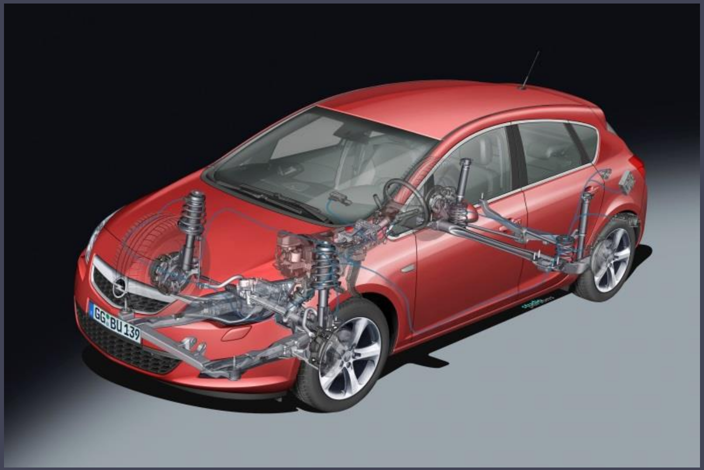

Suspension System

Non-linear Asymmetrical shock Absorber

Vehicle Dynamics Term Project

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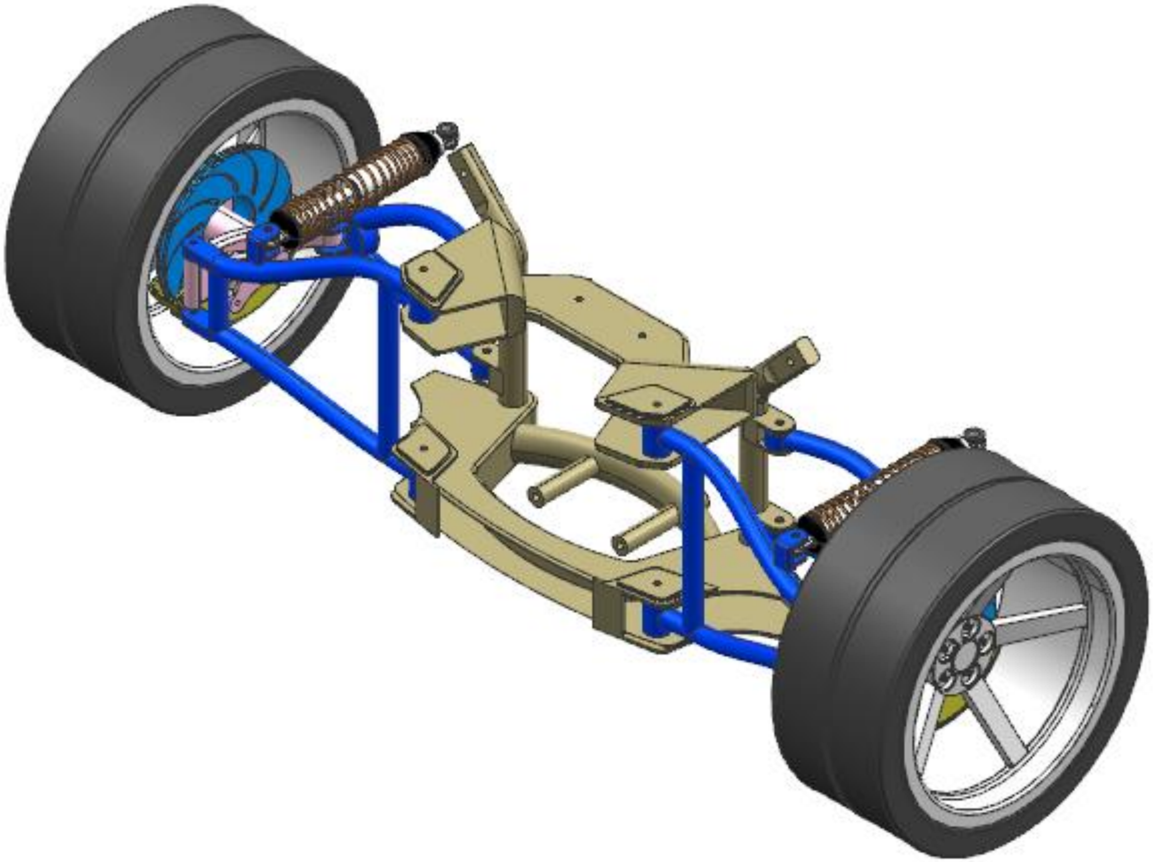
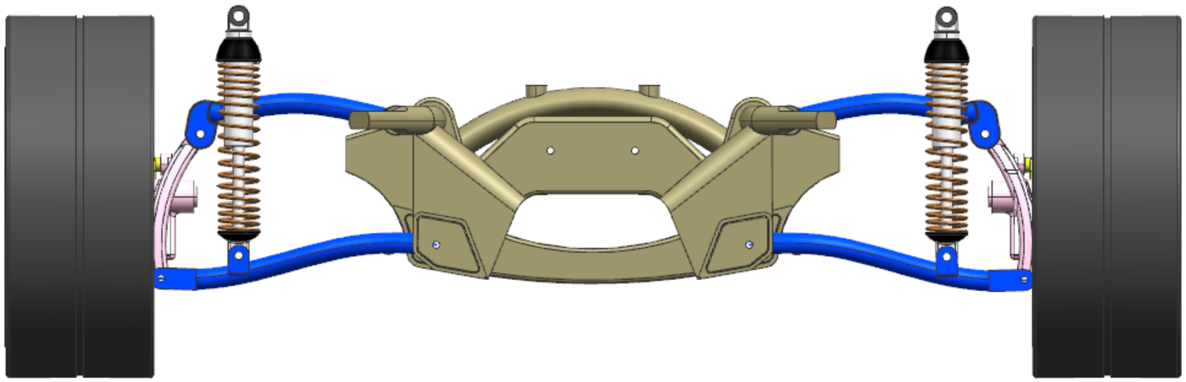
Agenda

- Introduction of suspension system
- CAD Model
- Components
- Working principle
- Popular suspension systems
- Mathematical Model

