ENR 261 Spring 2023 Simulink Homework

General Instructions:

Save your all your Matlab files for this chapter in the folder named **Simulink** located inside your local repository on your USB Memory Stick. When finished be sure to add, commit, and push your changes to your remote repository on GitHub.

Assigned Exercises

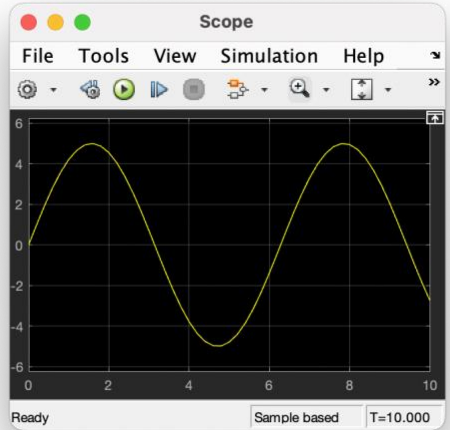
Create the Simulink Tutorials on the following pages.

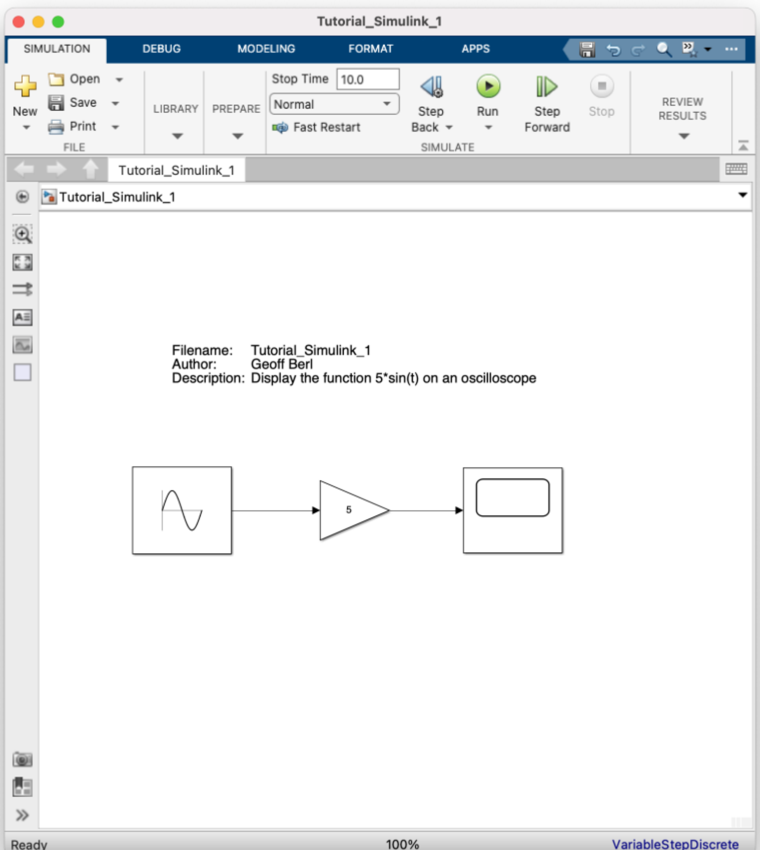
Required File Name: **Tutorial_Simulink_1.slx**

1. To open the Simulink interface, click the Simulink button found on the “Home” tab.

2. You will need to read the Getting Started with Simulink “Simple Block Diagrams” and “Create a Simple Model” documentation here in order to complete **Tutorial_Simulink_1.slx**

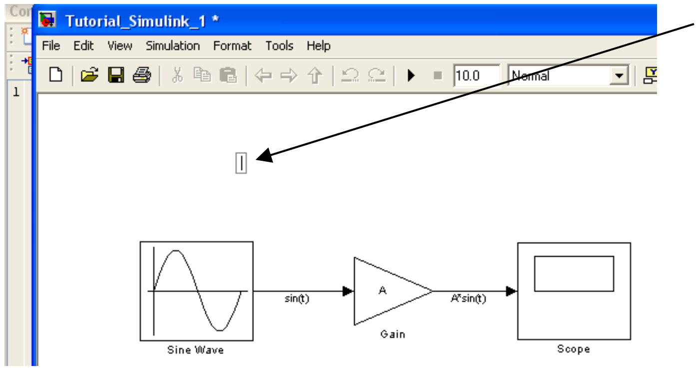
3. Create the Simulink file to implement the function: 5*sin(t). Display the output with a scope. Use descriptive labels for all components and connecting lines as shown below.


