Midterm Exam - Lab

10/31/2017

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

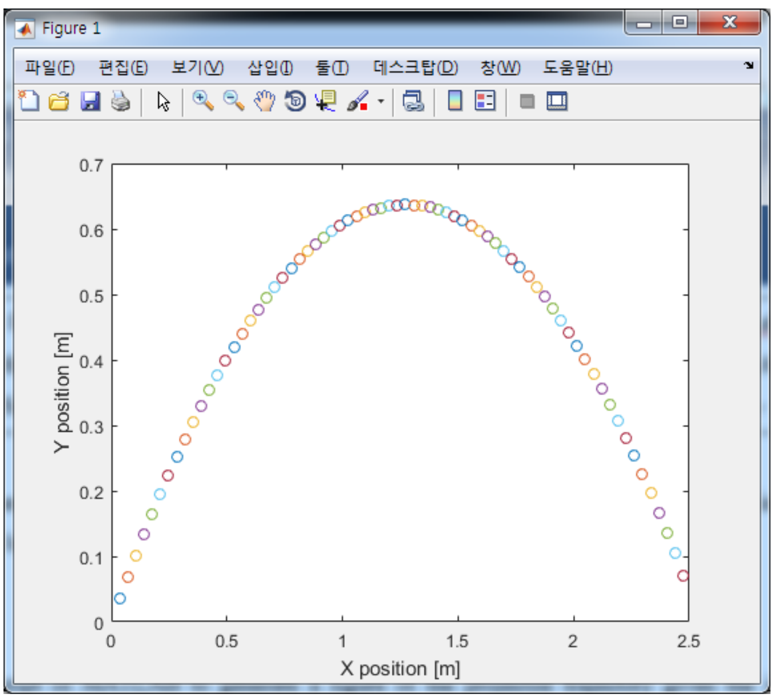
1. [MATLAB] In the absence of air resistance, the Cartesian coordinates of a projectile launched with an initial velocity and angle can be computed with following equations:

$$x = v_0 \cos(\theta_0) t$$

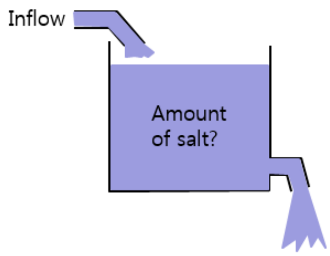
$$y = v_0 \sin(\theta_0) t - 0.5 g t^2$$

Develop a function script of MATLAB to generate a figure of the projectile trajectory given the input parameters: v_0, θ_0, and g. Add the label on the figure as follow by using the plotting options. Use "hold on" option to plot. (time step = 0.01 s, time range 0 to 0.7 s) (15 pts)

```
>> pb1_position(5,45*pi/180,9.81)
```



2. [MATLAB] Mixing problems with water and salt in a single tank can be modelled as the following ODE. $y(t)$ denotes the amount of salt in the tank at time t. The salt inflow rate is 10 and the salt outflow rate is $0.025y$. Solve the following initial value problem over the interval from $t=0$ to 200 where $y(0)=40$.