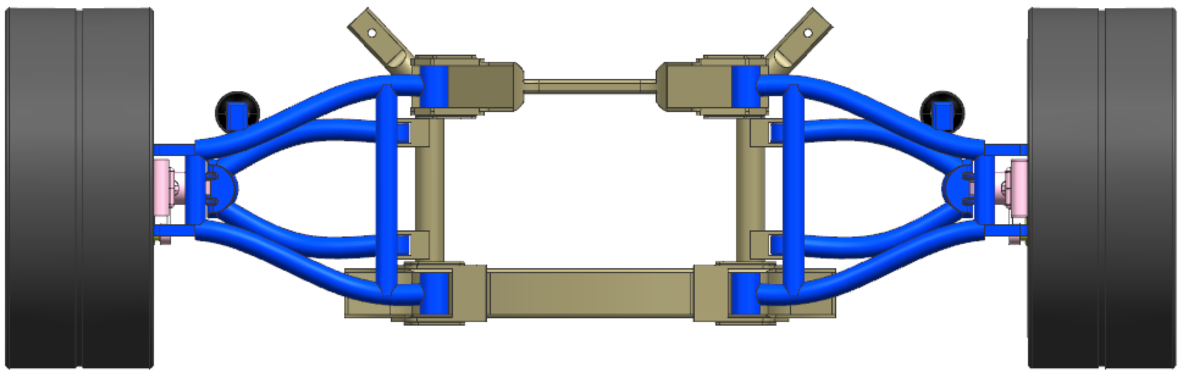
SUSPENSION SYSTEM – ASSEMBLY CAD MODELS (Modelled in Unigraphics)