Scope
File Tools View Simulation Help
Ready
Sample based
T=10.000


Tutorial_Simulink_1
SIMULATION
DEBUG
MODELING
FORMAT
APPS
New
Open
Save
Print
FILE
LIBRARY
PREPARE
Stop Time 10.0
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
SIMULATE
REVIEW RESULTS
Filename: Tutorial_Simulink_1
Author: Geoff Berl
Description: Display the function 5*sin(t) on an oscilloscope
5
Ready
100%
VariableStepDiscrete

4. Add a Block Description to your Simulink model, follow the steps below.

   a. Double Click in the Simulink Model window and a small rectangle and blinking cursor should appear.



   b. Type in the filename, your name, and a description of the model.

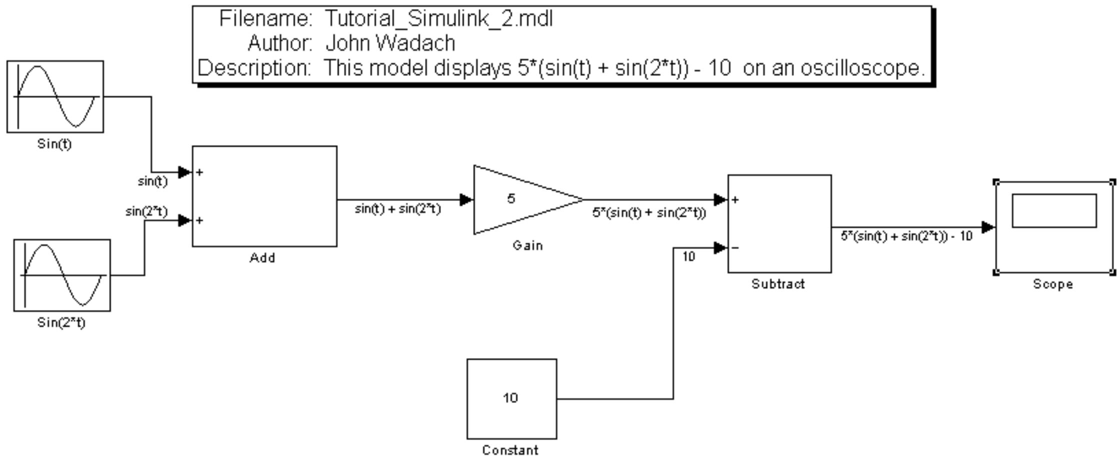
Filename:	Tutorial_Simulink_1
Author:	Geoff Berl
Description:	Display the function 5*sin(t) on an oscilloscope

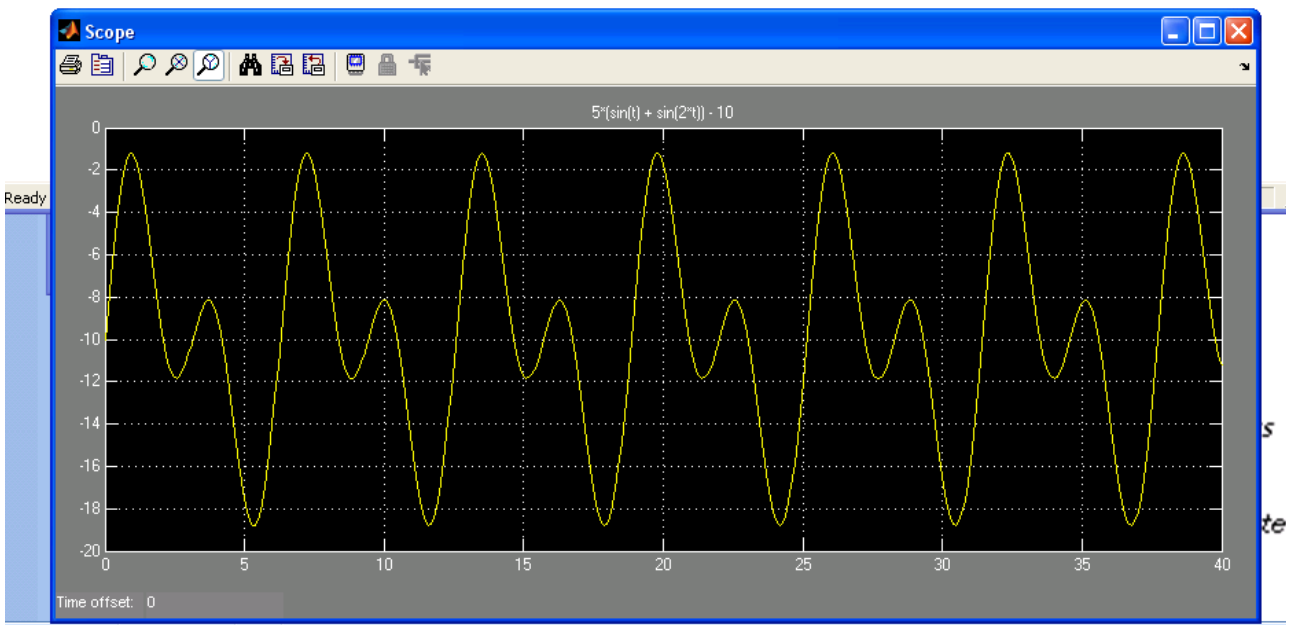
   c. Type out the comments, using tabs between the descriptor and values in order to align text as shown in the example.

