Submit the compressed file as `(ID)_(name).zip` to [ftp://cdl.hanyang.ac.kr → Undergraduate_CAE → lab → midterm] folder. It should contain the final results (graphs) of each problem using PowerPoint (`ID.ppt`), MATLAB file (`problem#_#.m`), Simulink file (`problem#_#.slx`)

1.[MATLAB] The Volume V of liquid in a hollow horizontal cylinder of radius r and length L is related to the depth of the liquid h by

$$V = \left[r^2 \cos^{-1}\left(\frac{r-h}{r}\right) - (r-h)\sqrt{2rh-h^2} \right] L$$

Develop an M-file to create a plot of volume versus depth. (20 pts)

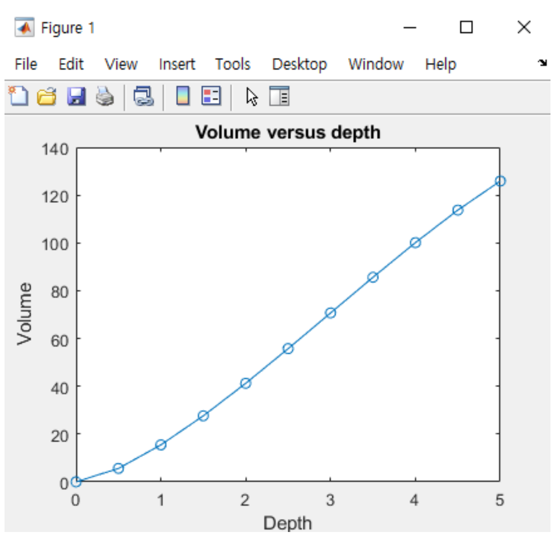
(Satisfy all the post-processing styles of the plot provided below.)

Here are the first few lines:

```
function problem1(r,L,plot_title)
% volume of horizontal cylinder
% inputs :
% r = radius
% L= length
% plot_title=string holding plot title
```

Test your program with

```
>>problem1(3,5,'Volume versus depth')
```



Sol)

```
function problem1(r,L,plot_title)

% volume of horizontal cylinder
% inputs :
% r = radius
% L= length
% plot_title=string holding plot title
H=0:0.5:L;
v= @(h) (r^2*acos((r-h)./r)-(r-h).*sqrt(2*r*h-h.^2))*L;
V=v(H);
plot(H,V,'o-')
title(plot_title)
xlabel('Depth')
ylabel('Volume')
end
```

2.[MATLAB] Solve the Van der poll equation with initial value.

$$\frac{d^2y}{dt^2} - \mu\left(1-y^2\right)\frac{dy}{dt} + y = 0$$

initial condition

at t=0, y=1 $\dfrac{dy}{dt} = 1$

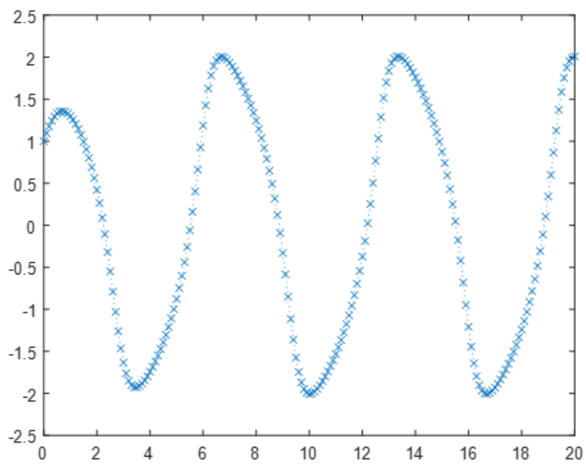
(1) Given the following two scripts (main, vander), Develop a single function script (RK4.m) that covers the fourth-order RK method for second-order ODE and obtain the solution (20 pts)

$\mu = 1$, tspan=[0 20],step size h=0.1 plot style “x:” ex: plot(x,y,’x:’)

[Fourth-order RK]

$$y_{i+1} = y_i + \frac{1}{6}\left(k_1 + 2k_2 + 2k_3 + k_4\right)h$$

$$\begin{cases} k_1 = f(x_i, y_i) \\ k_2 = f(x_i + \frac{1}{2}h, y_i + \frac{1}{2}k_1 h) \\ k_3 = f(x_i + \frac{1}{2}h, y_i + \frac{1}{2}k_2 h) \\ k_4 = f(x_i + h, y_i + k_3 h) \end{cases}$$



[main.m]

```
clc; clear all; close all;

h=0.01;
tf=20;
[t,y]= RK4(@vander,[0 tf],[1,1],h);

figure(1)
plot(t,y(:,1),'x:')
```

[vander.m]

```
function yp = vander(t,y)
...
```

(2) Modify main.m and vander.m to obtain MATLAB built in function ODE45 solution with default setting, compare the results, and explain the difference between the two ODE solvers. (5 pts)

[main.m]

```
clc; clear all; close all;

h=0.1;
tf=20;
[t,y]= RK4(@vander,[0 tf],[1,1],h);
[t,y]= ode45(@vander,[0 tf],[1,1]);


figure(1)
subplot(2,1,1)
plot(t,y(:,1),'x:')
subplot(2,1,2)
plot(t,y(:,1),'o-')
```

(3) When solving the equation with parameter setting in $\left[\mu = 1000, \text{tspan=[0 1000],step size h=0.1}\right]$, ode45 takes an excessive amount of computation. Explain this phenomenon and Apply MATLAB built-in function solution for it. Compare with the step size with ode45 results and the built-in function. (5 pts)

Sol) 2.

