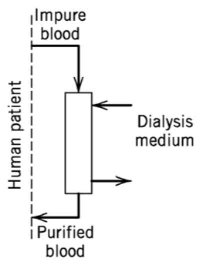
Exercise

1. Consider a home heating system consisting of a natural gas-fired furnace and a thermostat. In this case the process consists of the interior space to be heated. The thermostat contains both the measuring element and the controller. The furnace is either on (heating) or off.

   Do / answer each of the following:

   (a) Identify the controlled variables, manipulated variables, and disturbance variables.
   (b) Propose a feedback control method and sketch the schematic diagram.
   (c) Suggest a feed-forward control method and sketch the schematic diagram.

2. Consider a **kidney dialysis unit**, a medical equipment that is used to remove waste products from the blood of human patients whose own kidneys are failing or have failed. A schematic of the unit is shown below. The blood flow rate is maintained by a pump, and "ambient



conditions" such as the temperature in the unit are controlled by adjusting a flow rate. The dialysis is continued long enough to reduce waste concentrations to acceptable levels. Is this process a continuous, batch or semi-batch process? Identify the controlled, manipulated and disturbance variables.

3. Consider the following model of 2-stage absorption model:

$$\frac{dw}{dt} = -\frac{L+Va}{M}w + \frac{Va}{M}z$$
$$\frac{dz}{dt} = \frac{L}{M}w - \frac{L+Va}{M}z + \frac{V}{M}z_f$$

where w and z are liquid concentrations on stage 1 and 2, respectively. L and V are the liquid and vapour molar flow rates, z_f si the concentration of the vapour stream entering the column.

The steady-state input values are $L = 80$ gmol inert liquid/min and $V = 100$ gmol inert vapour/min. The parameter values are $M = 20$ gmol inert liquid, $a = 0.5$ and $z_f = 0.1$ gmol solute / gmol inert vapour.

Do / answer each of the following:

(a) Find the steady-state values of w and z.

(b) Obtain a linearized state-space model around the normal steady-state operation assuming that L and V are the inputs.

(c) Find the eigenvalues of the system. What are the expected "slowest" and "fastest" initial condition directions of the system?

(d) Set up the non-linear system in MATLAB. Solve for steady-state (use `trim`) and obtain a linearized model using the linear analysis tools in MATLAB/SIMULINK.

(e) Plot and compare the step responses of the non-linear system with that of the linearized model for two different magnitudes of steps (i) 5% and (ii) 15% change in the flow rate.

4. Answer the following

(a) Find the Laplace Transform of the signal $x(t) = \begin{cases} t-3 & 0 \le t < 3 \\ 0 & 3 \le t < 4 \\ \sin(3\pi(t-4)) & 4 \le t < 5 \\ e^{-2t}\sin(5\pi t) & t \ge 5 \end{cases}$.

(b) Find the inverse Laplace transform of $X(s) = \dfrac{(s-1)}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$, where $\tau > 0$. Consider three different cases: (i) $\zeta > 1$, (ii) $\zeta = 1$ and (iii) $0 \le \zeta < 1$