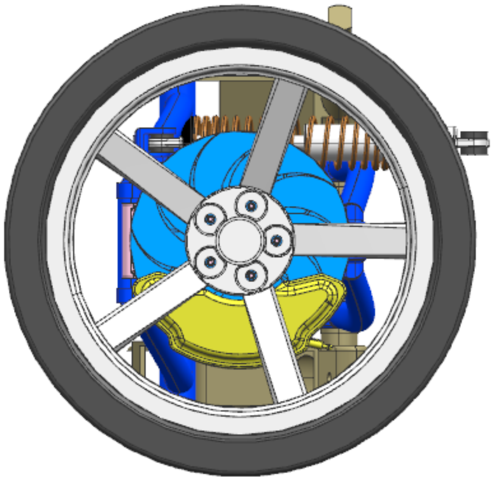
Isometric View



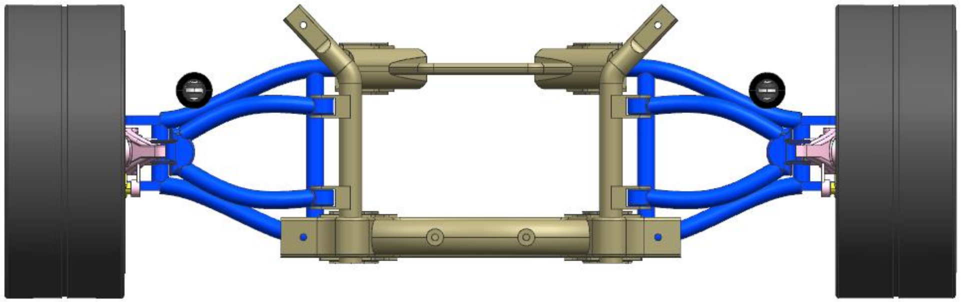
Top View



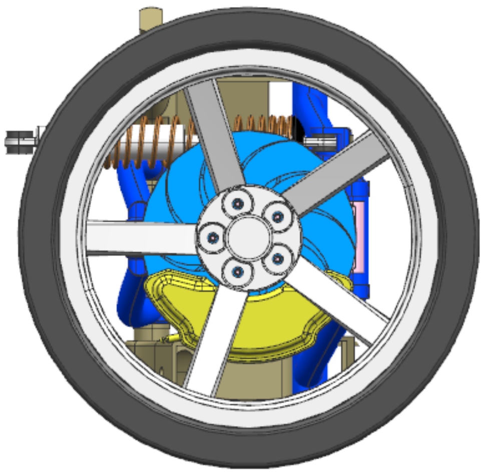
Front View



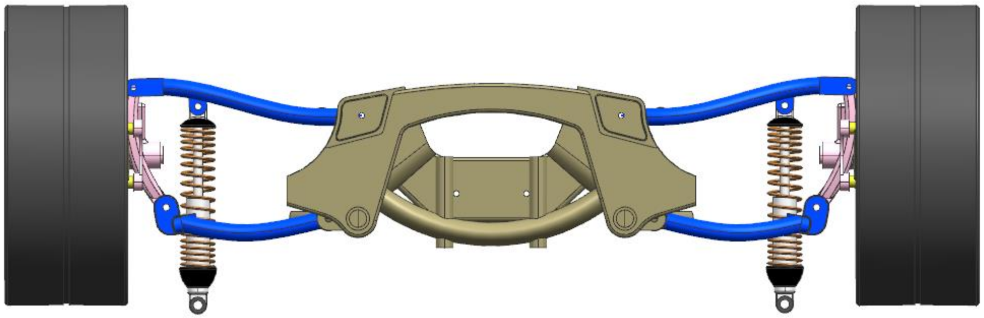
Right Side View



Back side View

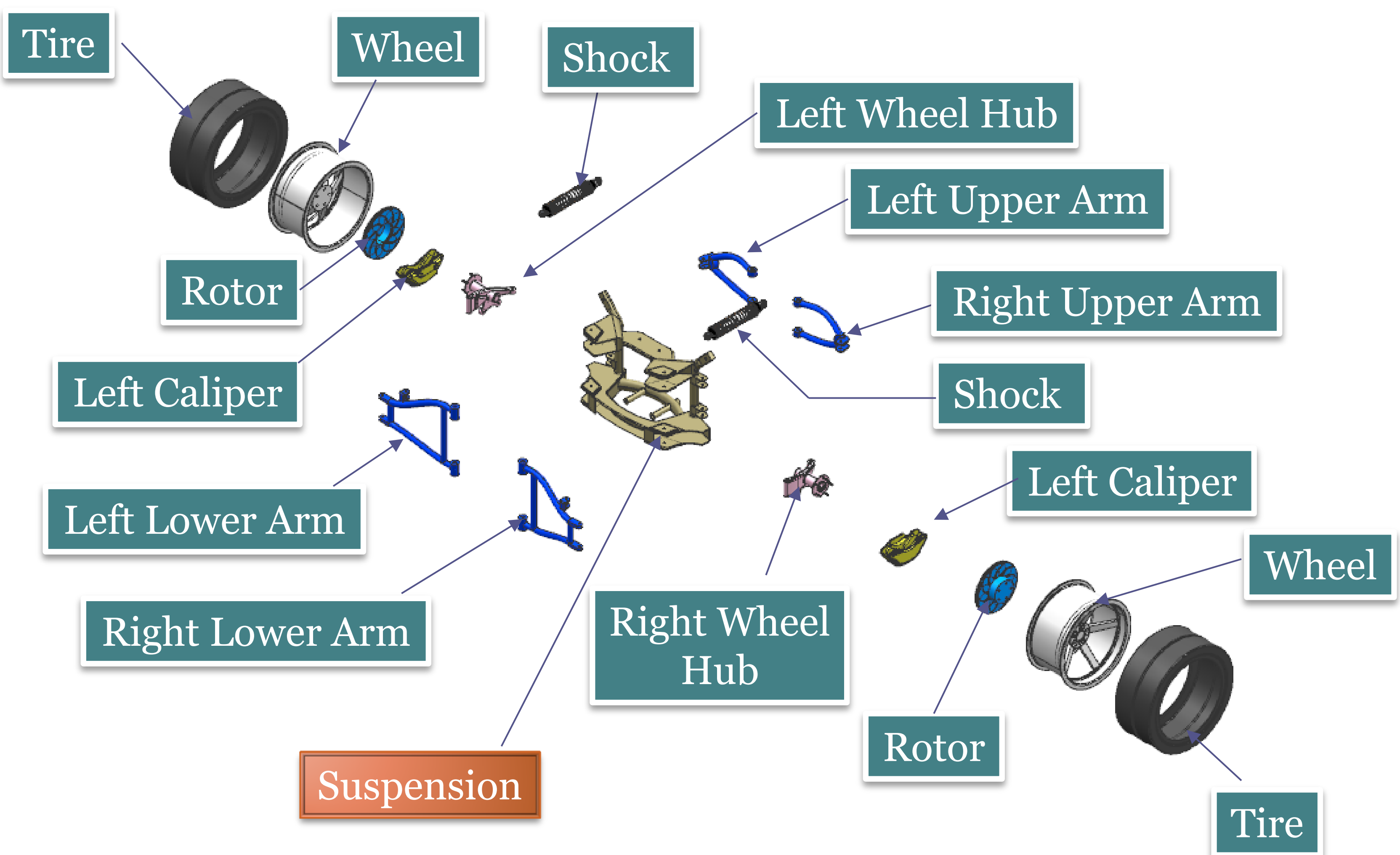


Left Side View

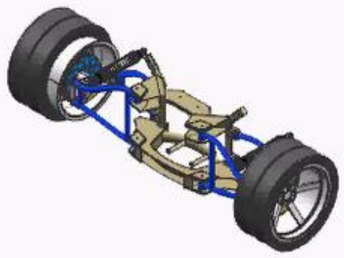


Bottom View

Suspension System Parts



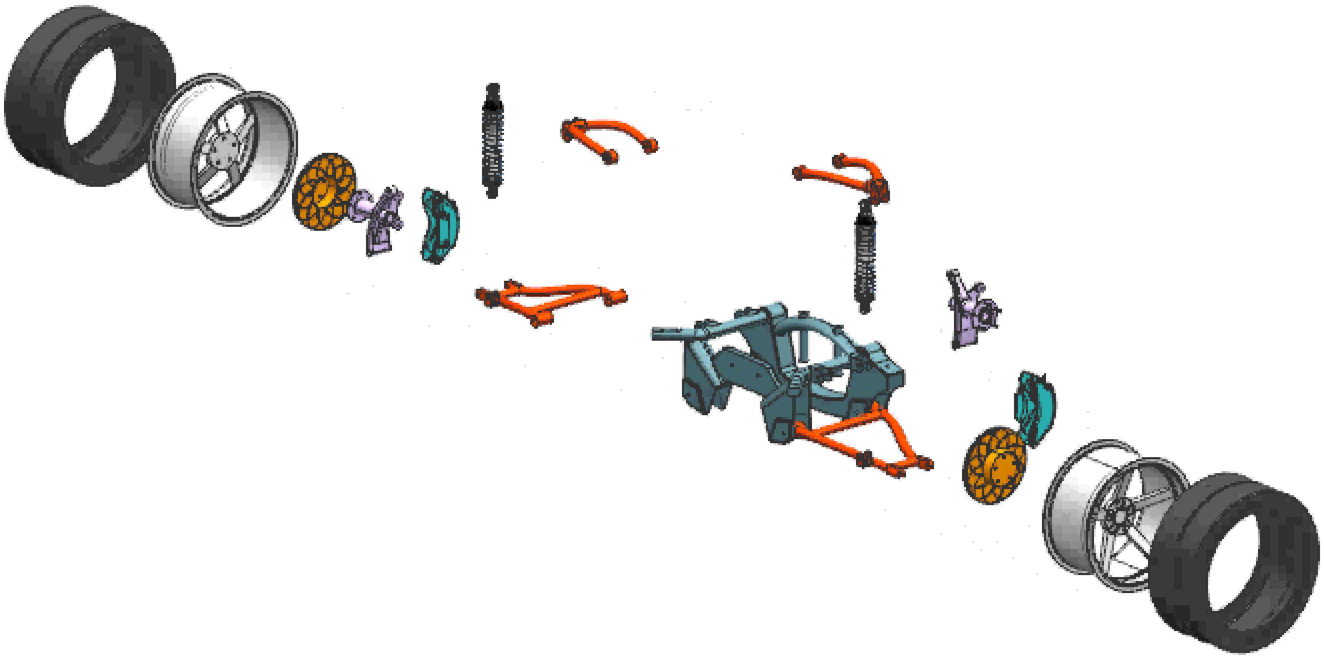
EXPLODED VIEW



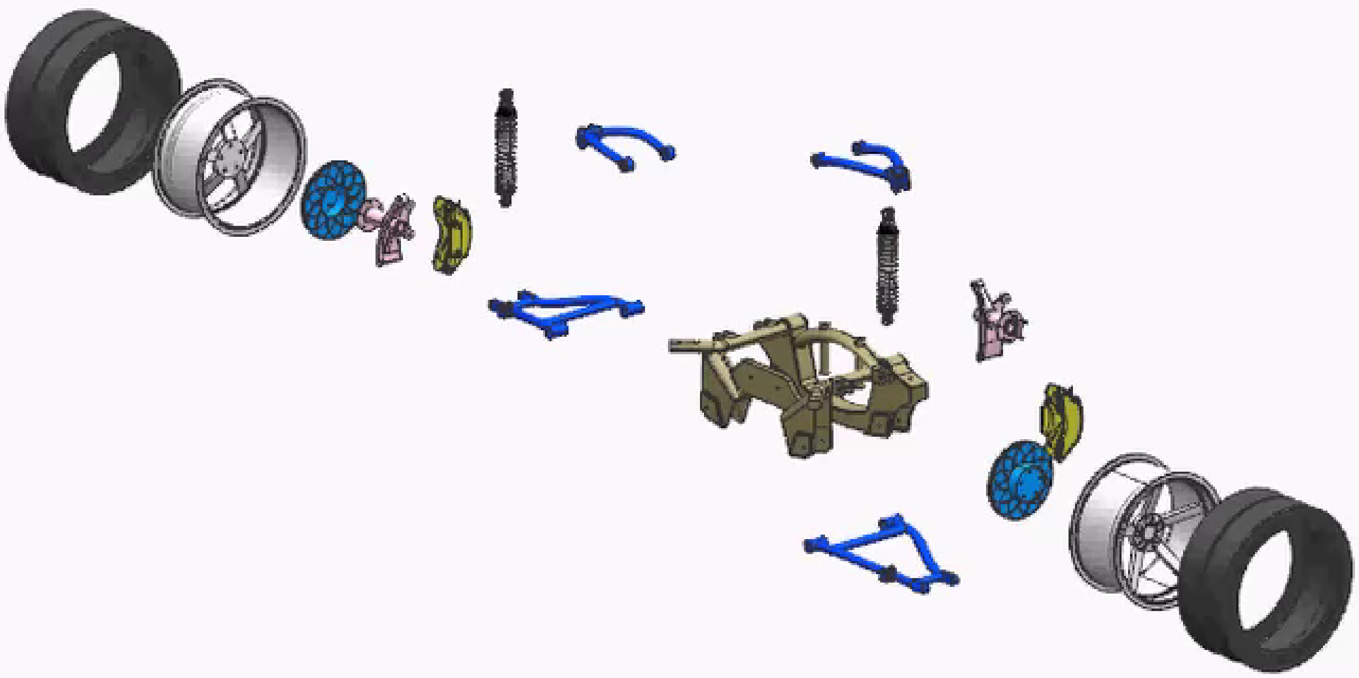
Functions

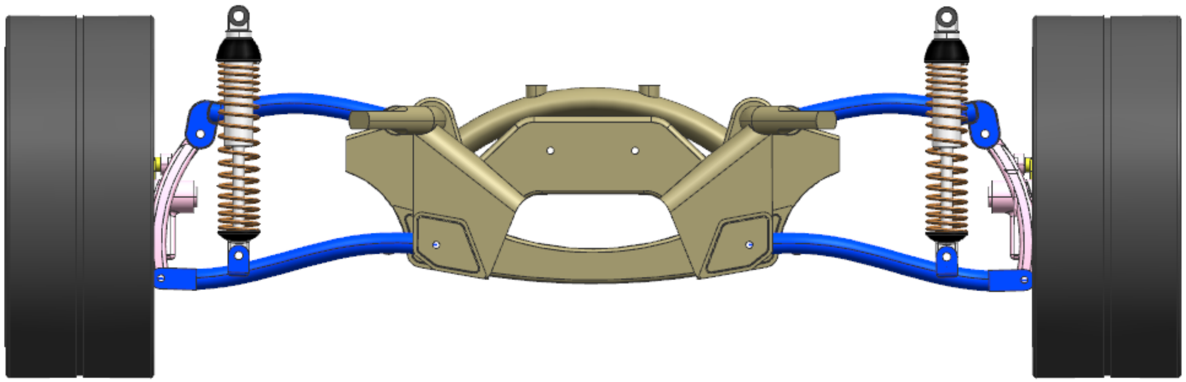
- ***Rotor*** is to dissipate the heat that is generated during braking events. Front rotors absorb up to 80% of the heat, so they usually are vented with ribs, while rear rotors absorb less and are typically solid discs.
- ***Caliper*** integrity is vital to the function of the brake system and can be compromised as a result of exposure to road grit, heat and contaminated brake fluid.
- The ***wheel hub*** is fixed rigidly to an upright, telescopic, tubular strut which has its top end anchored to the frame or to a reinforced wing.
- A ***control arm*** is a bar that has a pivot at both ends which are arranged to form the letter A.
  They attach suspension members to the chassis and manage the motion of the wheels so that it synchronizes with that of the body of the car.