(1)

```
clc; clear all; close all;
h=0.1;
tf=1000;

[t,y]= RK4(@vander,[0 tf],[1,1],h);
[t2,y2]= ode45(@vander,[0 tf],[1,1]);
[t3,y3]= ode23s(@vander,[0 tf],[1,1]);


figure(1)
subplot(3,1,1)
```

```
plot(t,y(:,1),'x:')

subplot(3,1,2)
plot(t2,y2(:,1),'o-')
subplot(3,1,3)
plot(t3,y3(:,1),'*--')

function [t, y] = RK4(dydt, tspan, y0, h)

t0 = tspan(1); tn = tspan(2);
t = (t0:h:tn)'; n = length(t);
m=length(y0);
y = y0 .* ones(n,m);
for i = 1:n-1

    k1 = dydt(t(i), y(i,:));
    k2 = dydt(t(i) + h/2, y(i,:) + k1'*h/2);
    k3 = dydt(t(i) + h/2, y(i,:) + k2'*h/2);
    k4 = dydt(t(i) + h, y(i,:) + k3'*h);
    slope = (k1 + 2*k2 + 2*k3 + k4)/6;
    y(i+1,:) = y(i,:) + slope'*h;
end
end

function yp = vander(t,y)
mu=100;
yp=[y(2); mu*(1-y(1).^2)*y(2)-y(1)];
end
```

(2) RK45 함수의 경우, 4차, 5차 룽게쿠타법을 이용해 정확도에 따라 적응적으로 step size를 조절하여 높은 계산효율성을 갖는다.

(3) 반데르폴 방정식은 parameter에 따라 system이 stiff해저 수치해석적 근사해 계산에서 과도한 계산량을 갖게된다. MATLAB built-in function인 ode23s, ode23t 등을 활용하여 stiff system에 대한 솔루션을 효율적인 계산으로 얻을 수 있다.

3.[Simulink] Solve the following RLC second order system using signal-based solution (10 pts)

Show the transient current and electrical charge on capacitor using scope block.

