

Mathematical Modeling of Dynamic Systems in State Space I

(s)





Technology Development

For Energy, Environment and Safety



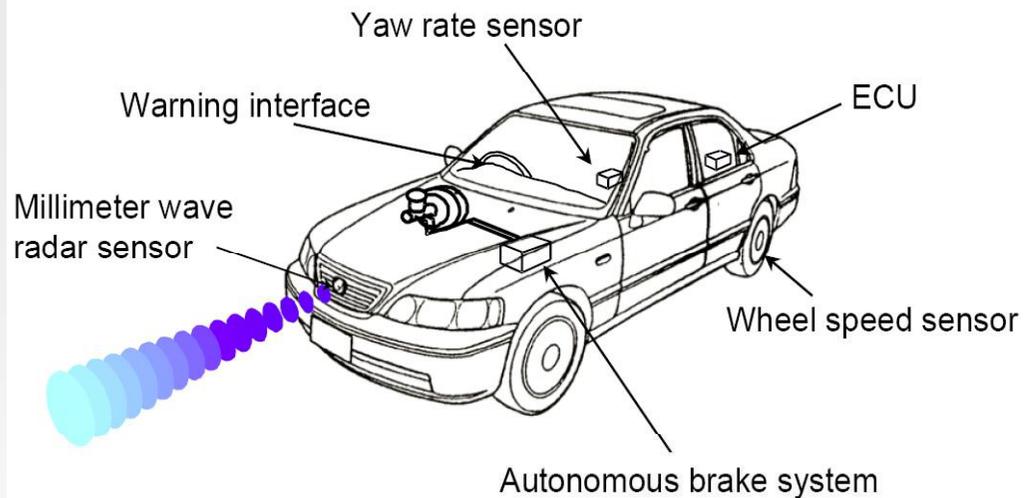
Automated Highway Systems (AHS), 1997 UC Berkeley PATH



- AHS lanes will have three times the capacity of regular highway lanes - Vehicles will travel together in closely-packed "platoons".
- Dedicated to automated vehicles - regular passenger cars will have to be specially instrumented to travel on AHS lanes.



CMS (Collision Mitigation brake Systems, Honda, 2003)



1. effective reducing rear-end collision
2. prevent interference with driver
 - warning and brake intervention



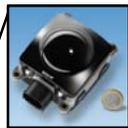
Smart Cruise Control

Hyundai Motor Company, GENESIS, in 2008

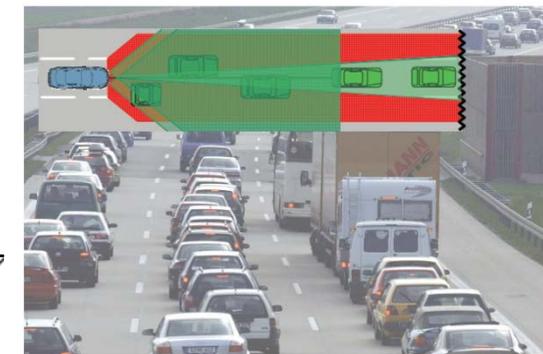
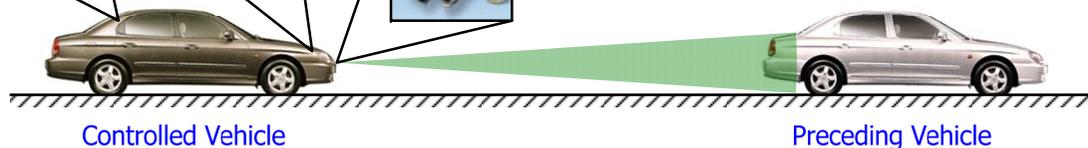
Acceleration Control
(Engine Control)



Deceleration
(ABS,ESC,ESC+)



Lidar / Radar
(Detecting Preceding Vehicle)



The infrared ranging system



Continental

**“Car Safety” for
tailgater**

2009 Volvo XC60

**20 ft sweep with
three infrared beams**

**The greatest danger
for accidents is in
normal city driving-
75% of rear end
collisions occur
between vehicles
traveling at less than
20 mph.**