Required File Name: **Tutorial_Simulink_2.slx**

1. Create the Simulink file to implement the function: 5*(sin(t) + sin(2*t)) – 10 with a maximum step size of 0.1 and a total run time of 40. Display the output with a scope. Use descriptive labels for all components and connecting lines, as shown below.

2. **2.** Display the output with a scope.





Required File Name: **Tutorial_Simulink_3.slx**

1. In the MATLAB Workspace define two column vectors as shown below.

   t = [0: 0.05: 10]'; u = sin(t.^2);

   simin = [t, u];

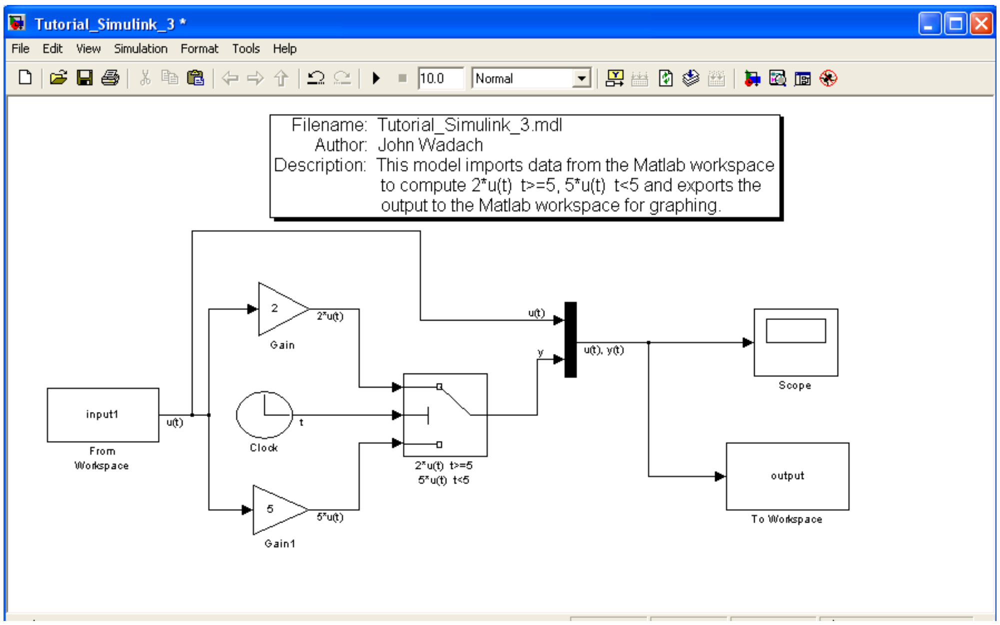
2. Import the input1 values into a Simulink model to implement the following equation:

