# Process Control, 3P4 Your name: ____________

# Tutorial 5 - Monday Student number: ____________

This tutorial provides some practice for the first midterm.

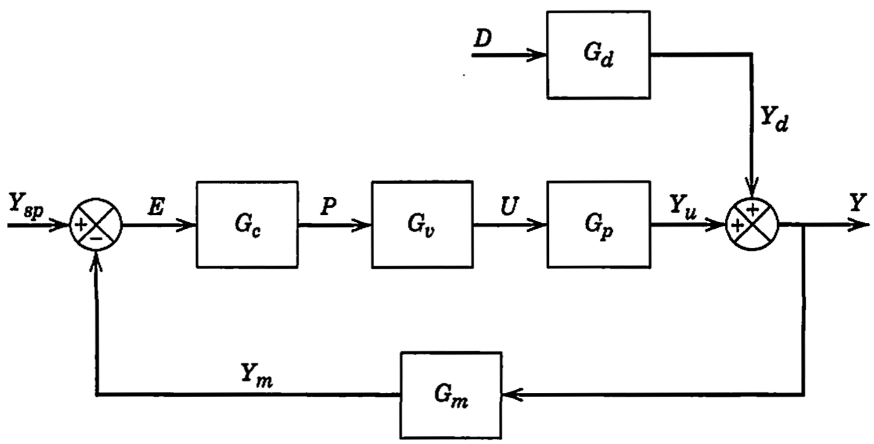
#### Question 1

Below is the standard feedback control diagram for any process, $G_p$, which has an input $U$ and output $Y_u$. There are other transfer functions, such as $G_c$, which takes the set point value, $Y_{\text{sp}}$ and *subtracts* from it the measurement from the sensor, $Y_m$. The controller then issues a signal to the valve to open or close, via the value $P$. The valve also has a (fast) transfer function, $G_v$, which creates the actual process input signal $U$.

Our measurement on the process, $Y$, is made up of two parts, $Y_d$ and $Y_u$. The transfer function $G_m$ represents the dynamics of the sensor (measurement), a similar idea to the transfer function for the thermocouple in question 2 of assignment 3.

Each of the transfer functions for the *systems* are in Laplace form, i.e. $G_p$ should actually be written as $G_p(s)$. Each of the transfer functions for the *signals* are in Laplace form, i.e. $Y$ should actually be written as $Y(s)$.

Today's task is simple: become comfortable with the notation in the block diagram - we are going to see and use this many times, which is why we drop off the $(s)$ parts on the *systems* and *signals*.




1. Derive an expression which gives the output $Y(s)$ for a given valve input signal $P(s)$ and a given disturbance signal $D(s)$. Your answer should be $Y(s) =$ ____
2. Derive a single transfer function which gives the output $Y(s)$ for a given input $Y_{\text{sp}}(s)$. For this part of the question, assume input $D$, and consequently $Y_d$ are both zero (for today). Your answer: $\dfrac{Y(s)}{Y_{\text{sp}}(s)} = \ldots$

**Question 2**

1. The continuous stirred tank chemical reactor shown in the figure is to be analyzed. Assumptions and data for deriving a dynamic model are given below.

i) the tank is well mixed and isothermal (T = constant)
ii) the density and the heat capacity ($C_p \approx C_v$) are constant and independent of composition
iii) flow rates in and out and the volume are constant
iv) the system is initially at steady state
v) the reaction $A \rightarrow B$ is irreversible
vi) the feed stream contains the reactant ($C_{A0}$) and the inhibitor ($C_{I0}$)

vii) the rate of reaction of A is $r_A = - k_0 e^{-E/RT} C_A/(1+k_I C_I)$ where $C_I$ is the concentration of inhibitor. The parameters $k_0$, E/R, and $k_I$ are constant.

| |
|---|
| The inhibitor influences the reaction rate but is neither generated nor consumed in the reaction. |

**Goal: Determine the dynamic response of the concentration of reactant A after the step in the inhibitor feed concentration.**

**A. (20 points)**

1. By applying basic balances, derive the differential equation(s) that describe the dynamic behavior of the inhibitor concentration ($C_I$) in the reactor for any change in $C_{I0}$.
2. Express the equation derived in Part A.1 as a linear (or linearized, as needed) equation in deviation variables. Identify the steady-state gain and the time constant.

**B. (20 points)**

1. From the basic balances, derive the differential equation(s) that describe the dynamic behavior of composition of A ($C_A$) in the reactor for any change in $C_I$.
2. Express the equation derived in Part B.1 as a linear (or linearized, as needed) equation in deviation variables. Identify the steady-state gain and the time constant.

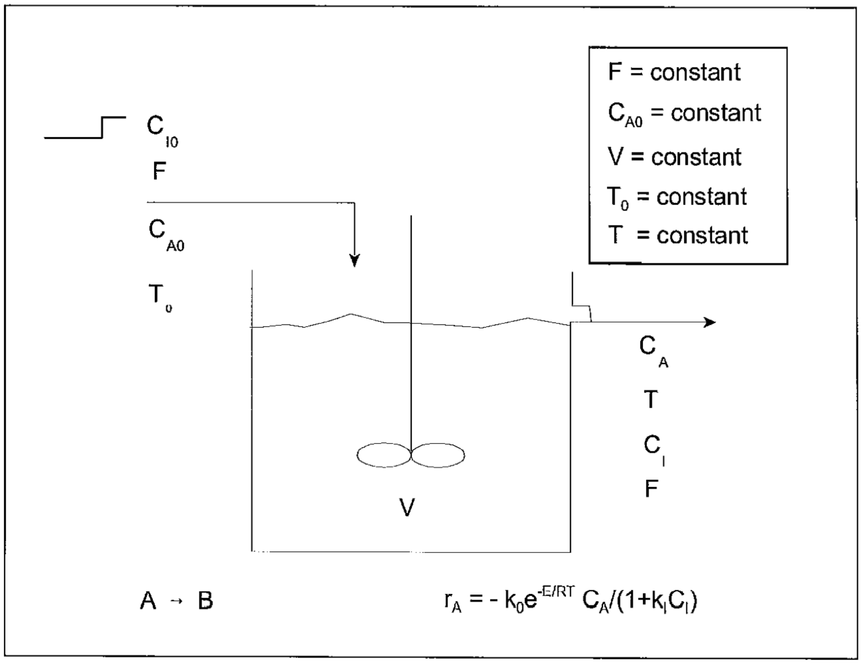



Figure 1. CSTR analyzed in Question 1.