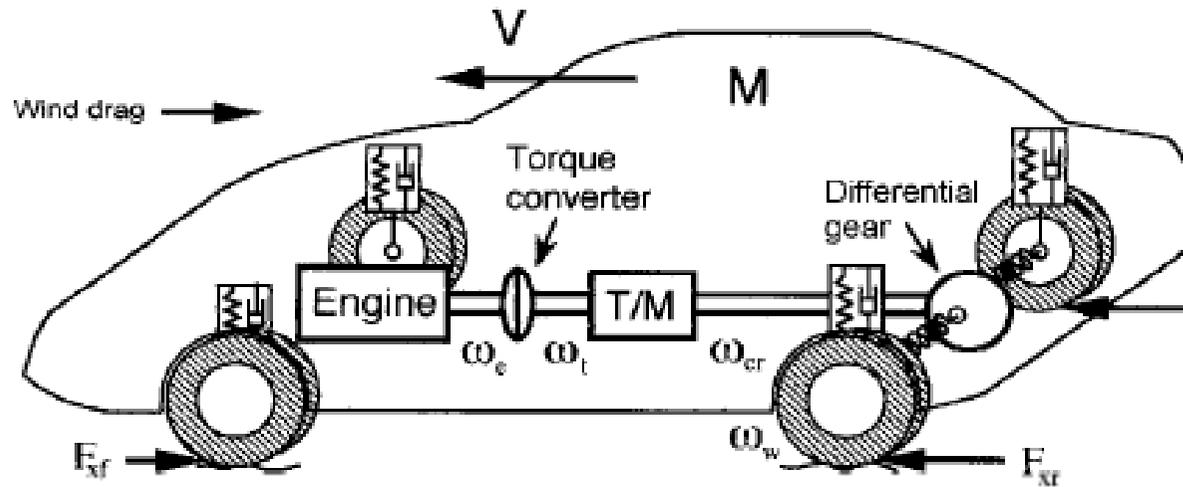
Vehicle



Vehicle Chassis/Powertrain



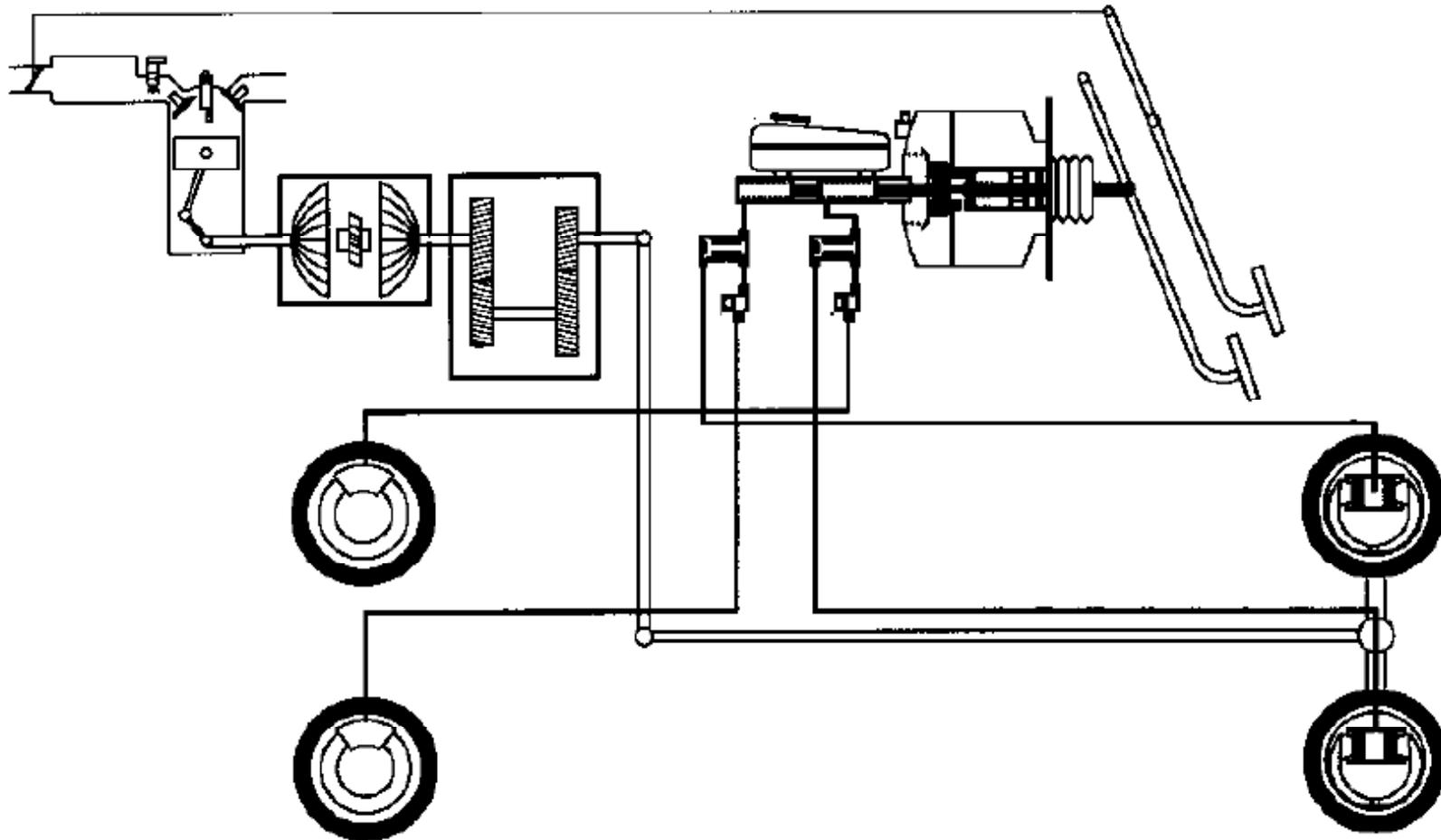
Powertrain

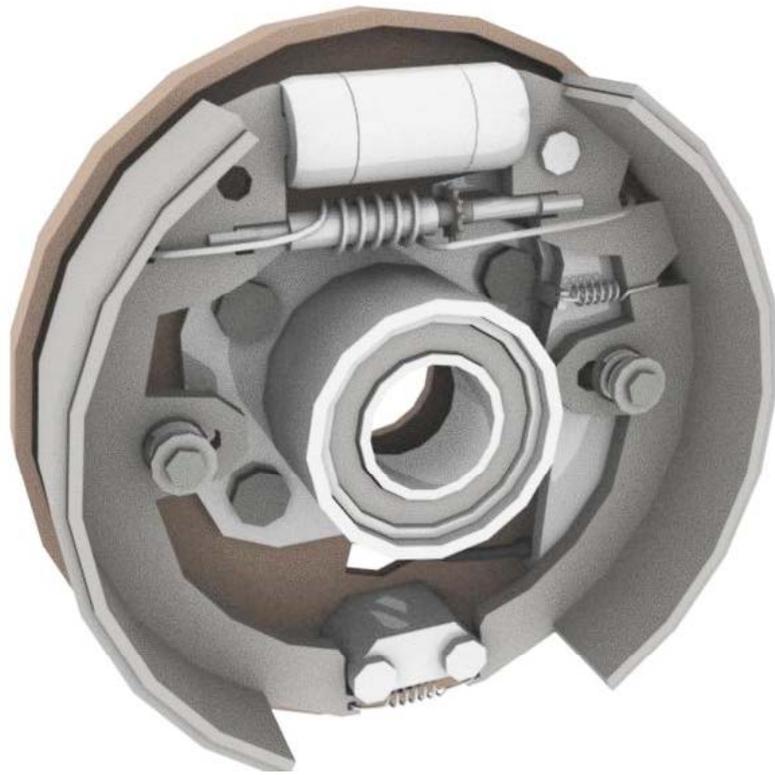


- Engine
- Torque Converter