Equation of the transient RLC circuit

$$L\frac{di}{dt} + Ri + \frac{q}{c} - E(t) = 0 \text{ and } i = \frac{dq}{dt}$$

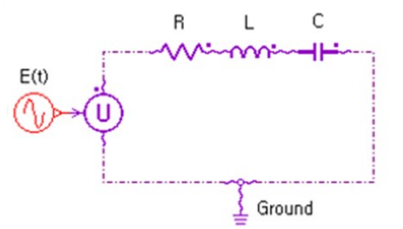
L : inductor

R : resistance

C : capacitance

E : voltage source

q : electrical charge



$E = E_0 \sin(\omega t)$

$L = 2$ H

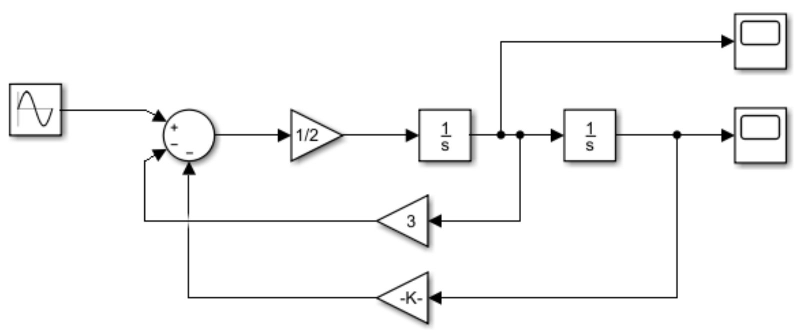
$E_0 = 5$ V

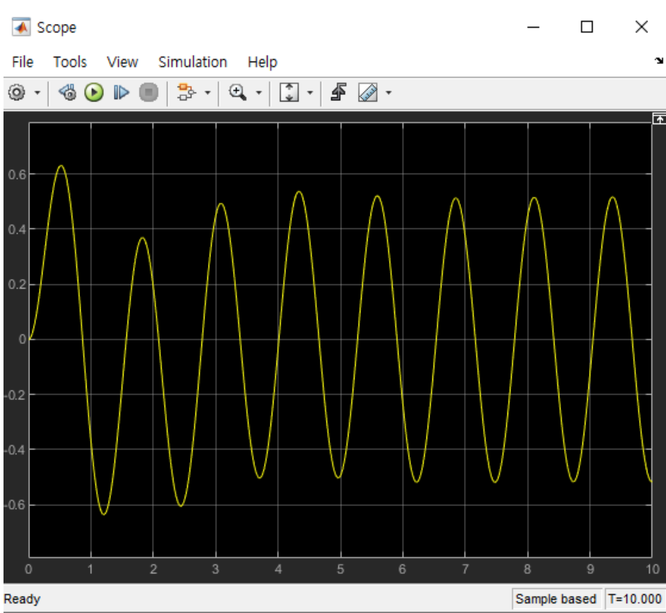
$C = 0.25$ F

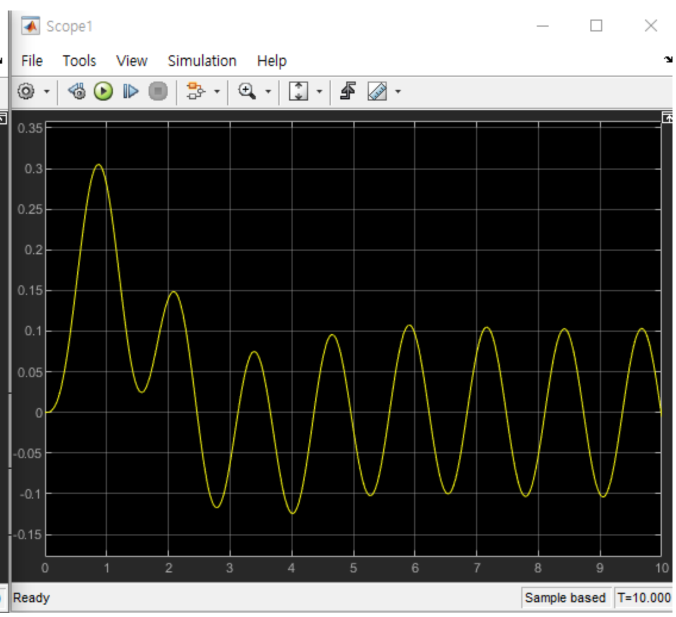
$\omega = 5$ rad/s

$R = 3$ Ohm

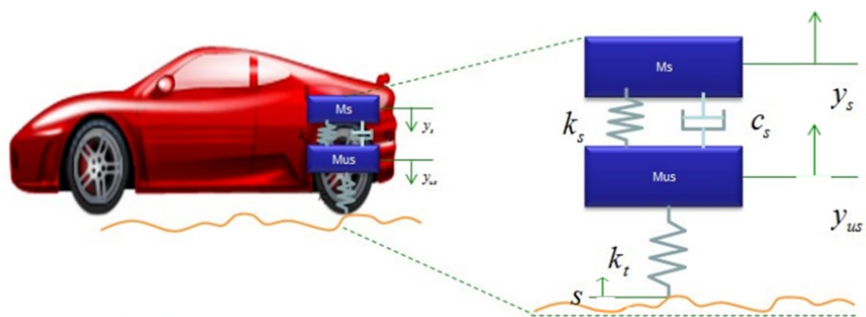
Sol)

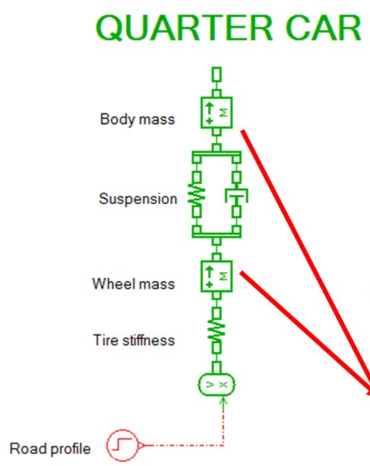






4. [Simulink]Consider quarter car model by Simulink. The parameter values in the model are as follows.

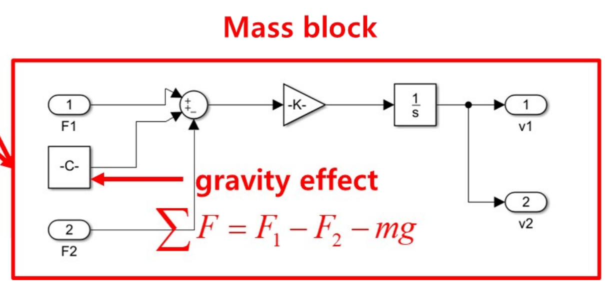




$$m_{body} = 400\,\text{kg}$$

$$k_{sus} = 15000\,\text{N/m},\ c_{sus} = 1000\,\text{Ns/m}$$

$$m_{wheel} = 50\,\text{kg},\ k_{tire} = 200000\,\text{N/m}$$

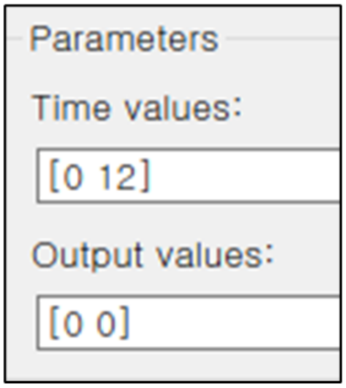


For this problem, you are required to construct a Simulink model of a quarter car to evaluate its suspension behavior under two specific scenarios: (Simulation time: 12 s)

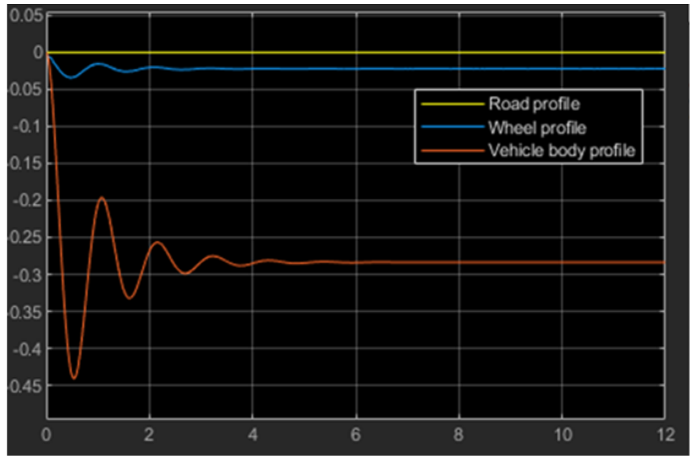
(1) Freefall due to Weight of Car (10 pts)

-Assume that the car undergoes a freefall due to its own weight.

-Build a Simulink model to simulate freefall road profile and obtain following scope plot.

