INDIAN INSTITUTE OF TECHNOLOGY MADRAS

Department of Chemical Engineering

Simulation lab (CH2082)

Assignment 4 – (26/03/2014)

Wednesday Batch

Instructions

1. Attempt all problems on your own.
2. You may discuss with the TAs for assistance.
3. All variables should be declared or initialized within your program
4. Name each program using the following convention using a combination of your roll number, assignment number and question number. i.e., if your roll number is CH12B001, name the program in the first question of the first assignment as follows:CH12B001_A1_Q1.m
5. Submit a single zipped folder (named accordingly e.g. CH12B001_A2) in moodle which contain matlab codes (m files) for each question and one pdf file (after publishing)
6. Comment wherever required

Note: All submissions are to be made by 5pm on the same day.

Questions

1. A) A golf ball of mass 46 gm, radius of 21 mm is propelled into the air with an initial speed of 35.5 m/s making an angle of 30^o with the ground. Assume the ground is perfectly flat and neglecting air resistance, determine the range (horizontal distance travelled) of the ball. Plot the trajectory of the ball. Do not use analytical solutions. All answers must be determined by numerical integration and MATLAB.

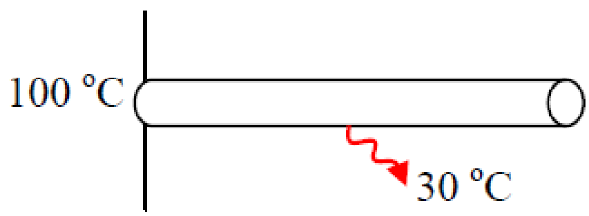
   B) Now, assume that the ball experiences drag friction, the magnitude of which is approximately given by the following formula:

$$F_{drag} = 0.5\rho r^2 v^2$$

   where ρ is the density of air, and v is the instantaneous speed of the ball. Assume ρ = 1.3kg/m3. Determine the range of the ball and plot the trajectory. (Note that the above equation only gives the magnitude of the total drag force. It acts opposite to the direction of motion, i.e, along the tangent to the trajectory. So, resolve the resistance force into the x and y components and then include in the equation of motion).

C) Plot the trajectory in part (A) and part (B) in the same figure window. Use proper captions, legend etc.

2. Consider a metal rod which has its one end connected to a hot equipment and the other end exposed to atmosphere such that it dissipates heat to the surroundings. Such structures are routinely used to manage heat: in car radiators, refrigerators, computer chips etc. We will model just one single rod of the assembly and solve it using an appropriate solver.



With appropriate derivation, the model for this system can be represented as:

$$\frac{d^2T}{dz^2} = 0.1(T - 30) \quad \text{subject to} \quad T_{(z=0)} = 100; T_{(z=5)} = 30$$

We discretize the above equation into 50 intervals. Thus, we will get linear equations in 51 variables.The linear set of equations that you need to solve are as follows:

$$T_1 = 100$$

$$100T_{i-1} - 200.1T_i + 100T_{i+1} = -3 \qquad \text{for } i = 2 \text{ to } 50$$

$$T_{51} = 30$$

With this, we define a vector containing all the temperatures as: $x = [T_1, T_2, \cdots, T_{51}]^T$

The above equations can then be written in the form: Ax = b

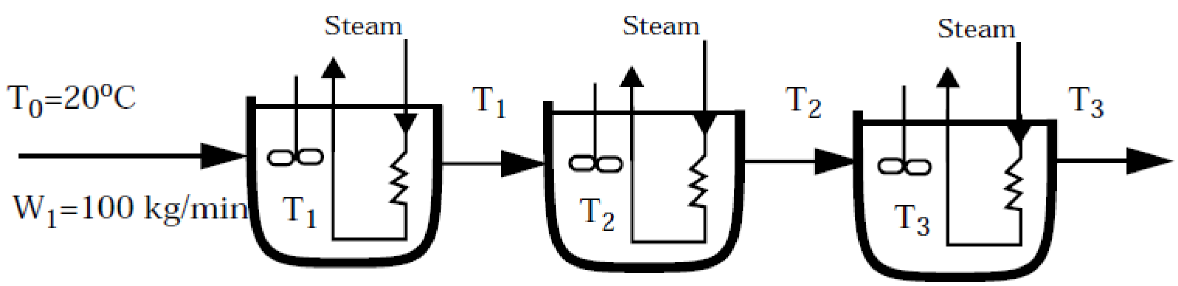
Solve the equations to get the steady state temperature profile of the rod.

3. Three tanks in series are used to preheat a multicomponent oil solution before it is fed to a distillation column for separation as shown in Figure 1. Each tank is initially filled with 1000 kg of oil at 20°C. Saturated steam at a temperature of 250°C condenses within coils immersed in each tank. The oil is fed into the first tank at the rate of 100 kg/min and

overflows into the second and the third tanks at the same flow rate. The temperature of the oil fed to the first tank is 20°*C*. The tanks are well mixed so that the temperature inside the tanks is uniform, and the outlet stream temperature is the temperature within the tank. The heat capacity, *Cp*, of the oil is 2.0 KJ/kg. For a particular tank, the rate at which heat is transferred to the oil from the steam coil is given by the expression

$$Q = UA(T_{steam} - T)$$

where *UA* = 10 kJ/min·°*C* is the product of the heat transfer coefficient and the area of the coil foreach tank, *T* = temperatureof the oil in the tank in ^{0}C, and *Q* = rate of heat transferred in kJ/min.



Heat transfer equation for first tank:

$$MC_p\frac{dT_1}{dt} = WC_pT_0 + UA(T_{steam} - T_1) - WC_pT_1$$

Determine the steady state temperatures in all three tanks. What time interval will be required for T3 to reach 99% of this steady state value during startup?