- Transmission
- Axle Shaft
- Differential Gear

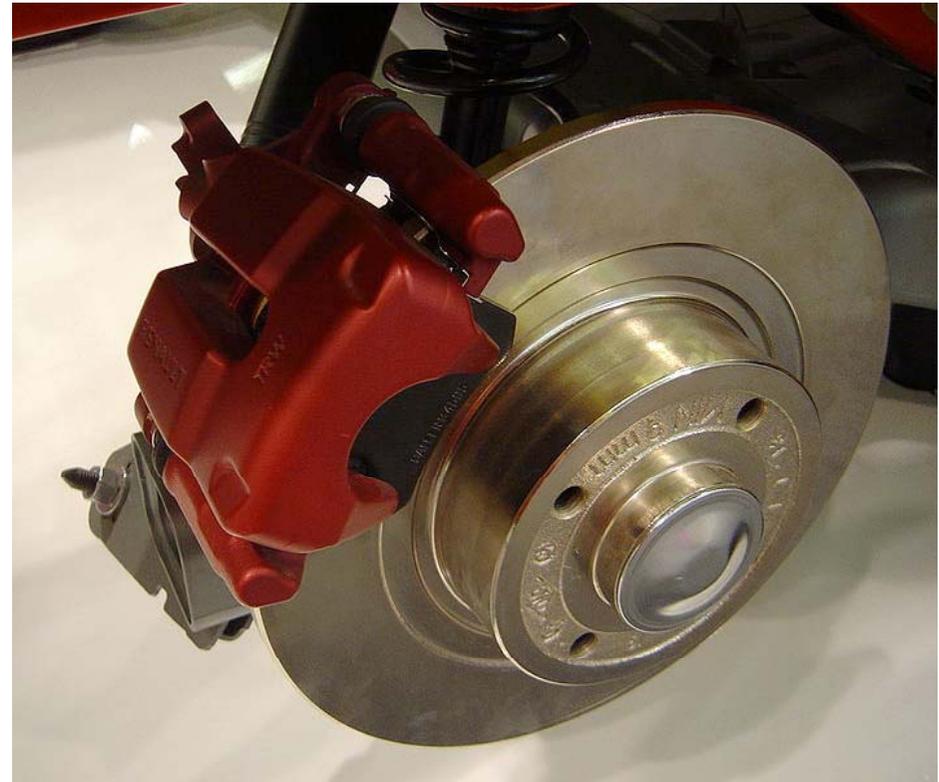


Powertrain and Brake System





Drum Brake

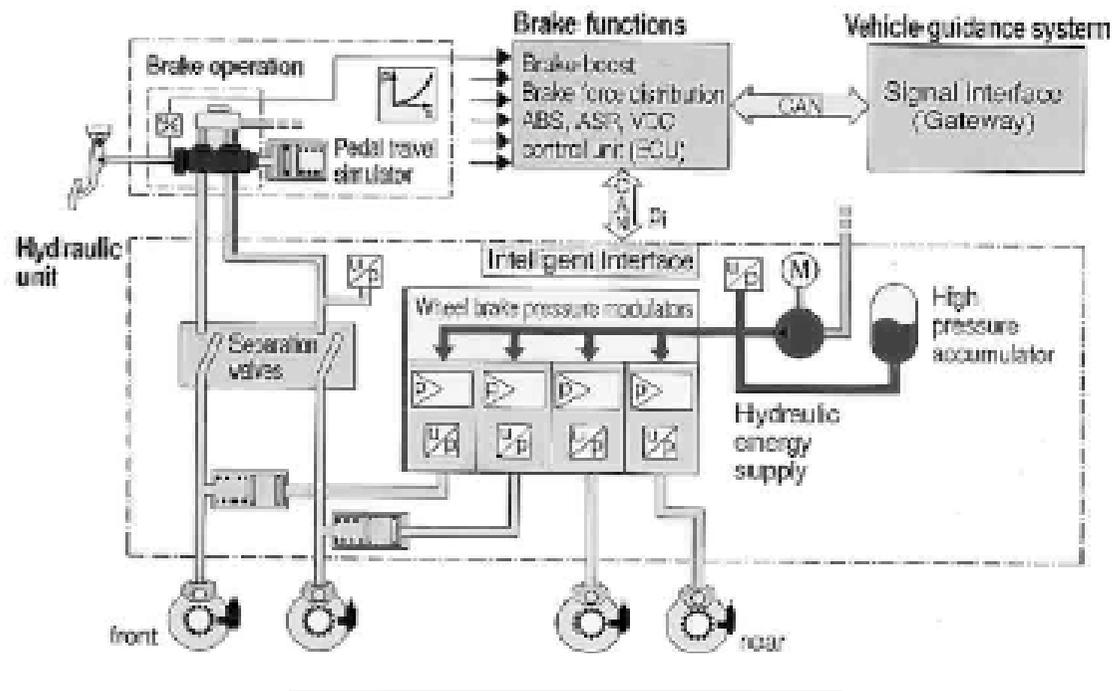


Disk Brake



Electro-Hydraulic Brake