  As a result, you are able to go on joy rides without feeling sick and dizzy, as there is control and smoothness in the movement of the car.
  Like other body parts, the control arms should also be lubricated at every oil inspection.
  Handling and steering could become erratic if the control arms are malfunctioning and the unsteady movement of your car could take away your riding comfort.

Suspension System Parts

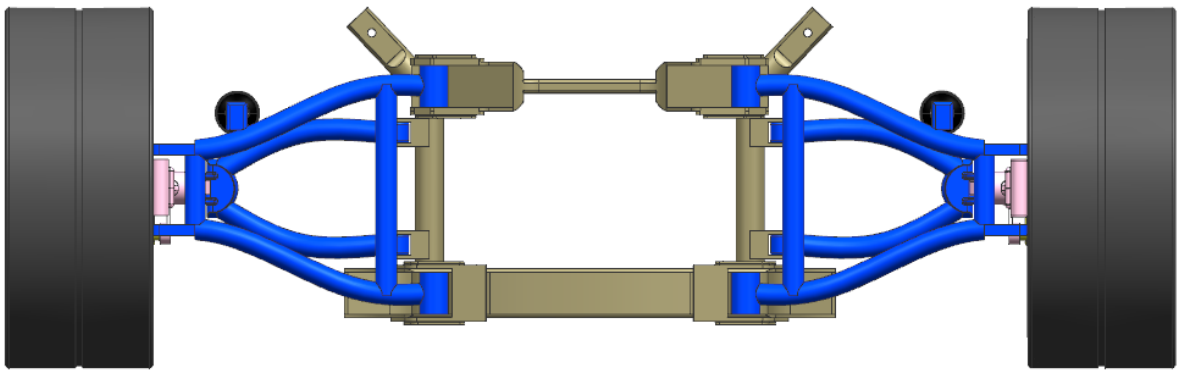


EXPLODED VIEW





Front View



Top View

Suspension system - functions

- to isolate the vehicle from disturbances so that the driver can keep control of the vehicle, without causing discomfort to passengers
- system should minimize vertical motion, as well as pitch and roll movements, as the vehicle passes over an irregular road, performs turning manouvres, and is accelerated or braked heavily.
- Apart from these basic operational aspects, the suspension should also provide a good level of comfort for the passengers, minimizing the movements and accelerations imposed on and perceived by them.
- The level of comfort is increasingly seen as one of the main contributing factors for purchase decision and satisfaction
- The disturbances can be caused by irregularities on the road, or caused by loads inherent of the operation of the vehicle, such as acceleration, braking and turning, as well as aerodynamic loads.