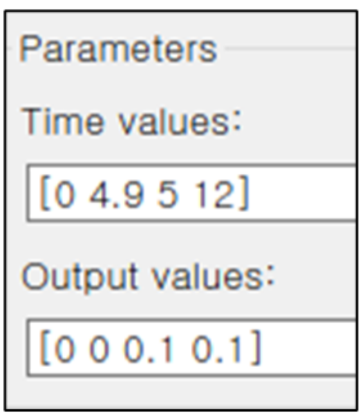


road profile

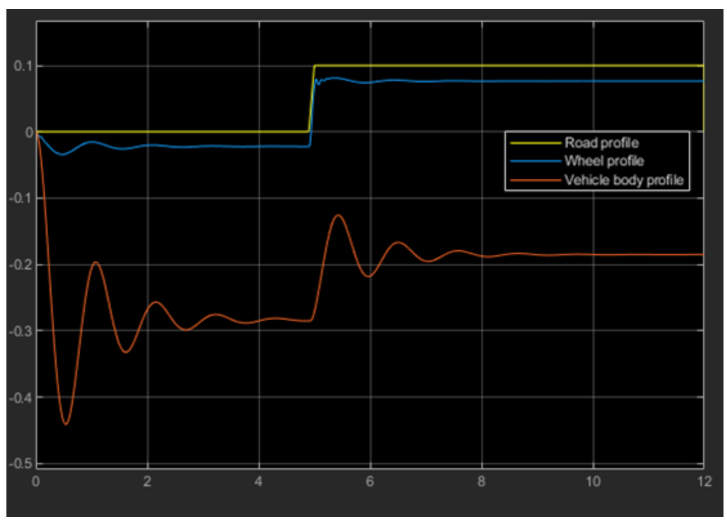


(2) Road Bump Interaction (10 pts)

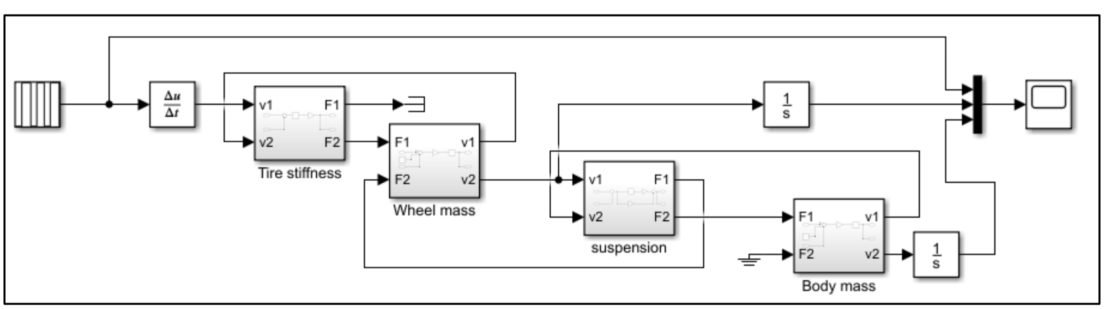
Starting from the car's stable position after the freefall (from Scenario 1), simulate its response when it encounters a 0.1m road bump at 5 s.



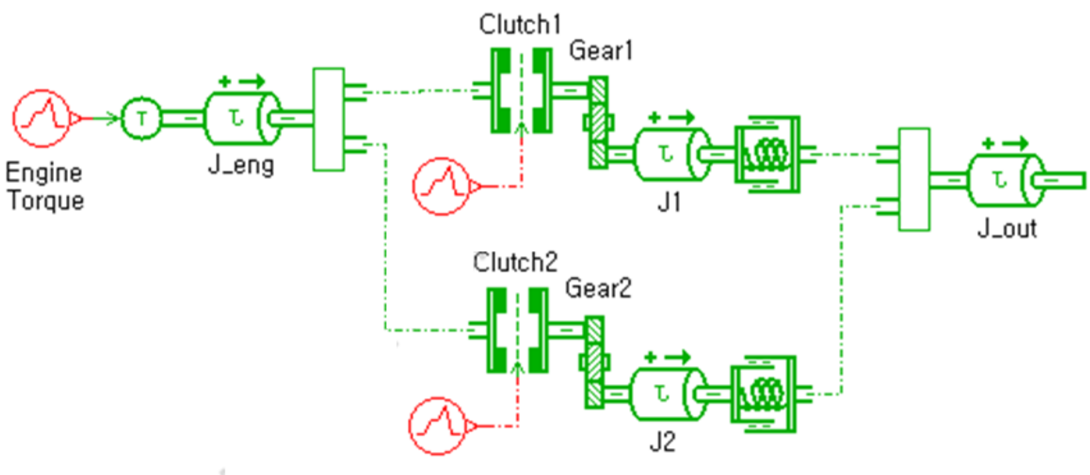
road profile



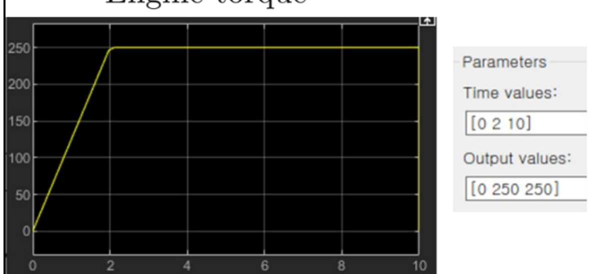
Sol)



5. [Simulink - Powertrain] the Following 2-speed transmission. The parameter values in the model are as follows. Construct a Simulink model for this system. Show the engine(J_eng) and vehicle side(J_out) side RPM. (20 pts) (Simulation time: 10 sec)