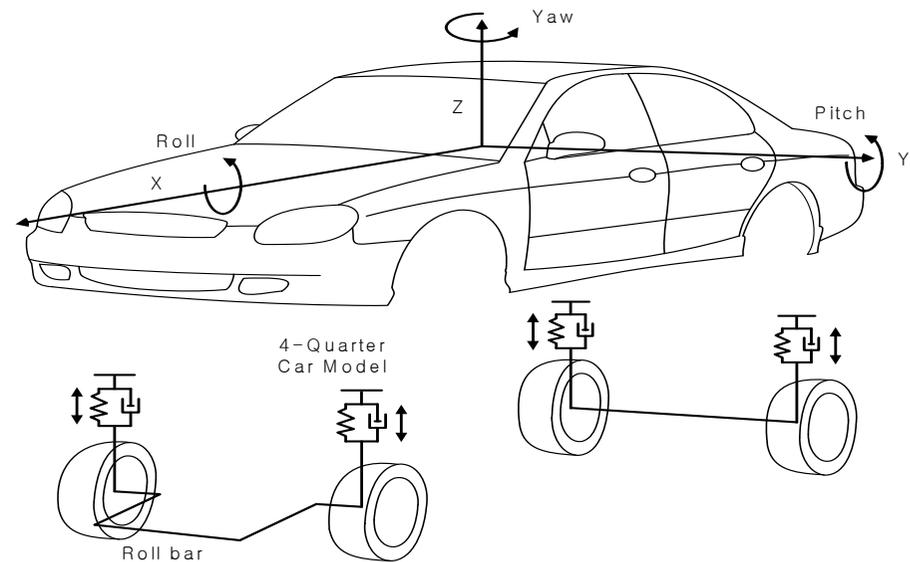
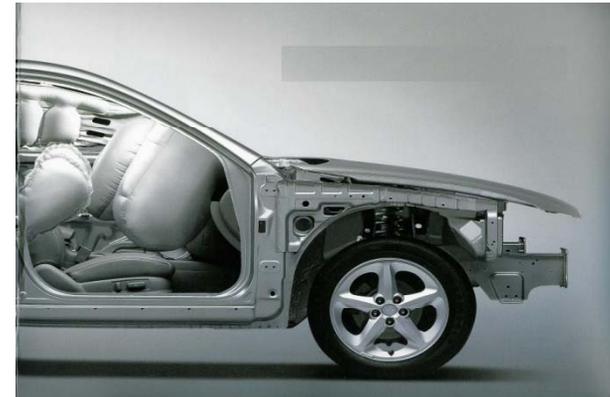
- Electro-Hydraulic Brake
- Brake-by-Wire
- Includes electronic pedal travel simulator
- Softstop, Brakewipe,
- Dev cost: 150M€