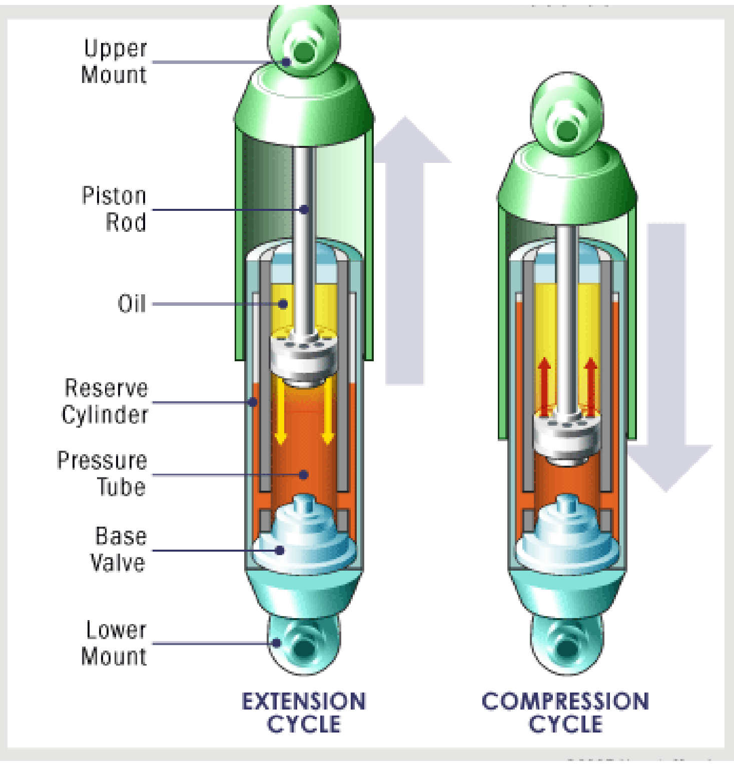
Suspension System - Components

- Spring
  - coil springs
  - leaf springs
- Damper shock absorber
  - Need for damper

Suspension System – Damper Working principle

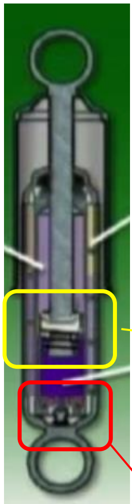
- Hydraulic dampers are prevalent
- During bumps or compression, rod & piston move into the Shock Absorber
- In rebound, or extension, they move out
- For dampening to be effective, resistance is needed in both directions – provided by oil and valves

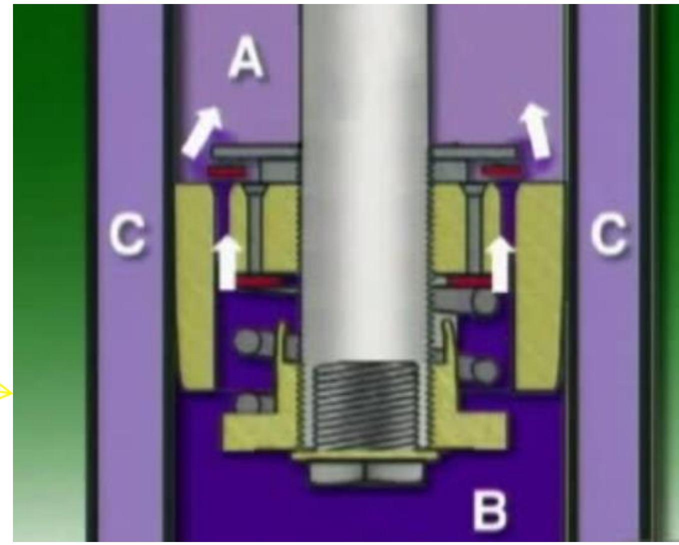
Hydraulic Damper



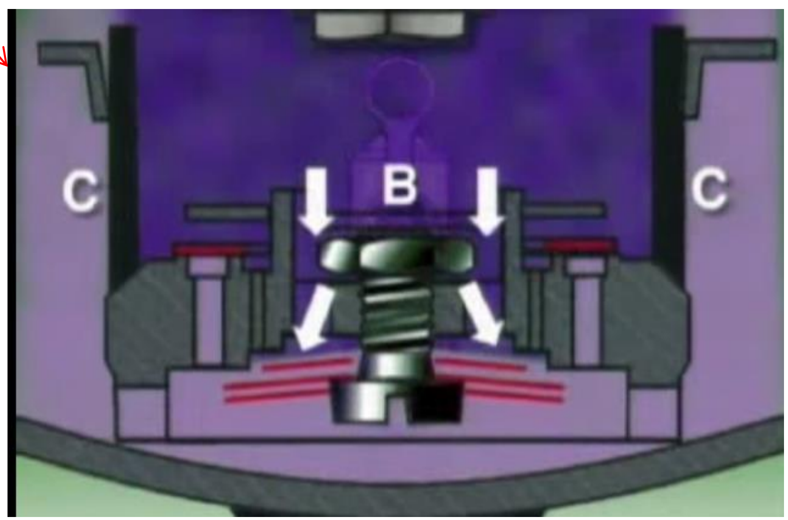
- Without a **damper structure** a car spring will extend and release the energy it absorbs from a bump at an uncontrolled rate.
- The spring will continue to bounce at its natural frequency until all of the energy originally put into it is used up.
- A suspension built on springs alone would make for an extremely bouncy ride and, depending on the terrain, an uncontrollable car