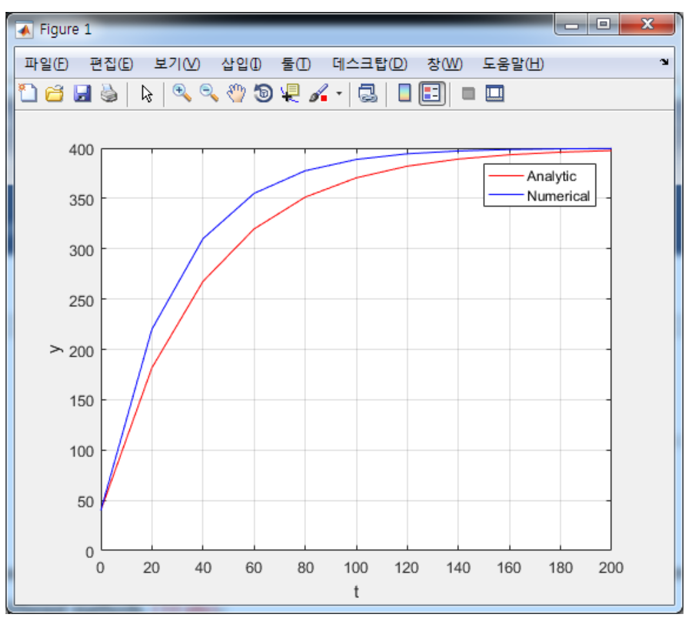
$$\frac{dy}{dt} = 10 - 0.025y$$

(1) Obtain solutions from Euler's method $h=20$. Compare the two results with the exact solution by using graphical method. Use plot options to effectively describe a figure. (10 pts)

Analytic solution: $y(t) = 400 - 360e^{-0.025t}$

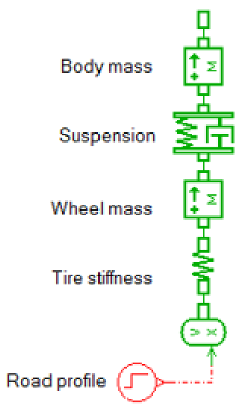
(2) Calculate the relative error at each point. Suggest the reasonable value of step size h which the average error is less than 1% except for the initial point ($t=0$). Develop a script to find this step size automatically not by using trial and error. (10 pts)

$$[\text{Euler's method}]\ y_{i+1} = y_i + f(x_i, y_i)h \quad [\text{Relative error}]\ error = \frac{|Sol_{numerical} - Sol_{analytic}|}{Sol_{analytic}}$$

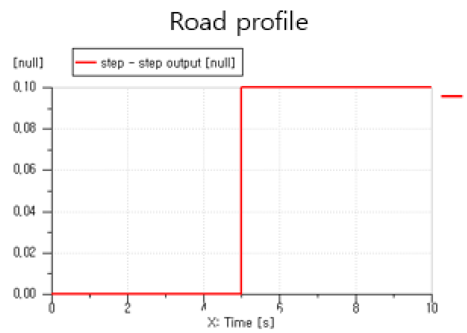


3. Consider a quarter car model by AMESim. The parameter values in the model are as follows.

QUARTER CAR



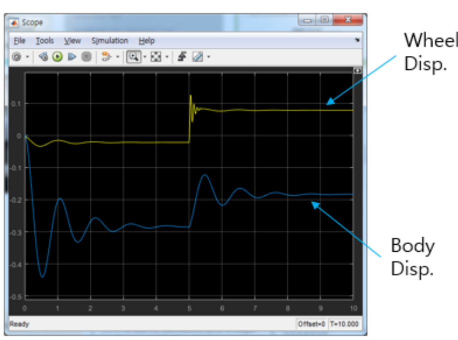
$$m_{body} = 400\,\mathrm{kg}$$
$$k_{suspension} = 15000\,\mathrm{N/m}$$
$$c_{suspension} = 1000\,\mathrm{Ns/m}$$
$$m_{wheel} = 50\,\mathrm{kg}$$
$$k_{tire} = 200000\,\mathrm{N/m}$$
$$g = 9.81\,\mathrm{m/s^2}$$

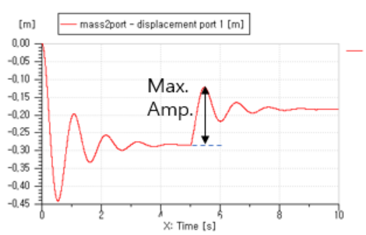


(1) [Simulink] Construct a Simulink model for this system. Show the result of body and wheel displacement by using a Scope block. Consider the gravity effect. (Simulation time: 10 s) (20 pts)

(2) [AMESim] Construct this AMESim model. Parameterize the all input values in the model blocks by using the Global Parameters option. (5 pts)