   y(t) = 2*u(t) for t >= 5

   y(t) = 5*u(t) for t < 5

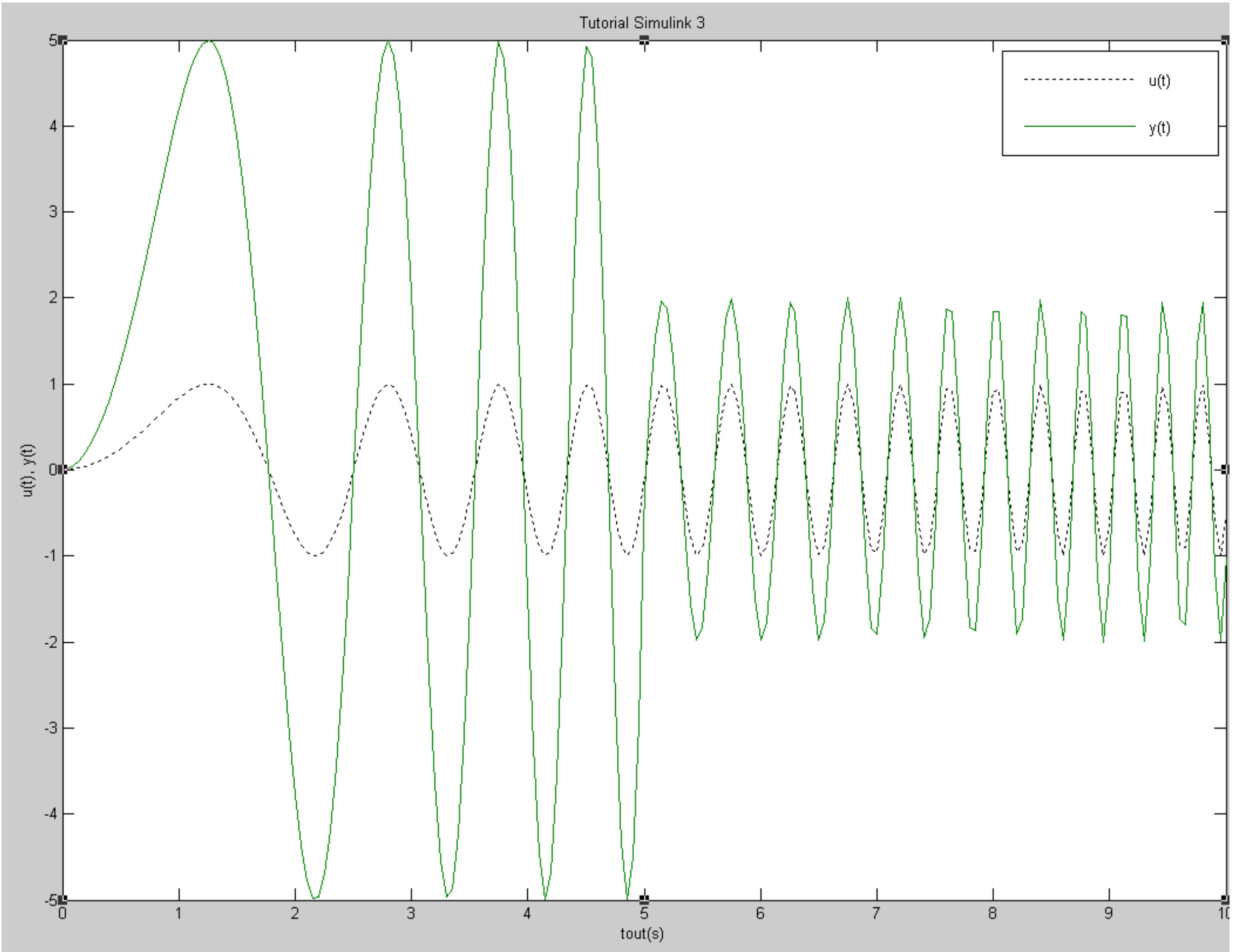
4. Set the max step size in the Simulink Model to 0.05.

5. Export the values of u(t) and y(t) from the Simulink Model to the Matlab Workspace in a variable named **output**.



6. In the Matlab Command Window execute the command **plot(tout, output).**

7. Edit your plot in the figure window so that it appears as on the next page. Save the figure with the name **Tutorial_Simulink_3.fig** .


Tutorial Simulink 3
u(t)
y(t)
u(t), y(t)
tout(s)
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
1
2
3
4
5
6
7
8
9
10