Bump/Compression



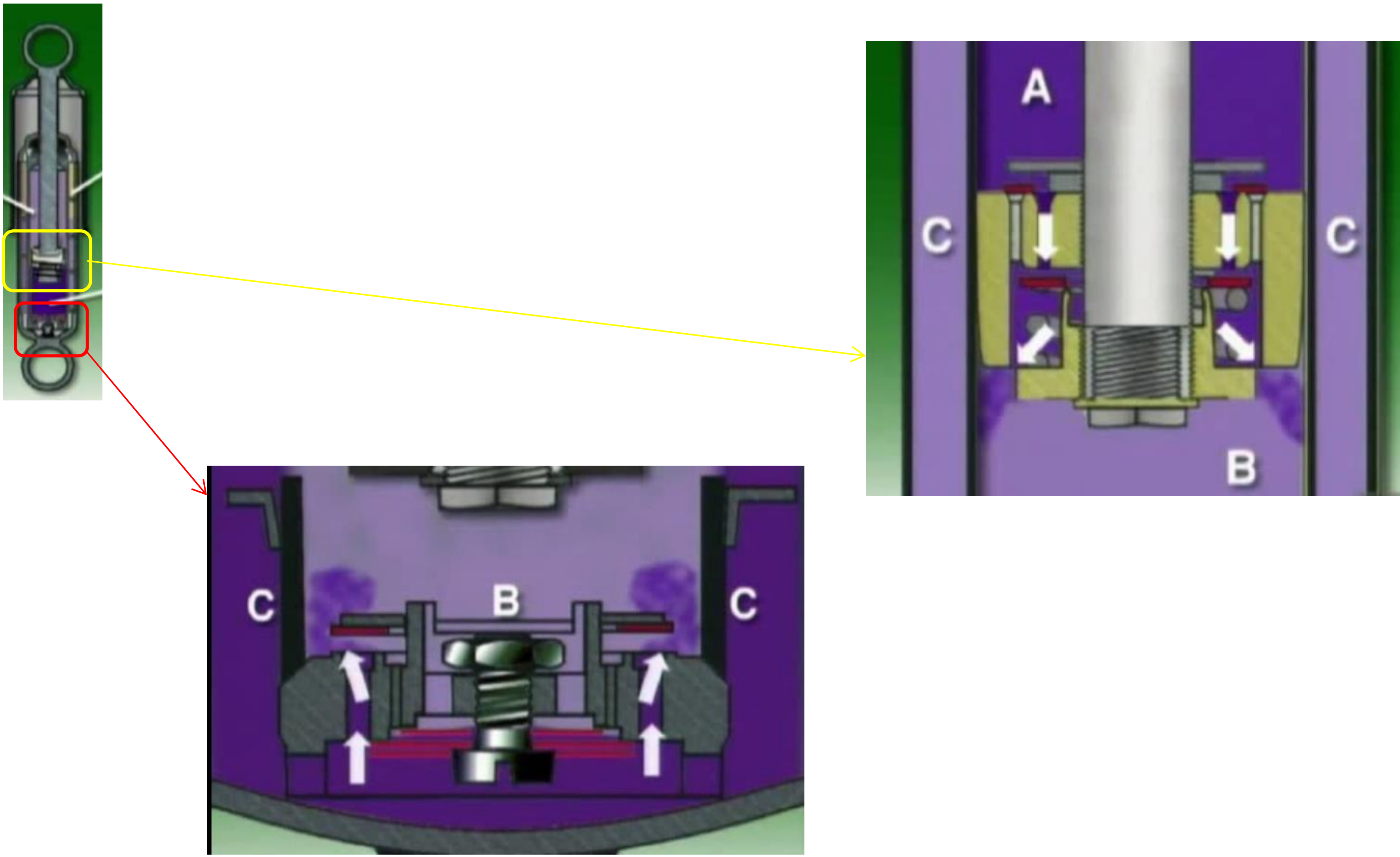


All of the oil in B
can not flow into A



Displaced fluid forced down through
a base valve into reservoir C

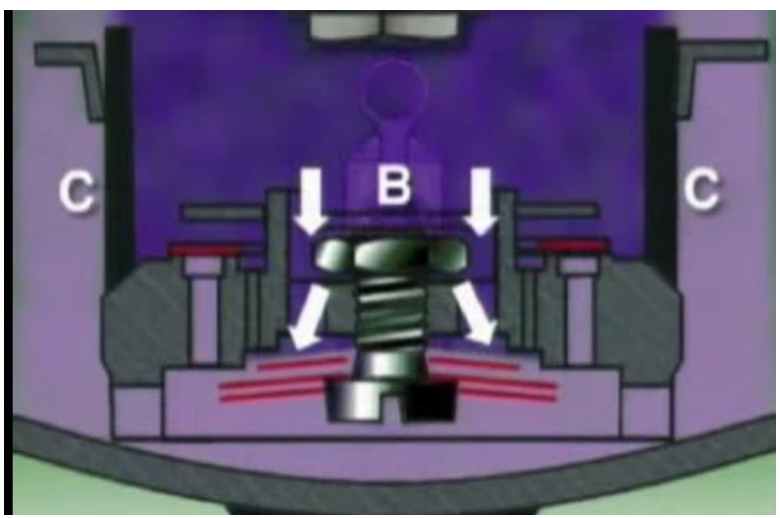
Rebound/Extension

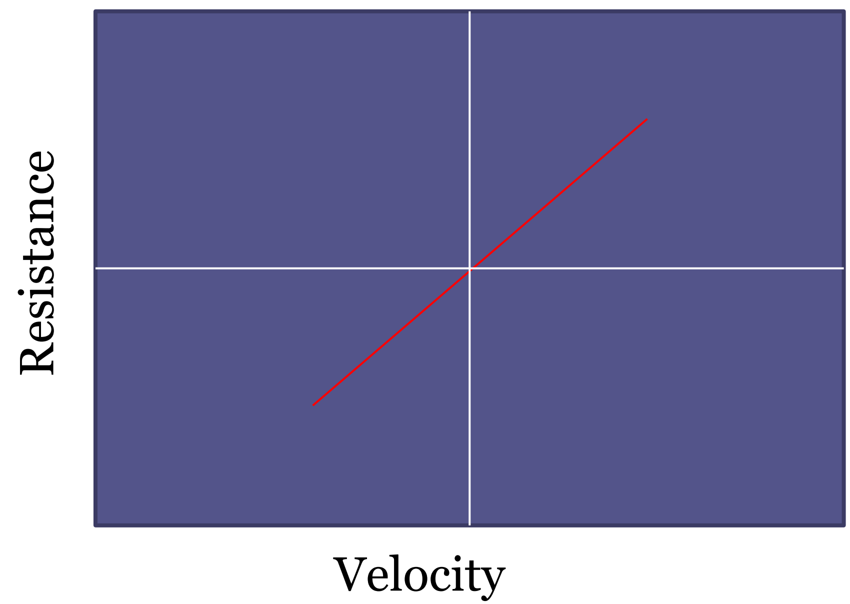


Response of Damper

The resistance can be tuned proportional to the velocity.