Vehicle Suspension

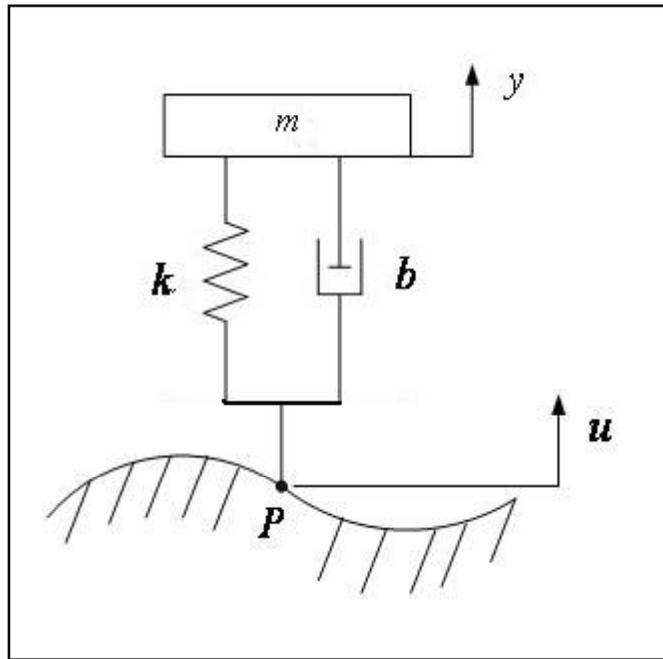


Vehicle Suspension Problem

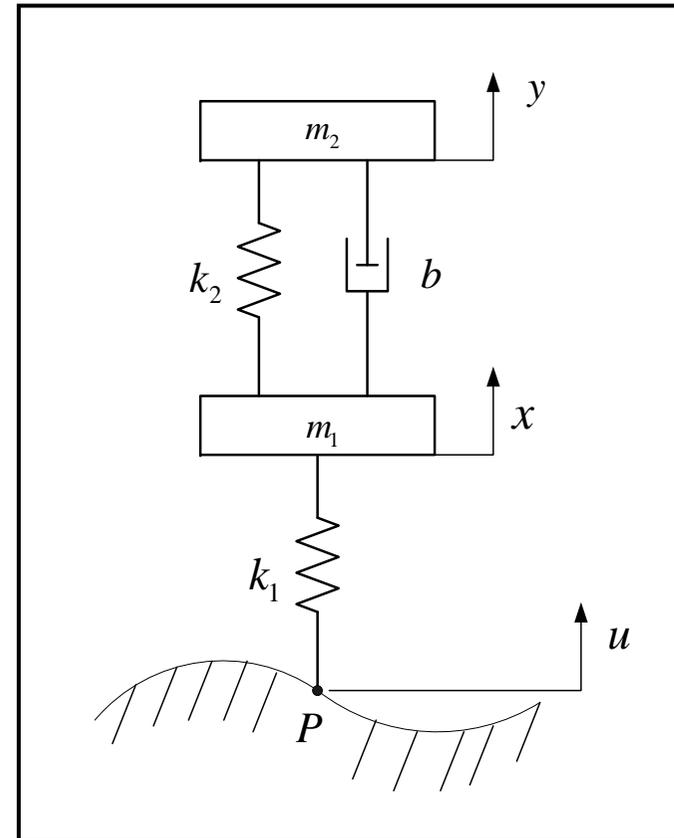


Vehicle Suspension Problem

ex1) Spring, damper, mass system

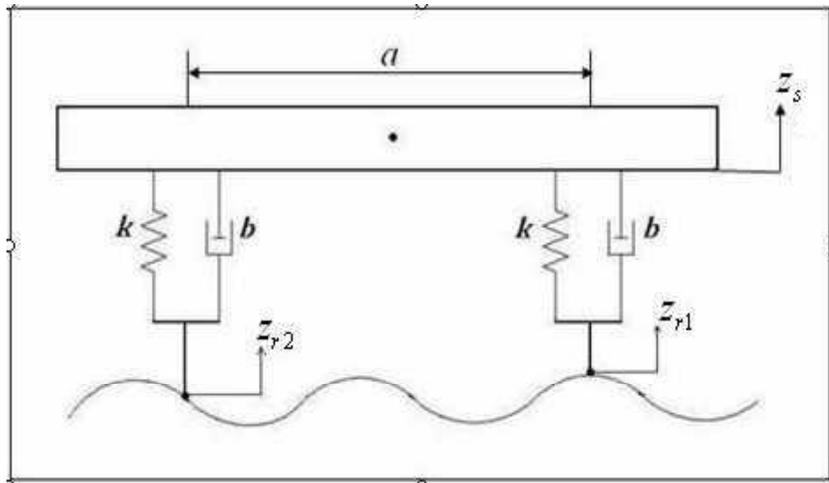


ex2) Body and tire model

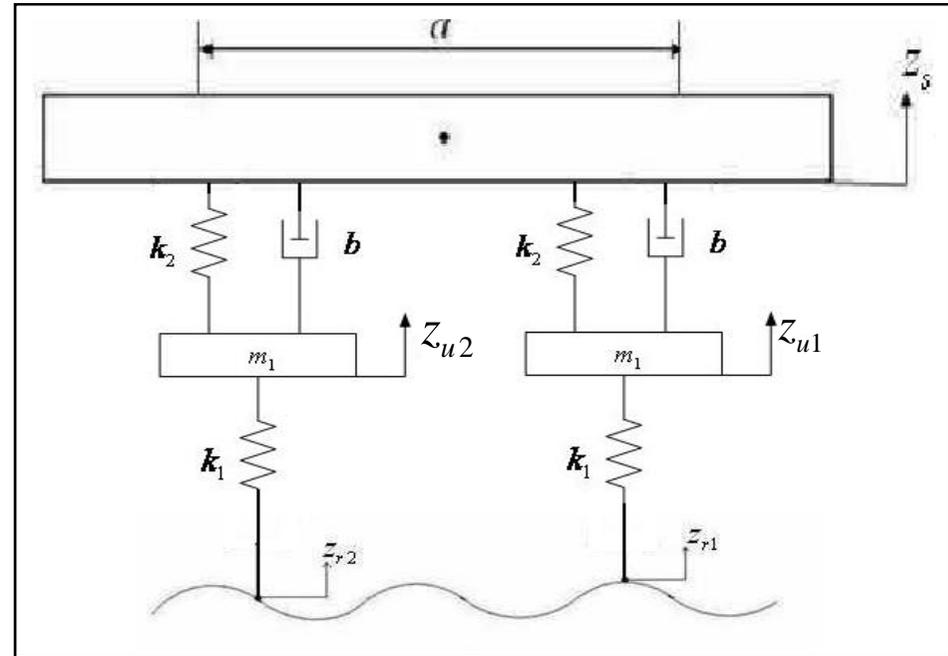


Vehicle Suspension Problem

ex3) Two inputs



ex4) Two inputs, Body and Tire Model

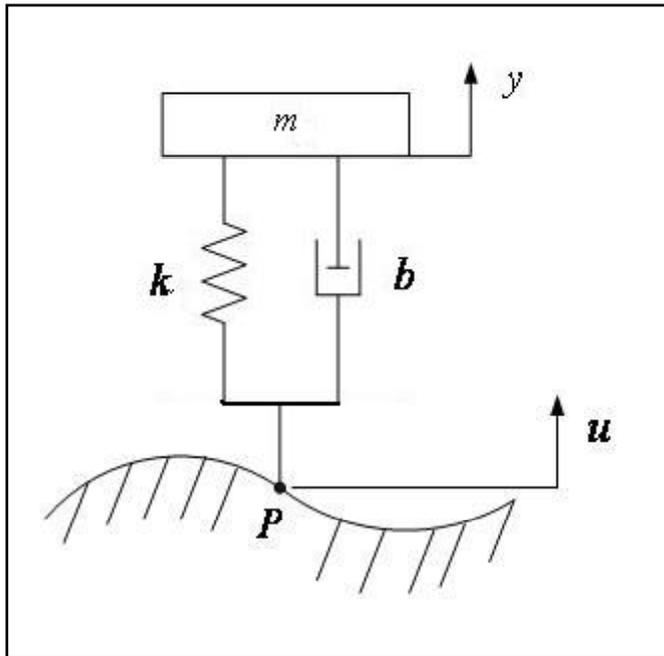