Engine torque



$$J_{eng} = 0.1kg \cdot m^2$$

$$J_{shaft\_1,2} = 0.01kg \cdot m^2$$

$$J_{shaft\_1,2} = 50kg \cdot m^2$$

$$k_{shaft\_1,2} = 1e7 {}^{N}/_{m}$$

$$c_{shaft\_1,2} = 1e5 {}^{N \cdot s}/_{m}$$

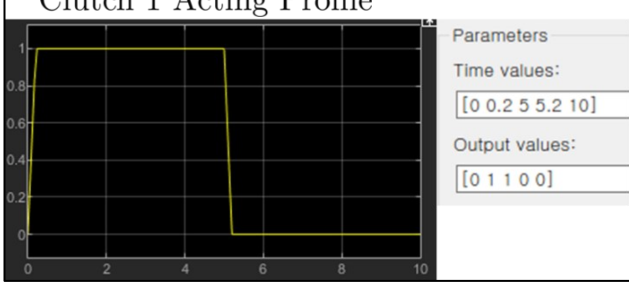
clutch friction torque

$$T_{clutch} = 1000N \cdot m$$

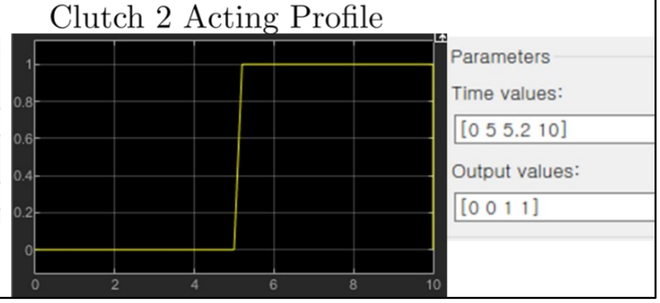
gear ratio

$1^{st}: 4,\ 2^{nd}: 2$

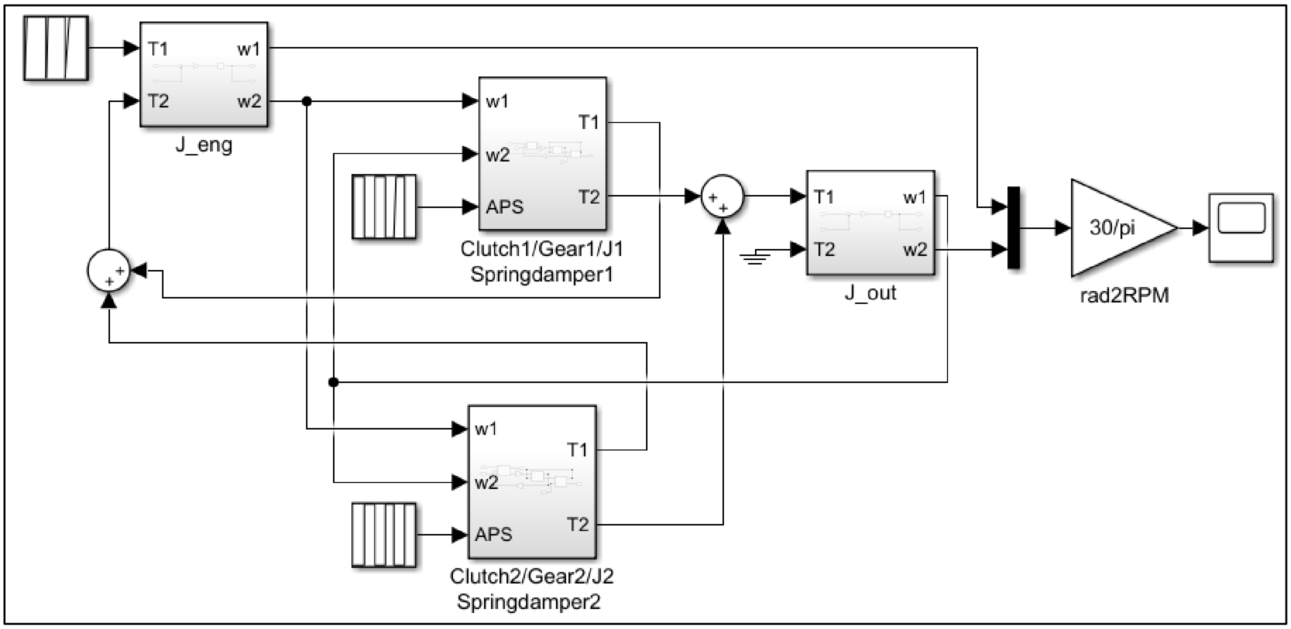
Clutch 1 Acting Profile

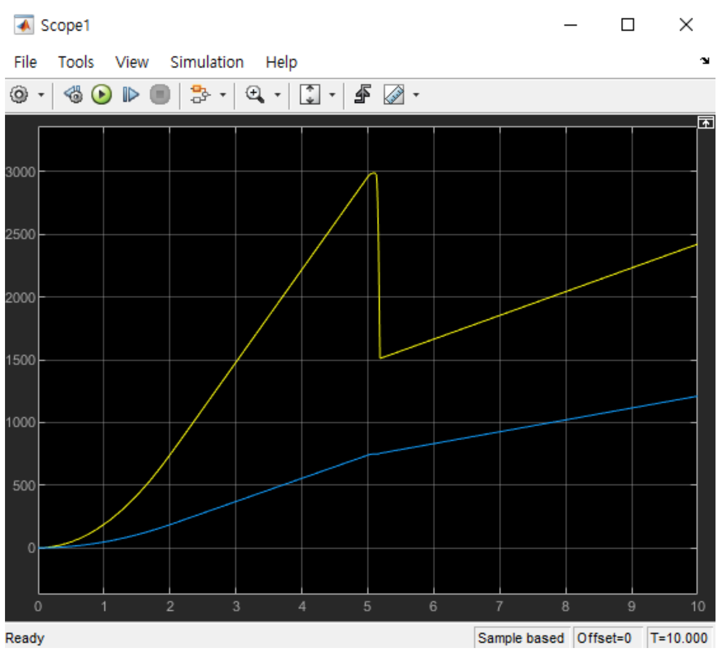


Clutch 2 Acting Profile



Sol)