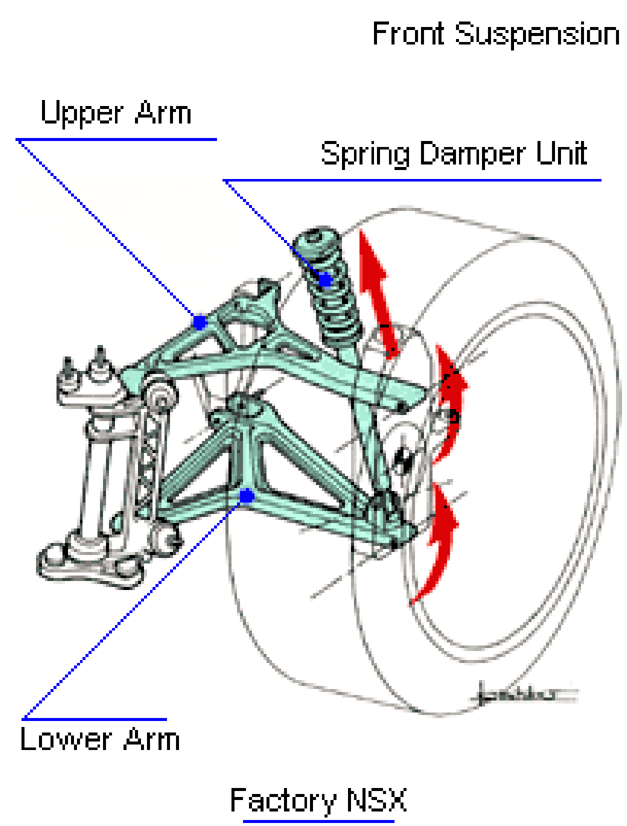
Higher resistance @ higher speeds
Lower resistance @ lower speeds





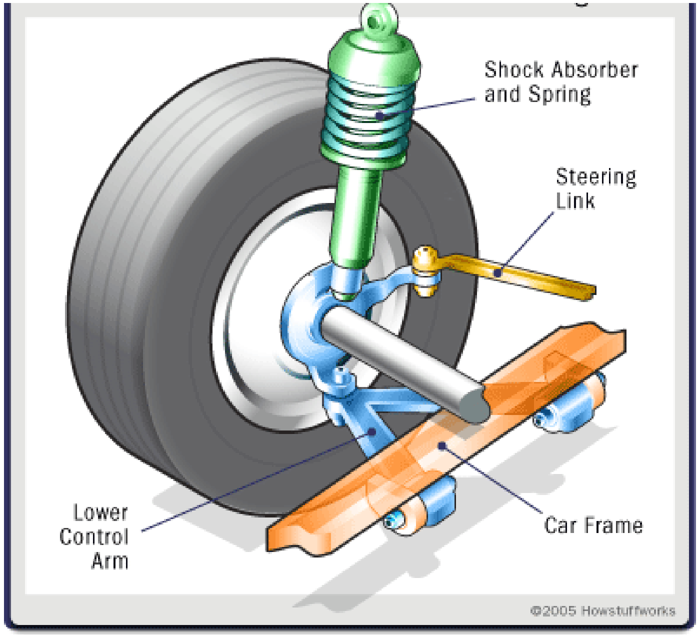
Double-wishbone suspension
A-arm suspension/parallelogram system

- Each wishbone, which has two mounting positions to the frame and one at the wheel, bears a shock absorber and a coil spring to absorb vibrations.
- Double-wishbone suspensions allow for more control over the camber angle of the wheel, which describes the degree to which the wheels tilt in and out.
- They also help minimize roll or sway and provide for a more consistent steering feel.
- allows the spindles to travel vertically up and down. When they do this, they also have a slight side-to-side motion caused by the arc that the wishbones describe around their pivot points. This side-to-side motion is known as scrub.
- common on the front wheels of larger cars.



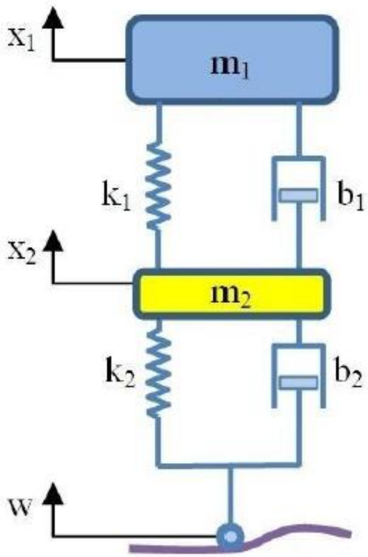
MacPherson strut

- Combines a shock absorber and a coil spring into a single unit.
- Provides a more compact and lighter suspension system used for front-wheel drive vehicles.



Mathematical Model

- Quarter car model with asymmetric damping:
- Components:
  a)Sprung mass
  b)Un-sprung mass
- Sprung mass:
  m1=sprung mass
  k1=stiffness coefficient of suspension
  k2=stifness of tire
  b1=damping coefficient of suspension
  b2=damping co-efficient of tire
- Damping coefficient of tire is usually negligibile in comparison with that of spring.



gure 1 *The passive suspension system*

Basic Equations of quarter car model:

- Basic equation for sprung mass:

$$m_1\ddot{x}_1+b_1(\dot{x}_1-\dot{x}_2)+k_1(x_1-x_2)=0$$

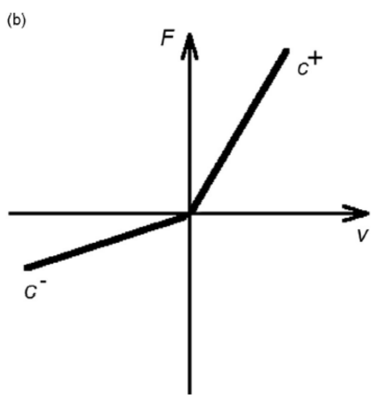
- Basic equation for unsprung mass:

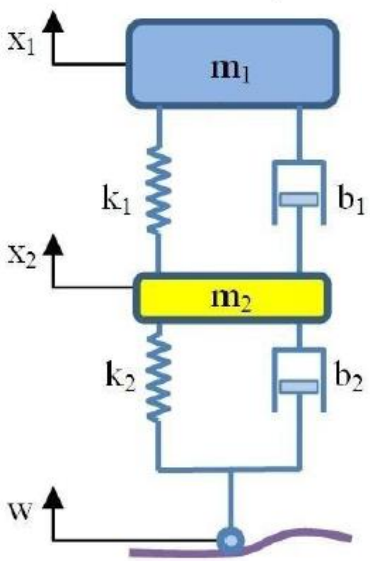
$$m_2\ddot{x}_2+b_1(\dot{x}_1-\dot{x}_2)+k_1(x_2-x_1)+b_2\dot{x}_2+k_2x_2=0$$

$$f_{ku}=k_u(z_u-z_r)$$

$$f_{cu}=c_u(\dot{z}_u-\dot{z}_r)$$

$$D(\dot{z}_s-\dot{z}_u)=\begin{cases} c_s^+ & \text{if } \dot{z}_s-\dot{z}_u\geq 0 \\ c_s^- & \text{if } \dot{z}_s-\dot{z}_u<0 \end{cases}$$





gure 1 *The passive suspension system*

- Road profile used:

