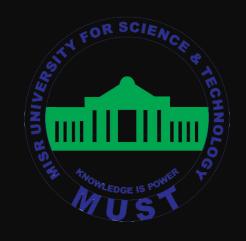
# MISR UNIVERSITY FOR SCIENCE AND TECHNOLOGY COLLEGE OF ENGINEERING MECHATRONICS DEPARTMENT



# MTE 506 DIGITAL CONTROL

LAB 1 - SPRING 2020

# Goals of The Lab

Discretization of Analog Control Systems





Assertion on the notion of modeling and simulation

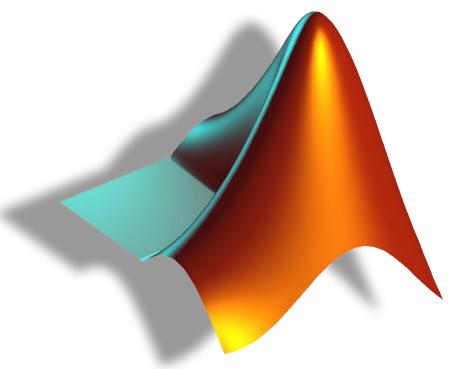


Converting a dynamic system to mathematical model

Lab 1

## Software For Simulation

Needed for all labs



## **MATLAB**

R2017b or above

Student must install software in advance before attending any lab

# Simulating Water Tank

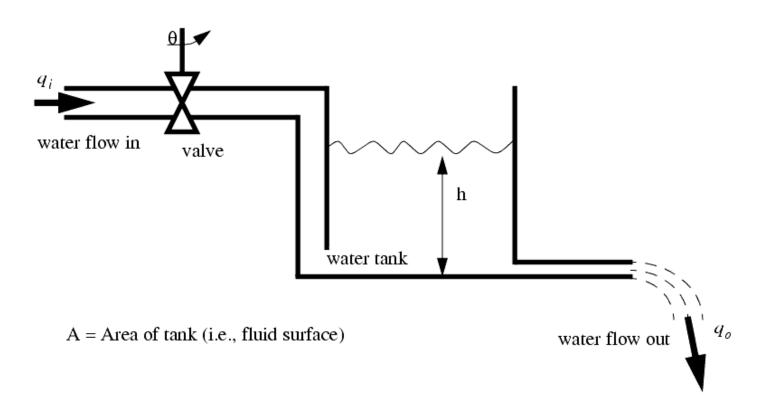
From physical simulation to modeling

## Simulating behavior

Using MATLAB script for simulation

## Mathematical Modeling

Using Simulink for implementing tank response



# Quick review on concepts

Mechatronics notation

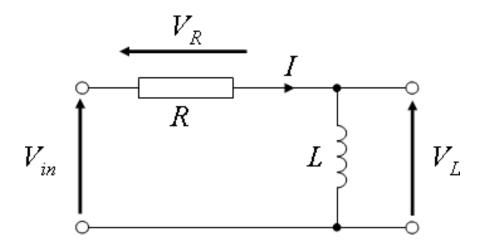
## Modeling

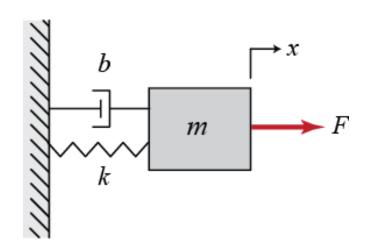
Converting behavior of objects into mathematical equations stating the relationship of system input(s) and output(s)

## **Examples**

Mechanical:  $mx\ddot{(t)} + c\dot{x}(t) + kx(t) = f(t)$ 

Electrical: Li(t) + Ri(t) = v(t)





#### Lab<sub>1</sub>

## Quick review on concepts

Mechatronics notation

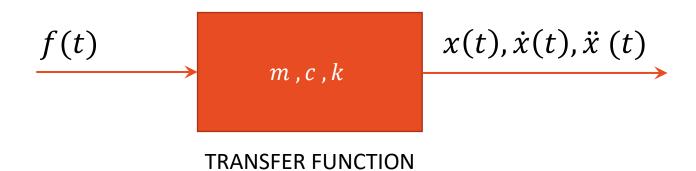
## Modeling

Converting behavior of objects into mathematical equations stating the relationship of system input(s) and output(s)

## **Examples**

Mechanical:  $mx\ddot{(t)} + c\dot{x}(t) + kx(t) = f(t)$ 

Electrical: Li(t) + Ri(t) = v(t)