T1
w1
T2
w2
J_eng
w1
T1
w2
APS
T2
Clutch1/Gear1/J1
Springdamper1
T1
w1
T2
w2
J_out
30/pi
rad2RPM
w1
T1
w2
APS
T2
Clutch2/Gear2/J2
Springdamper2

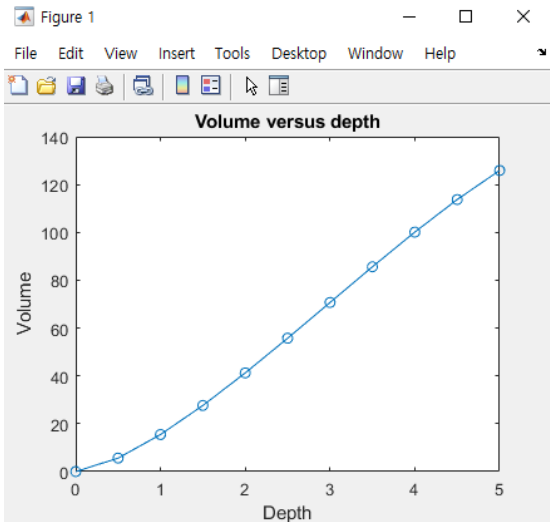

Scope1
File
Tools
View
Simulation
Help
3000
2500
2000
1500
1000
500
0
0
1
2
3
4
5
6
7
8
9
10
Ready
Sample based
Offset=0
T=10.000

Midterm Exam
Evaluation Criteria

Computational Design Laboratory
Department of Automotive Engineering
Hanyang University, Seoul, Korea

PROBLEM.1 EVALUATION CRITERIA

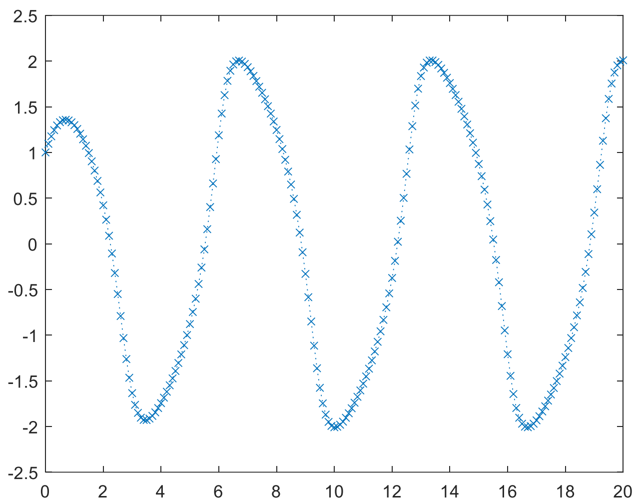
```
function problem1(r,L,plot_title)
% volume of horizontal cylinder
% inputs :
% r = radius
% L= length
% plot_title=string holding plot title
H=0:0.5:L;
v= @(h) (r^2*acos((r-h)./r)-(r-h).*sqrt(2*r*h-h.^2))*L;
V=v(H);
plot(H,V,'o-')
title(plot_title)
xlabel('Depth')
ylabel('Volume')
end
```