Two inputs : z_{r1}, z_{r2} $z_{r2}(t) = z_{r1}(t - \tau)$



Vehicle Suspension Problem

ex1) Spring, damper, mass system



▪ Design Considerations

1. Ride Quality

→ Sprung mass acceleration : \ddot{y}

2. Rattle space

→ Suspension Deflection : y

▪ Suspension Design Parameters

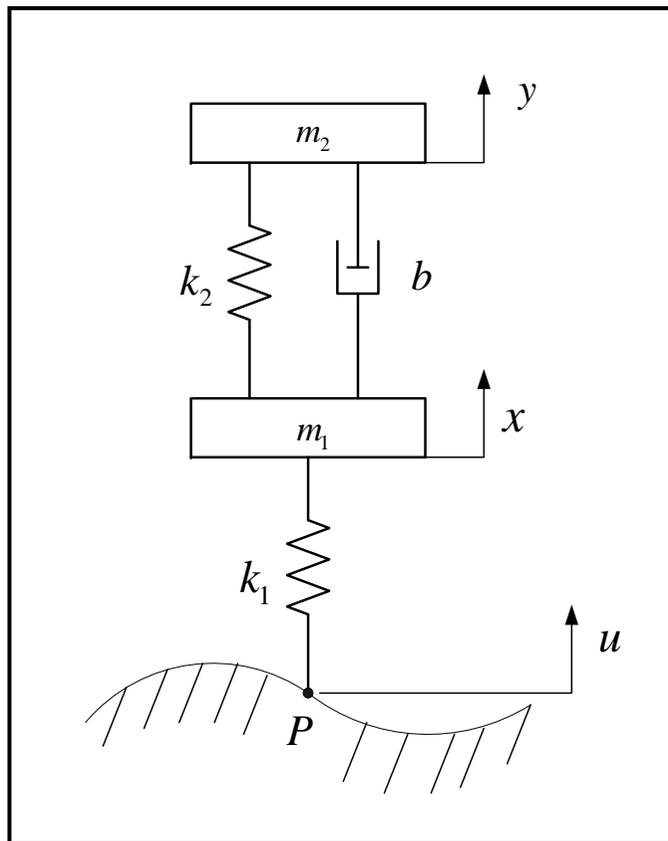
→ Spring Stiffness : k

→ Damping Ratio : b



Vehicle Suspension Problem

ex2) Body and tire model



▪ Design Considerations