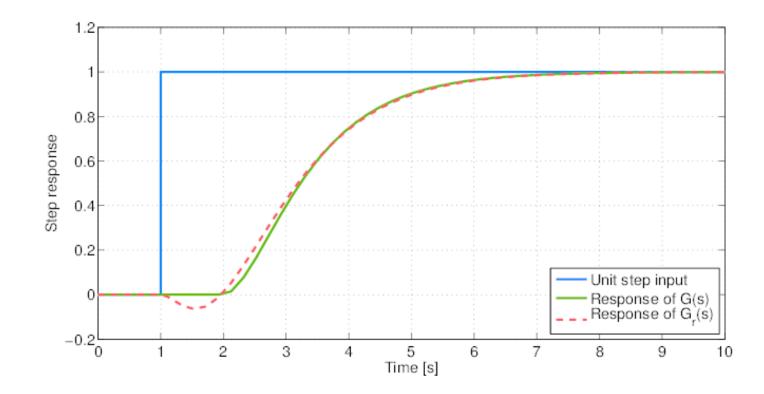


# Quick review on concepts

Mechatronics notation

## **Simulation**

Plotting the output(s) when the model is stimulated by an input

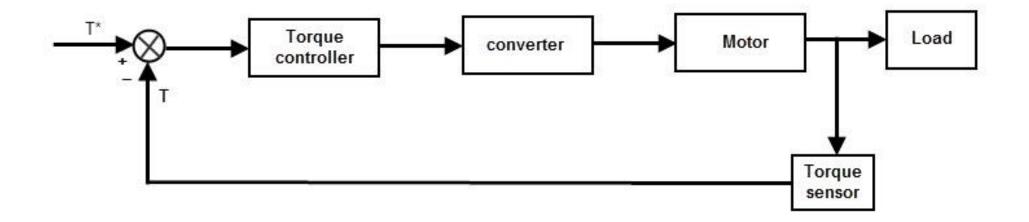


# Quick review on concepts

Mechatronics notation

## Control

Forcing an output to reach a desired level based on knowing the error in reading and desired input



# Modeling of the tank

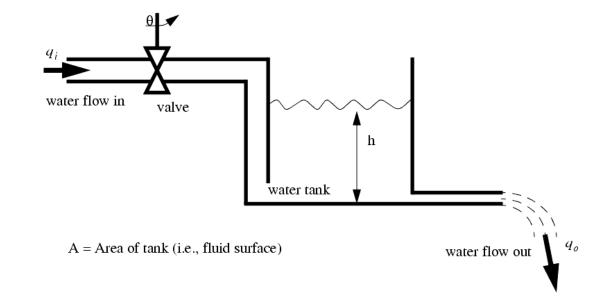
Simple example

We will ignore input valve (for simplification)