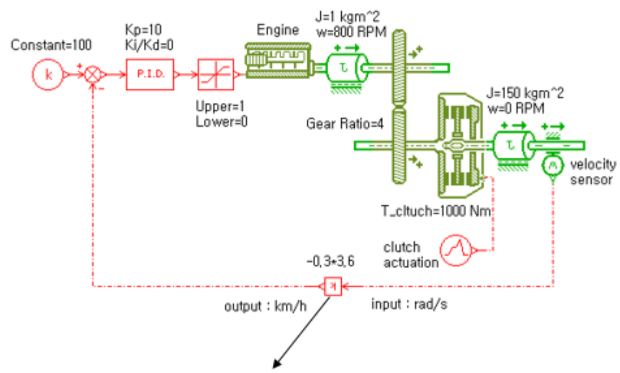
(3) From the AMESim model, when you change the $k_{suspension}$ and $c_{suspension}$ values to $\pm 20\%$ from the initial values, check the maximum amplitude of body displacement and fill the following table. Which case of the parameters shows the minimum value of maximum amplitude? (10 pts)





Amp. [m]	K(-20%)	K(0%)	K(+20%)
C(-20%)			
C(0%)		0.162	
C(+20%)			

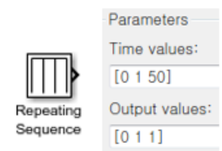
4. [Simulink] Consider the following powertrain system for 0 to 100 km/h test by AMESim. Construct a Simulink model for this system. Check the vehicle speed(km/h) and the time which the speed is reached about 100 km/h. (Use "ode23tb" solver in Model Configuration Parameters) (30 pts)



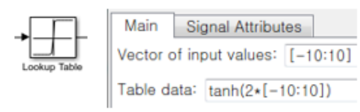
Engine torque data

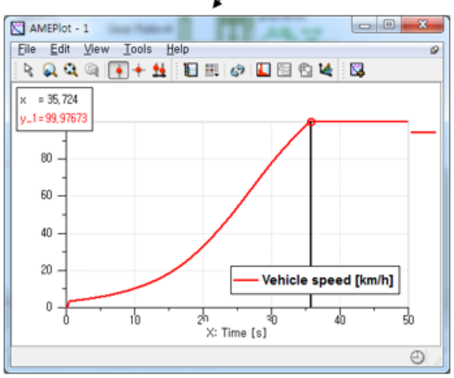
		TPS 1	TPS 2
RPM	x2 \ x1	0	1
1	0	0	0
2	1000	-18	129
3	1500	-22	161
4	2000	-25	186
5	2500	-30	186
6	3000	-35	161

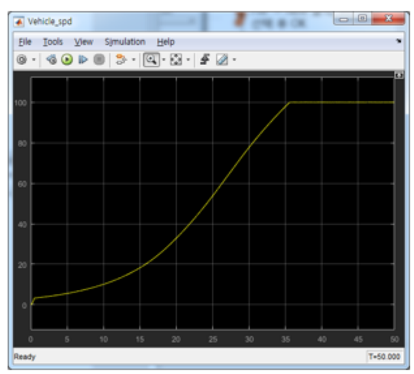
Clutch actuation data

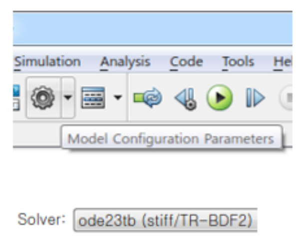


Clutch slip data









1. (15 pts)

```
function pb1_position(v0,theta0,g)
t(1) = 0; x = 0; y = 0;
plot(x,y,'o')
dt = 1/100;
for j = 2:71
    t(j) = t(j-1)+dt;
    x = v0*cos(theta0)*t(j);
    y = v0*sin(theta0)*t(j)-0.5*g*t(j)^2;
    plot(x,y,'o')
    hold on
end
xlabel('X position [m]')
ylabel('Y position [m]')
```

2.