Required File Name: **Tutorial_Simulink_4.slx**

1. Modify **Tutorial_Simulink_3.slx and save it as Tutorial_Simulink_4.slx** by making the following changes.

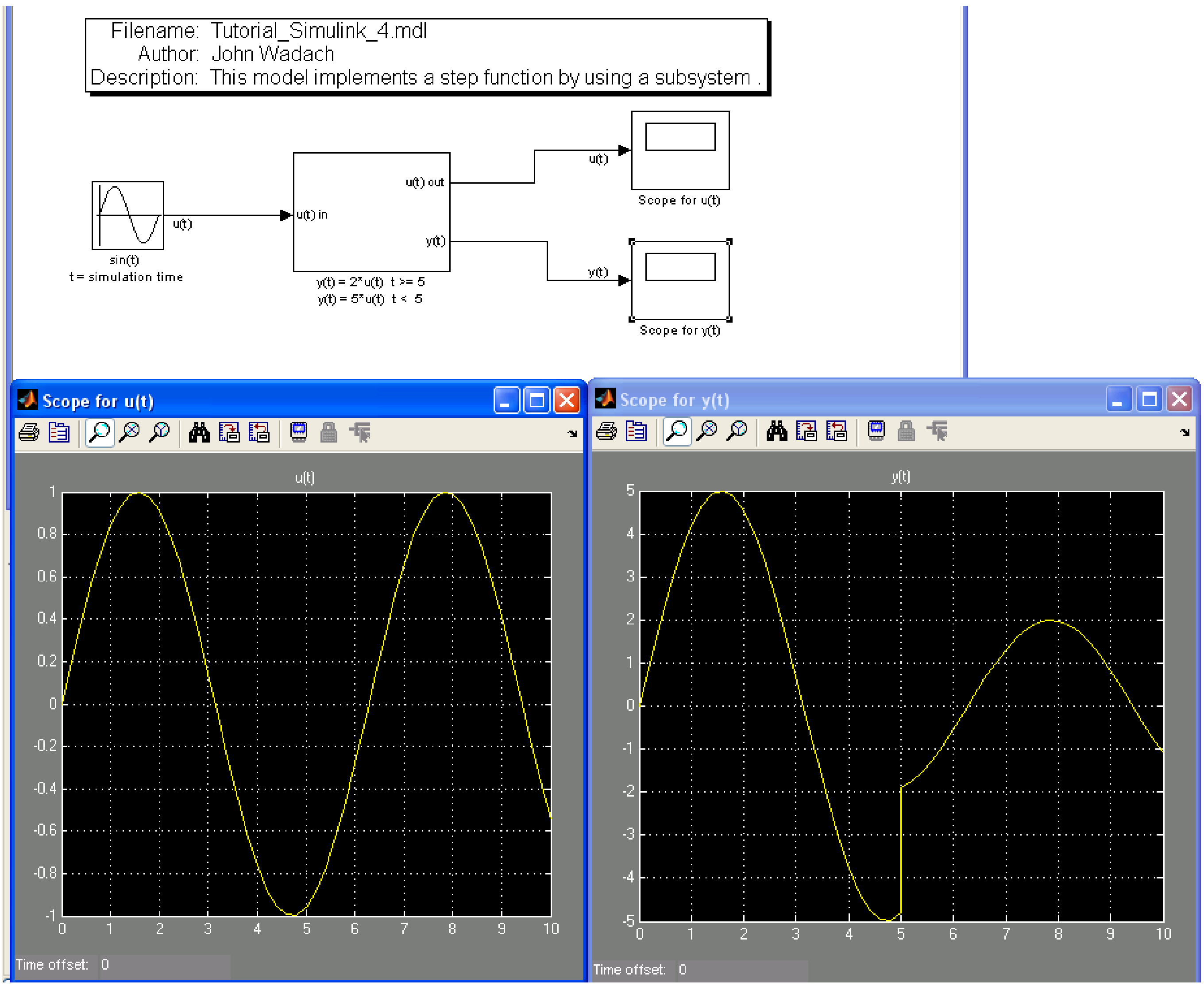
   a. Create a Subsystem for all components except the **From Workspace**, **Scope** and **To Workspace Blocks**.

   b. Remove the Mux Block in the subsystem and create two outputs labeled u(t) out and y(t).

   c. Replace the From Workspace Block with a Sine Wave Block. Double click on the Sine Wave Block and make sure that Time(t) uses Simulation Time.

   d. Replace the To Workspace Block with a second scope.

   e. Run the simulation from 0 to 10 seconds using the default step size.



Unfortunately I have been unable to locate the portion of the On-Ramp Tutorials regarding these assignments. However, the models are shown in the images below (with the exception of the Laplace transform). What you have learned thus far is enough to get you through the remaining tutorials.

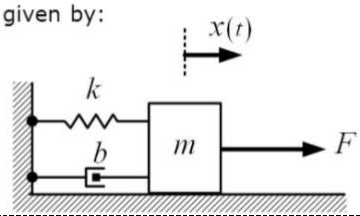
Using Simulink to Model Continuous Dynamical Systems (approximately 30 minutes)

Modeling Transfer Functions (12:50)
Implement a derived transfer function, and understand how Simulink propagates a continuous dynamical system through time