$$\Delta V = q_o - q_i$$

$$A \frac{h(t) - h(t - \Delta t)}{t - (t - \Delta t)} = q_o - q_i$$

$$q_o = kh(t - \Delta t)$$



$$h(t) = \frac{\Delta t * (kh(t - \Delta t) - q_i)}{A} + h(t - \Delta t)$$

#### Lab<sub>1</sub>

# Modeling of the tank

Simple example

$$\Delta V = q_i - q_o$$

$$A\frac{h(t) - h(t - \Delta t)}{t - (t - \Delta t)} = q_i - q_o$$

$$q_o = kh(t - \Delta t)$$

dh

 $q_i$  ... Tank input flowrate  $(\frac{m^3}{2})$ 

 $q_o$  ... Tank output flowrate (

h ...Tank height (m)
A ...Tank cross sectional area  $(m^2)$ 

k ... friction coefficient  $(\frac{m^2}{2})$ 

$$h(t) = \frac{\Delta t * (q_o - q_i)}{A}$$

$$-h(t-\Delta t)$$

**Previous State** 

#### Lab<sub>1</sub>

## MATLAB scripting

Exercise 1

- What is the value of qin to reach a level of 3m?
- Will the final level be changed if K is changed?

```
Z Editor - D:\University\MTE 506 Digital Control\Lab 1\Exercises\Exercise 1\tank_simulation.m
   tank_simulation.m × +
22
         %% Simulate the tank model
23 -
        qin = 0.4 * ones([1 length(t)]); % convert qin single value to array
        h = zeros([1 length(t)]); %allocate h values with zeros
       \exists for i = 1 : length(t)

■ Figure 1: Step Response

26 -
             if (i == 1)
                                                        File Edit View Insert Tools Desktop Window Help
                  28 -
             else
                                                                               Plotting step response
29 -
                  hprev = h(i-1); %h(t - dt)
                                                             1.4
                                                                                                                0.16
30 -
                                                                                                     Input Discarge
             end
                                                             1.2
                                                                                                     Tank Level
31 -
             gout = k * abs(sqrt(hprev)); % gour
                                                                                                                0.14
32
             % h(t) = [(qout - qin(t))/area] +
33 -
             h(i) = dt * (qin(i) - qout)/a) + hi
                                                             0.8
                                                                                                                0.12
34 -
                                                          (m<sub>3</sub>/s)
                                                             0.6
35
                                                           Discharge
36 -
        figure ('name', 'Step Response')
Command Window
   >> tank simulation
                                                                                                                0.08
fx >>
                                                             -0.2
                                                                                                                0.06
                                                             -0.4
                                                                                                                0.04
                                                             -0.6
                                                                               10
                                                                                       15
                                                                                               20
                                                                                                       25
                                                                       5
                                                                                                               30
                                                                                     time (s)
```

# Modeling of the tank

Laplace Transform

We will ignore input valve (for simplification)

$$\Delta V = q_i - q_o$$

$$A \frac{h(t) - h(t - \Delta t)}{t - (t - \Delta t)} = q_i - q_o$$

water flow in valve

$$A = Area \text{ of tank (i.e., fluid surface)}$$

water flow out

$$Q$$

$$A\frac{dh}{dt} = q_i - kh$$

$$A\frac{dh}{dt} + kh = q_i \qquad \frac{A}{k}\frac{dh}{dt} + h = \frac{q_i}{k} \qquad \tau \frac{dh}{dt} + h = K_2 q_i$$

# Modeling of the tank

Laplace Transform

$$\Delta V = q_i - q_o$$

$$A\frac{h(t) - h(t - \Delta t)}{t - (t - \Delta t)} = q_i - q_o$$

$$A\frac{dh}{dt} = q_i - kh$$

$$A\frac{dh}{dt} + kh = q_i \qquad \frac{A}{k}\frac{dh}{dt} + h = \frac{q_i}{k} \qquad \tau \frac{dh}{dt} + h = K_2 q_i$$

$$\tau = \frac{A}{k} \qquad K_2 = \frac{1}{k}$$

$$\frac{H(s)}{Q_i(s)} = \frac{K_2}{\tau S + 1}$$

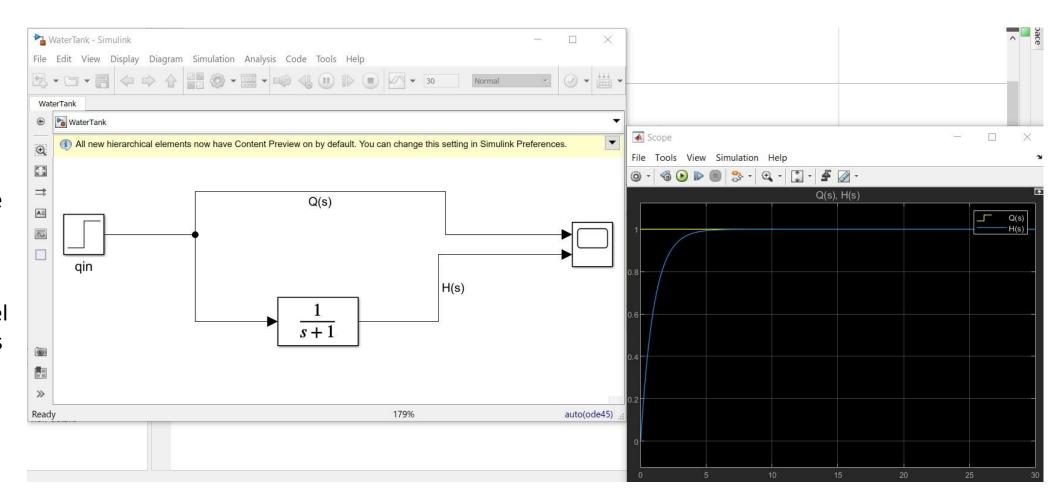
First Order System

$$\tau \frac{dh}{dt} + h = K_2 q_i$$

## **SIMULINK**

Exercise 2

- What is the value of qin to reach a level of 3m?
- Will the final level be changed if K is changed?



# END OF LAB 1