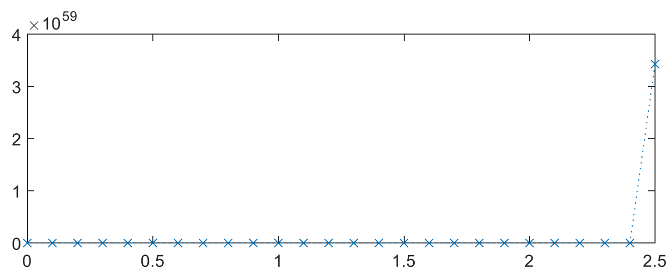


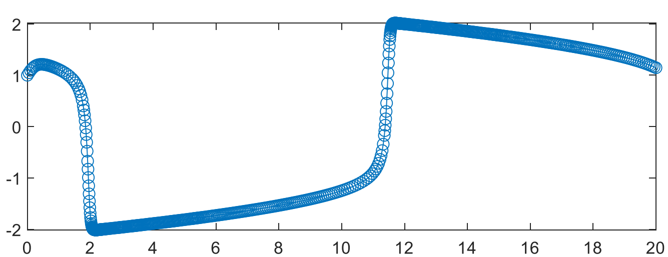
채점 기준

1.
코드(x,y plot 완성)작성 완성 – 10 점
x,y label – 각 2점
title – 2점
line style – 4점

PROBLEM.2 EVALUATION CRITERIA





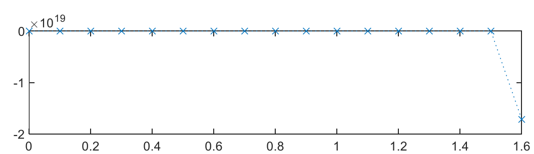


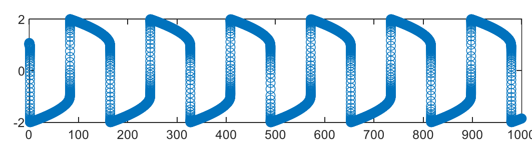
채점 기준

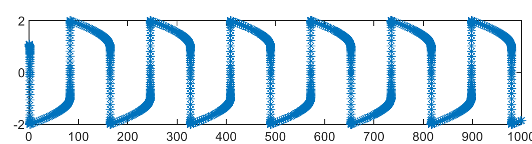
(1) 코드작성 완성 – 20점
RK function 코드 완성 5점

(2) 코드작성 완성 – 3점
두 solver 차이점 설명 2점
RK4는 고정 step size
Ode45 변동 step size

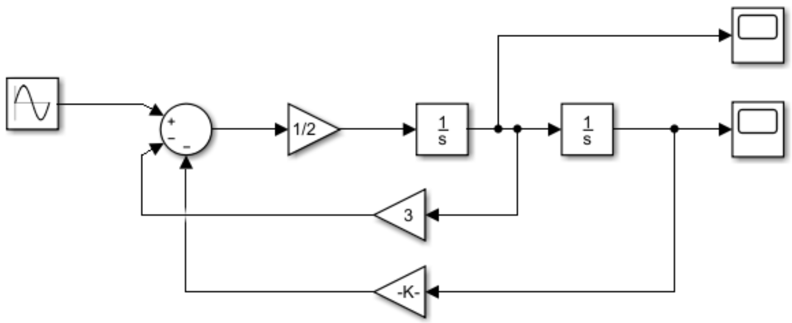
(3) Stiff 문제 설명 3점
Stiff 문제를 위한 solver 활용–2점