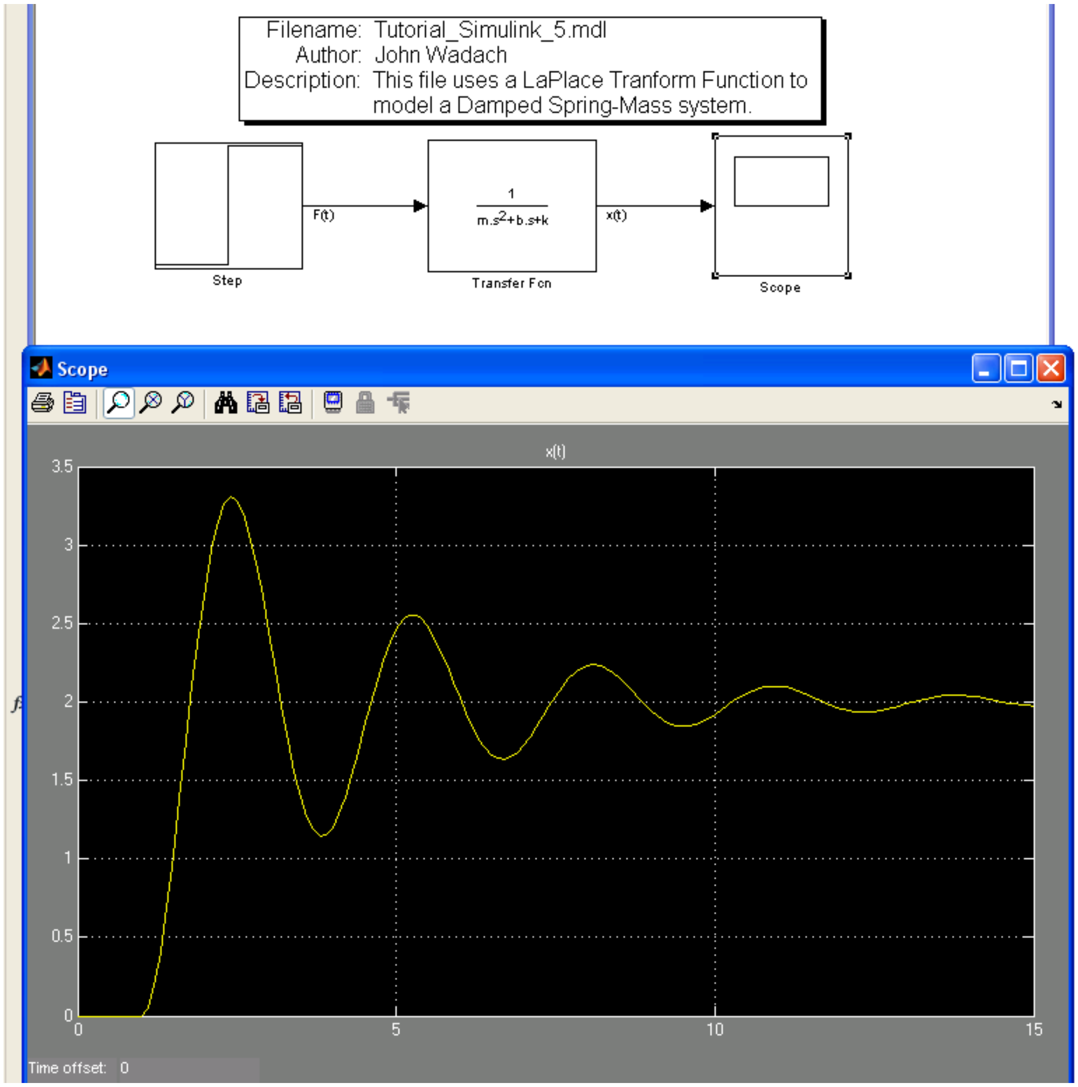
Modeling a System of Differential Equations (7:26)
Learn to use the Integrator block to model differential equations

Required File Name: **Tutorial_Simulink_5.slx**

- Consider the mass-spring-damper system below.
- The dynamic model of the process can be derived as:
  $m\ddot{x}(t)+b\dot{x}(t)+kx(t)=F(t)$
- Taking the Laplace Transform yields:
  $ms^2X(s)+bsX(s)+kX(s)=F(s)$
- The transfer function is then given by:
  $\frac{X(s)}{F(s)}=\frac{1}{ms^2+bs+k}$



1. Construct a Simulink file to model a Mass-Spring-Damper System using a Laplace Transform with m=1, b=0.6, k=5, and F(t)= a step function with an initial value of 0 and final value of 10.
2. *Hint:* You should use a Transfer Fcn block and set the denominator coefficients to [m b k] to create a Laplace Transform Transfer Function. More details as to why can be found in the Help Documentation.
3. Define m, b, and k in the Matlab Workspace so the program user can easily change these values.
4. Display the results from 0 to 15 seconds in steps of 0.1 sec using an oscilloscope as shown below.