1) (10 pts)

```
h=20;
%% analytic solution
t_a = [0:h:200]';
y_a = 400-360*exp(-0.025*t_a);

%% numerical solution
dydt = @(t,y) 10-0.025*y;
[t_n,y_n] = pb2_eulode(dydt,[0,200],40,h);

%% plot solution
plot(t_a,y_a,'r')
hold on
grid on
plot (t_n,y_n,'b')
legend('Analytic','Numerical')
xlabel('t'); ylabel('y')

%% euler ODE function
function [t_n,y_n] = pb2_eulode(dydt,tspan,y0,h)
ti = tspan(1);tf = tspan(2);
if ~(tf>ti)
    error('upper limit must be greater than lower')
end
t_n = (ti:h:tf)'; n = length(t_n);
y_n = y0*ones(n,1); % preallocate y to improve efficiency
for i = 1:n-1 % implement Euler`s method
    y_n(i+1) = y_n(i) + dydt(t_n(i),y_n(i))*h;
end
end
```

2) (10 pts)

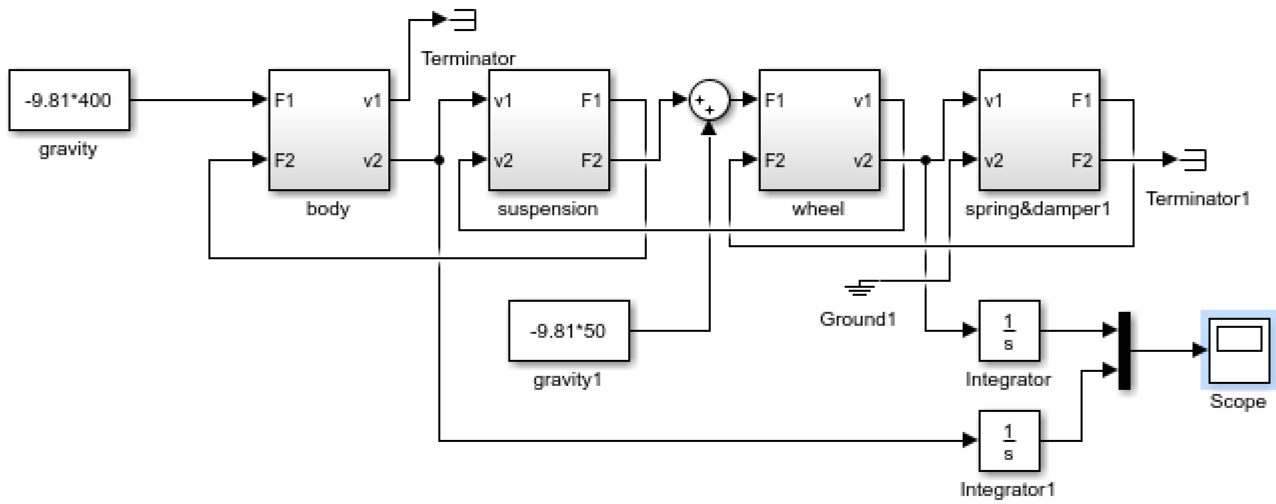
```
h=20;
ave_error=100;
while ave_error>1
%% analytic solution
t_a = [0:h:200]';
y_a = 400-360*exp(-0.025*t_a);

%% numerical solution
dydt = @(t,y) 10-0.025*y;
[t_n,y_n] = pb2_eulode(dydt,[0,200],40,h);

%% error calculation
error=abs(y_a-y_n)./y_a*100;
ave_error=mean(error(2:end))
h=h-0.1
end
```

3.