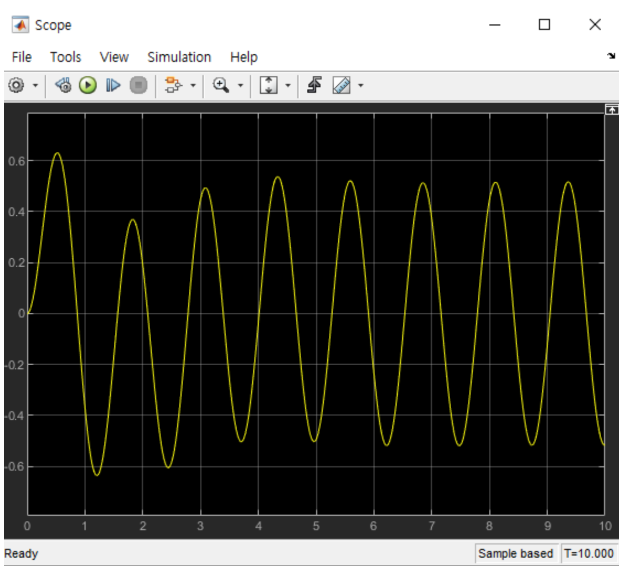


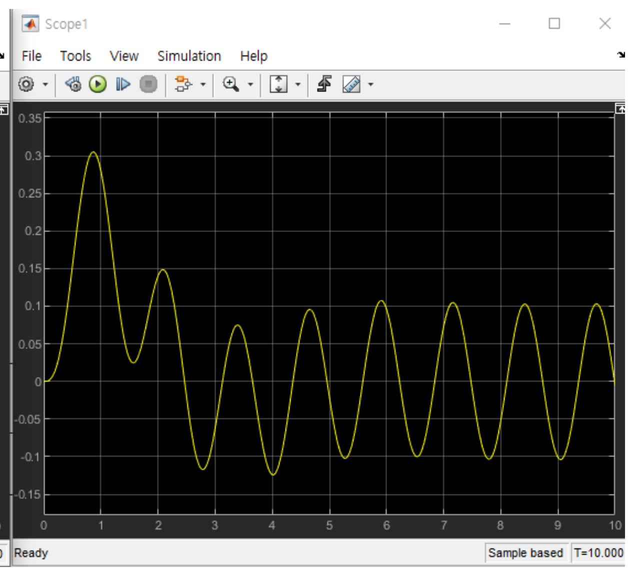




PROBLEM.3 EVALUATION CRITERIA



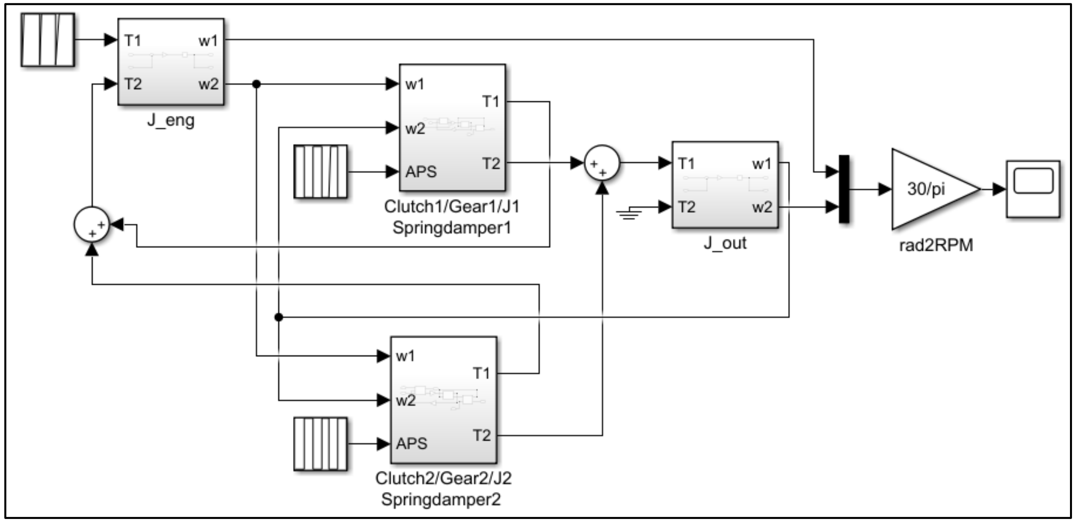


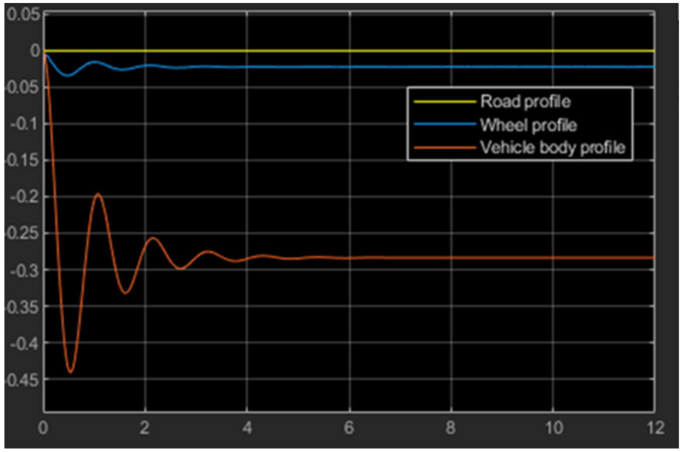


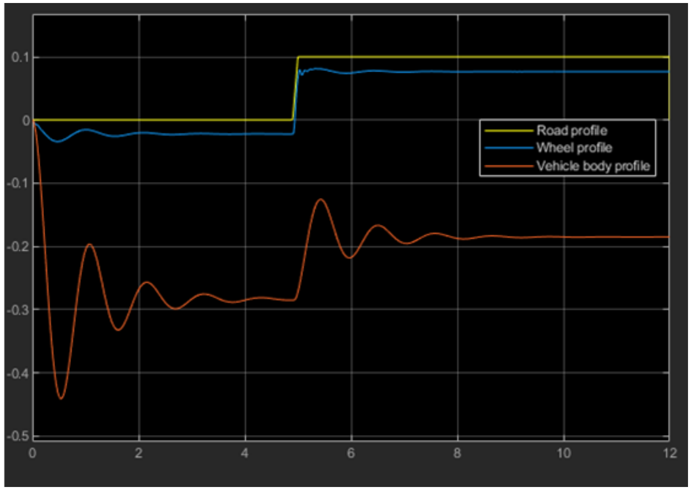
채점 기준

3. 블록다이어그램 완성 5점/ 시뮬레이션 결과 5점

PROBLEM.4 EVALUATION CRITERIA





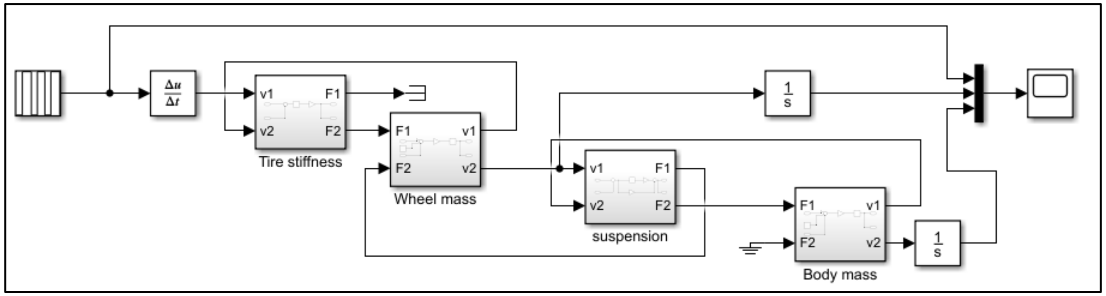


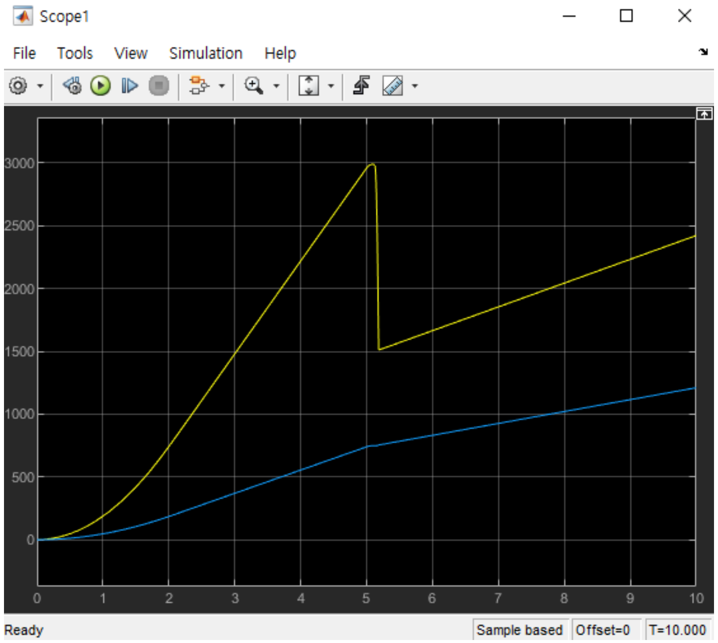
채점 기준

(1) 블록다이어그램 5점
올바른 해석 결과 5점

(2) 블록다이어그램 5점
올바른 해석 결과 5점

PROBLEM.5 EVALUATION CRITERIA





채점 기준

블록다이어그램 10점
올바른 해석 결과 10점