Filename: Tutorial_Simulink_5.mdl
Author: John Wadach
Description: This file uses a LaPlace Tranform Function to model a Damped Spring-Mass system.
F(t)
1
m.s2+b.s+k
x(t)
Step
Transfer Fcn
Scope
x(t)
Time offset: 0

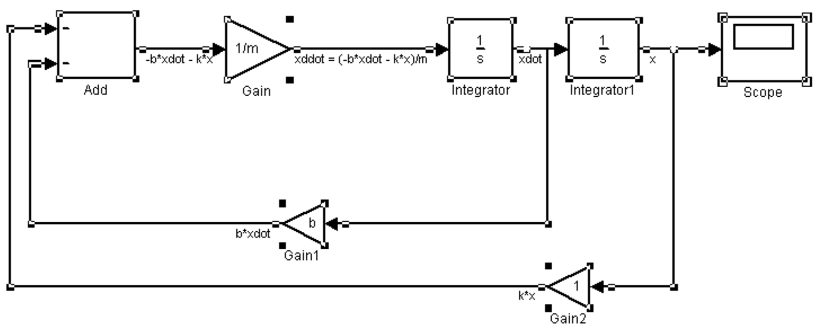
Required File Name: **Tutorial_Simulink_6.slx**

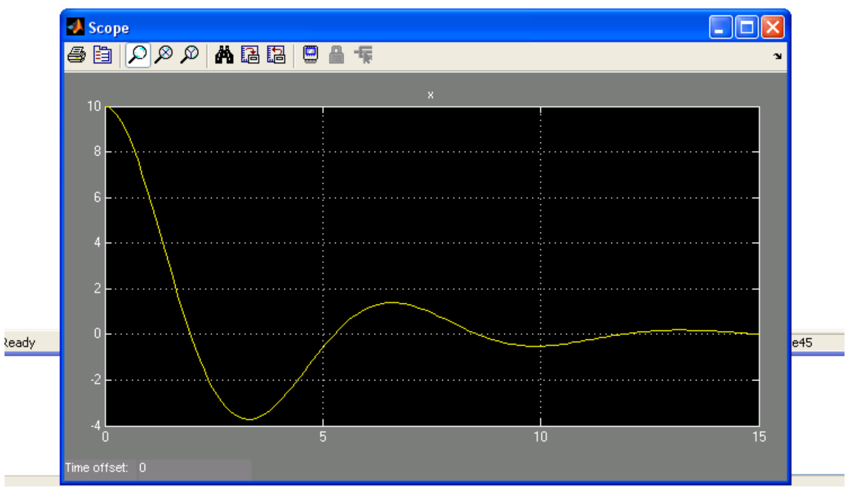
1. Construct a Simulink file to model a Mass-Spring-Damper System using a second order differential equation with m=1, b=0.6, k=5, x0=10, v0=0, and F=0.

2. Define m, b, k, x0, and v0 in the Matlab Workspace so the program user can easily change these values.

3. Display the results from 0 to 15 seconds in steps of 0.1 sec using an oscilloscope.

Filename: Tutorial_Simulink_6.mdl
Author: John Wadach
Description: This file uses a Integrator Blocks to model a Damped Spring-Mass system.





Complete the programs on the following pages for **Extra Credit**

Extra Credit File Name: **Program_Simulink_1.slx**

1. Create a Simulink model for the problem pictured below, but note that the rate of change of the height should be negative because as time increases, the height (y) decreases.
2. Define y0, g, and rh in the Matlab workspace.
3. The sqrt and square functions are located in the Math Function block that can be found in the Math Operations Library of Simulink.
4. Display the value of y in an oscilloscope from 0 to 3000 seconds. Use your oscilloscope image to determine the time to the nearest second that y reaches 0.1 m. Print this value in your title block of your model. You can use zoom with the oscilloscope image to improve your estimate.