1. Ride Quality

→ Sprung mass acceleration : \ddot{y}

2. Rattle space

→ Suspension Deflection : $y - x$

3. Tire Force Vibration

→ Tire Deflection : $x - u$

▪ Suspension Design Parameters

→ Spring Stiffness : k_2

→ Damping Ratio : b

→ Tire Stiffness : k_1



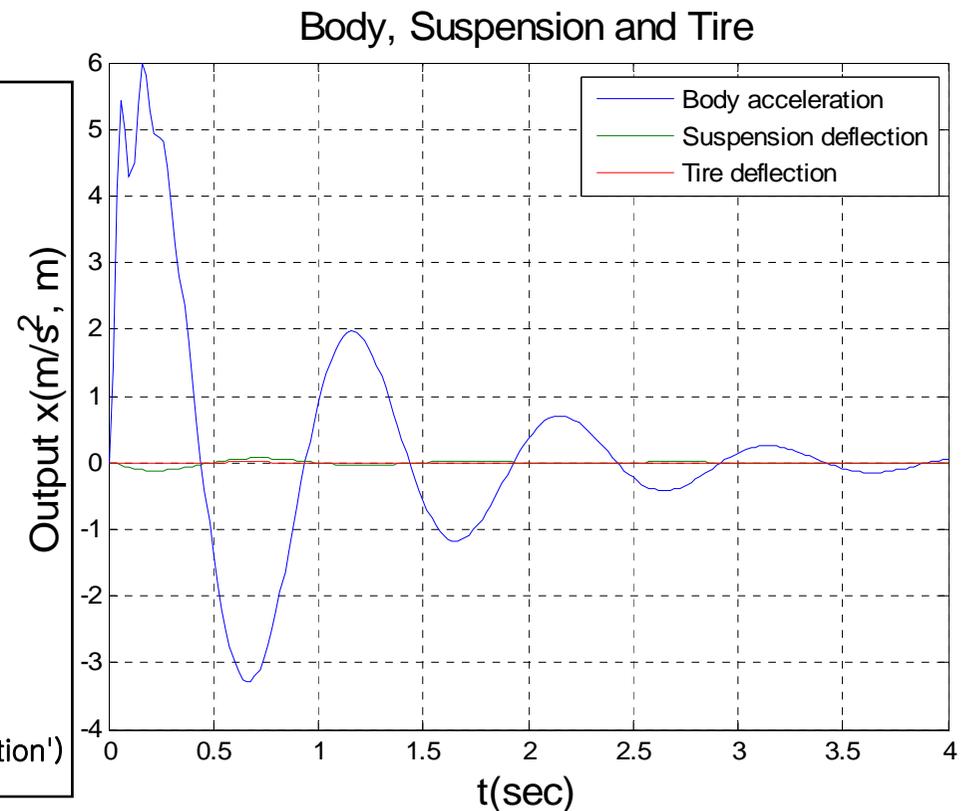
Vehicle Suspension Problem

Parameter : $M_1(\text{tire})=55\text{kg}$, $M_2(\text{body})=400\text{kg}$, $b=1000\text{Ns/m}$