1) (20 pts)



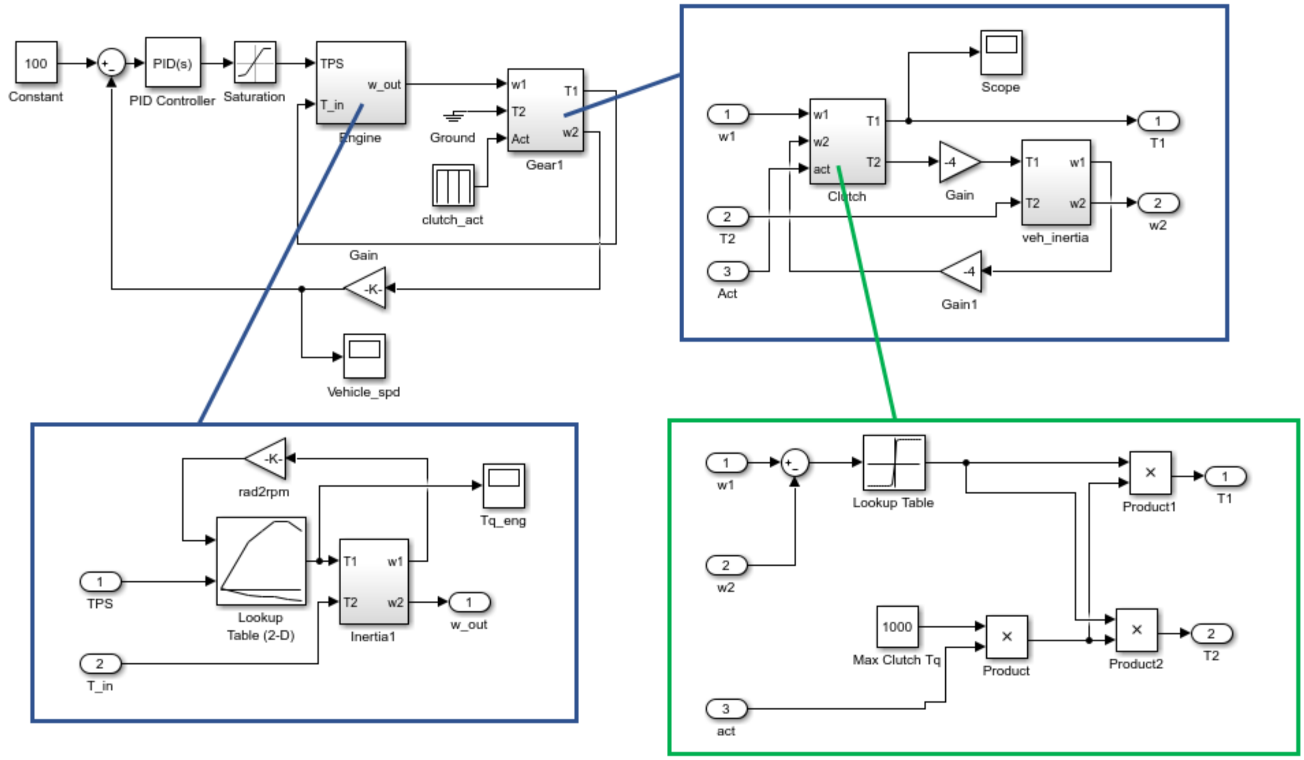
2) (5 pts) refer the lecture(7week) pp. 28.

3) (10 pts)

Amp. [m]	K(-20%)	K(0%)	K(+20%)
C(-20%)	0.158	0.171	0.163
C(0%)	0.154	0.162	0.162
C(+20%)	0.150	0.156	0.158

The case(C+20%, K-20%) minimizes a maximum amplitude.

4. (30 pts)


100
Constant
PID(s)
PID Controller
Saturation
TPS
w_out
T_in
Engine
Ground
clutch_act
w1
T2
Act
T1
w2
Gear1
Gain
-K-
Vehicle_spd
Scope
1
w1
w1
w2
act
T1
T2
Clutch
-4
Gain
T1
w1
T2
w2
veh_inertia
1
T1
2
w2
2
T2
3
Act
-4
Gain1
-K-
rad2rpm
Tq_eng
1
TPS
Lookup
Table (2-D)
T1
w1
T2
w2
Inertia1
1
w_out
2
T_in
1
w1
2
w2
Lookup Table
Product1
1
T1
1000
Max Clutch Tq
Product
Product2
2
T2
3
act