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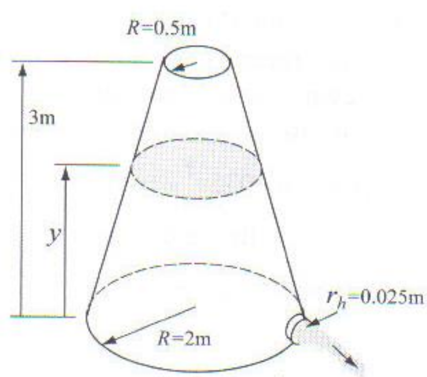
21. A water tank shaped as an inverted frustum cone has a circular hole at the bottom on the side, as shown. According to Torricelli's law, the speed v of the water that is discharging from the hole is given by:

$$v = \sqrt{2gh}$$

where h is the height of the water and $g = 9.81\ \text{m/s}^2$. The rate at which the height, y, of the water in the tank changes as the water flows out through the hole is given by:



negative rate of change

$$\frac{dy}{dt} = -\frac{\sqrt{2gy}\,r_h^2}{(2-0.5y)^2}$$

where r_h is the radius of the hole.

Solve the differential equation for y. The initial height of the water is $y = 2$ m. Solve the problem for different times and find the time where $y = 0.1$ m. Make a plot of y as a function of time.

Extra Credit File Name: **Program_Simulink_2.slx**

1. Create a Simulink model for the problem pictured below.
2. In order to simulate the movement of the circuit switch from B to A when Vr > 5v, you will need a **Switch Block** and a **MinMax Running Resettable Block** (found in the Math Operations Library). You will need the MinMax Running Resettable Block so that when Vr exceeds 5v for the first time, it will maintain an output of 5v to the Switch block so that 0 volts is selected instead of Vs.
3. Define R, L, and Vs in the Matlab workspace.
4. Display the value of Vr in an oscilloscope from 0 to 2.0 seconds.
5. You will need to set the maximum step size to 0.001 second.

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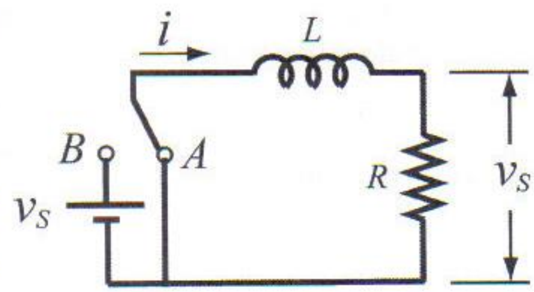
stant. Solve this differential equation symbolically for $x(t)$. Also, determine symbolically the time t at which the infection rate dx/dt is maximum.

21. A resistor R ($R = 0.4\Omega$) and an inductor L ($L = 0.08\,\text{H}$) are connected as shown. Initially, the switch is connected to point A and there is no current in the circuit. At $t = 0$ the switch is moved from A to B, such that the resistor and the inductor are connected to v_S ($v_S = 6\,\text{V}$), and current starts flowing in the circuit. The switch remains connected to B until the voltage on the resistor reaches 5V. At that time (t_{BA}) the switch is moved back to A.



The current i in the circuit can be calculated from solving the differential equations:

$iR + L\dfrac{di}{dt} = v_S$ During the time from $t = 0$ and until the time when the switch is moved back to A.

$iR + L\dfrac{di}{dt} = 0$ From the time when the switch is moved back to A and on.

The voltage across the resistor v_R at any time is given by $v_R = iR$.

Extra Credit File Name: **Program_Simulink_3.slx**

1. Create a Simulink model for the problem pictured below.
2. Display the acceleration, velocity, and position graphs from 0 to 13 seconds using oscilloscopes.
3. Output the velocity and position values to the workspace and use them to create a matrix variable named table with tout in the first column, position in the second column, and velocity in the third column.
4. Use your table matrix to determine the time, to the nearest tenth of a second, when the plane comes to rest. Also record the position when this occurs. Type these values into your Simulink heading block.

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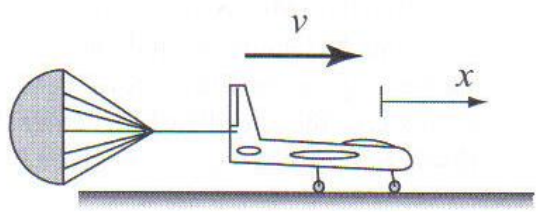
24. An airplane uses a parachute and other means of braking as it slows down on the runway after landing. Its acceleration is given by $a = -0.0035v^2 - 3$ m/s². Since $a = \frac{dv}{dt}$, the rate of change of the velocity is given by:



$$\frac{dv}{dt} = -0.0035v^2 - 3$$

Consider an airplane with a velocity of 300 km/h that opens its parachute and starts decelerating at $t = 0$ s.

a) By solving the differential equation, determine and plot the velocity as a function of time from $t = 0$ s until the airplane stops.

b) Use numerical integration to determine the distance x the airplane travels as a function of time. Make a plot of x vs. time.