$k_1(\text{tire})=180000\text{N/m}$, $k_2(\text{suspension})=18000\text{N/m}$

Input : Step input

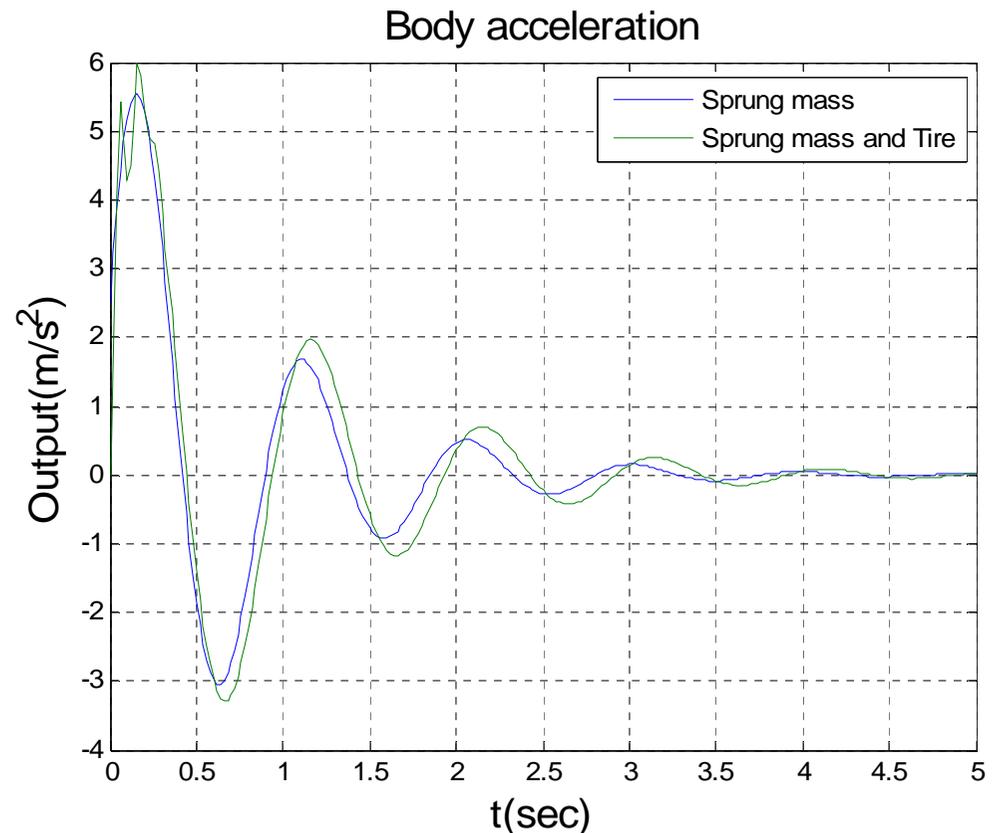
```
>>t=0:0.02:4;
>>A=[0 1 0 -1;-45 -2.5 0 2.5;0 0 0 1
      327.3 18.18 -3273 -18.18];
>>B=[0;0;-1;0];
>>C=[-45 -2.5 0 2.5;1 0 0 0;0 0 1 0];
>>D=0;
>>sys=ss(A,B,C,D);
>>[y,t]=step(sys,t);
>>plot(t,y)
>>grid
>>title('Body, Suspension and Tire','FontSize',15)
>>xlabel('t(sec)','FontSize',15)
>>ylabel('Output x(m/s^2, m)','FontSize',15)
>>legend('Body acceleration','Suspension deflection','Tire deflection')
```



Vehicle Suspension Problem

```
t=0:0.02:5;
A=[0 1;-45 -2.5];
B=[-1;2.5];
C=[-45 -2.5];
D=[2.5];
sys=ss(A,B,C,D);
[y,t]=step(sys,t);
A2=[0 1 0 -1;-45 -2.5 0 2.5;0 0 0 1
     327.3 18.18 -3273 -18.18];
B2=[0;0;-1;0];
C2=[-45 -2.5 0 2.5];
D2=0;
sys2=ss(A2,B2,C2,D2);
[y2,t]=step(sys2,t);
plot(t,y,t,y2)
grid
title('Body acceleration','FontSize',15)
xlabel('t(sec)','FontSize',15)
ylabel('Output(m/s^2)','FontSize',15)
legend('Sprung mass','Sprung mass and Tire')
```

Comparison 1. Acceleration of sprung mass (body)



Vehicle Suspension Problem

```
t=0:0.02:5;
A=[0 1;-45 -2.5];
B=[-1;2.5];
C=[1 0];
D=0;
sys=ss(A,B,C,D);
[y,t]=step(sys,t);
A2=[0 1 0 -1;-45 -2.5 0 2.5;0 0 0 1
     327.3 18.18 -3273 -18.18];
B2=[0;0;-1;0];
C2=[1 0 0 0];
D2=0;
sys2=ss(A2,B2,C2,D2);
[y2,t]=step(sys2,t);
plot(t,y,t,y2)
grid
title('Suspension deflection','FontSize',15)
xlabel('t(sec)','FontSize',15)
ylabel('Output(m)','FontSize',15)
legend('Sprung mass','Sprung mass and Tire')
```

Comparison 2. Suspension deflection