Standard Rouded profile

Road profile :

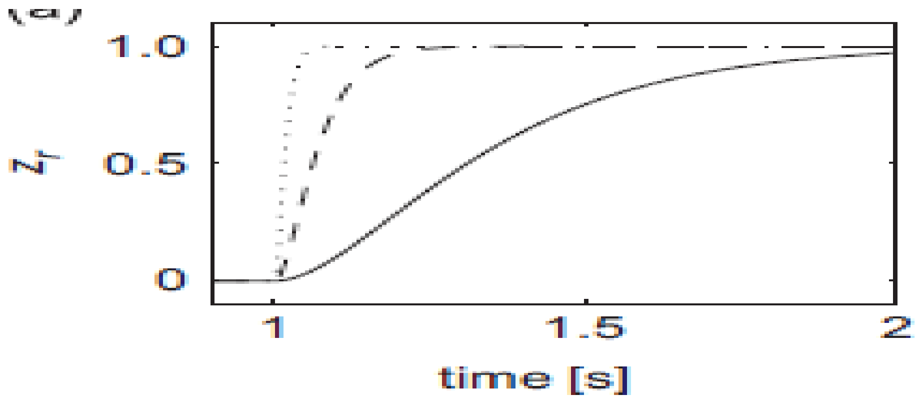
- Basic Rouded profile- Standard Equation

$$z_r(t) = z_{max}(1 - (1 + \gamma\omega_0 t)e^{-\gamma\omega_0 t})$$

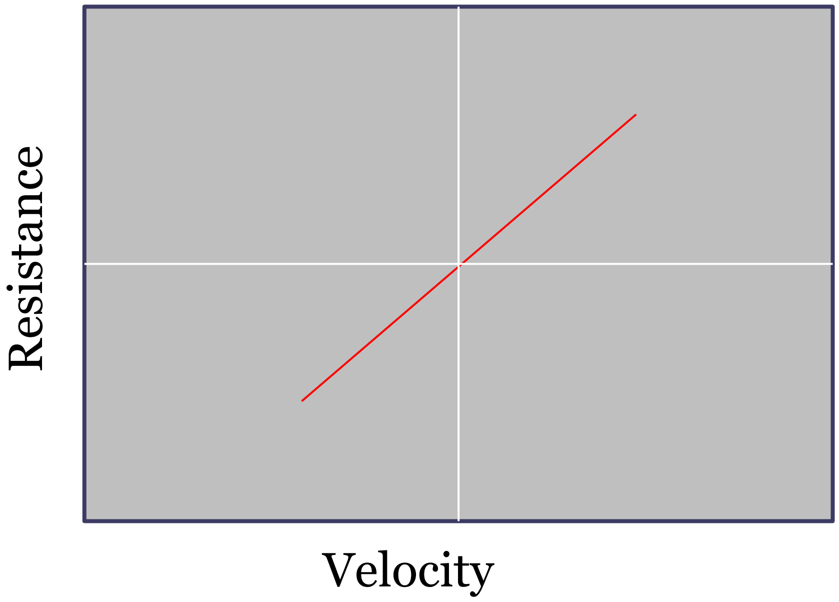
where,

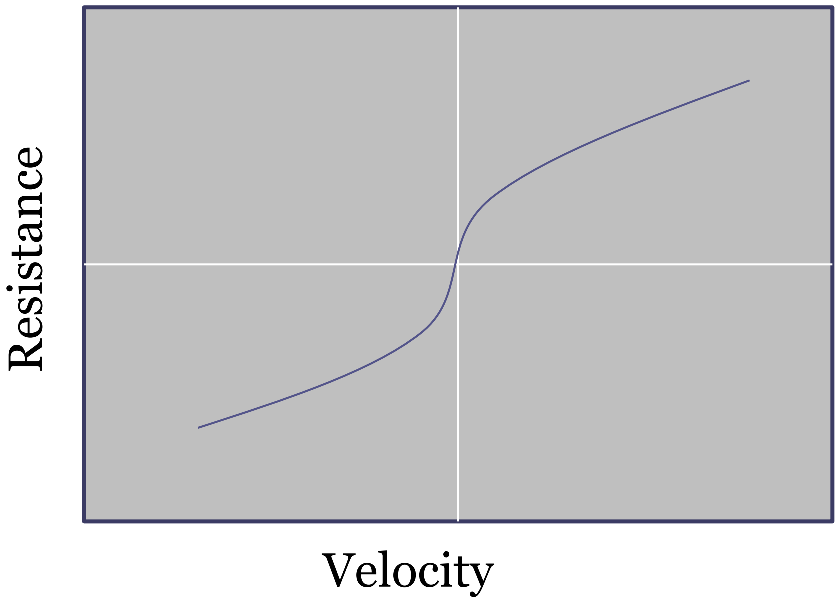
γ = severity parameter of road
w= natural frequency of sprung mass
z_{max}= maximum bump height

-
- Road plot:



Symmetric Response

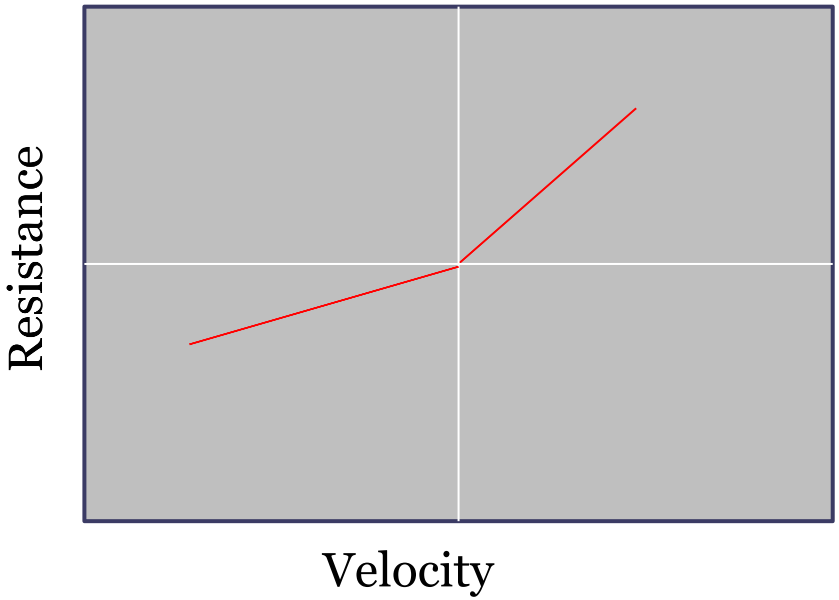




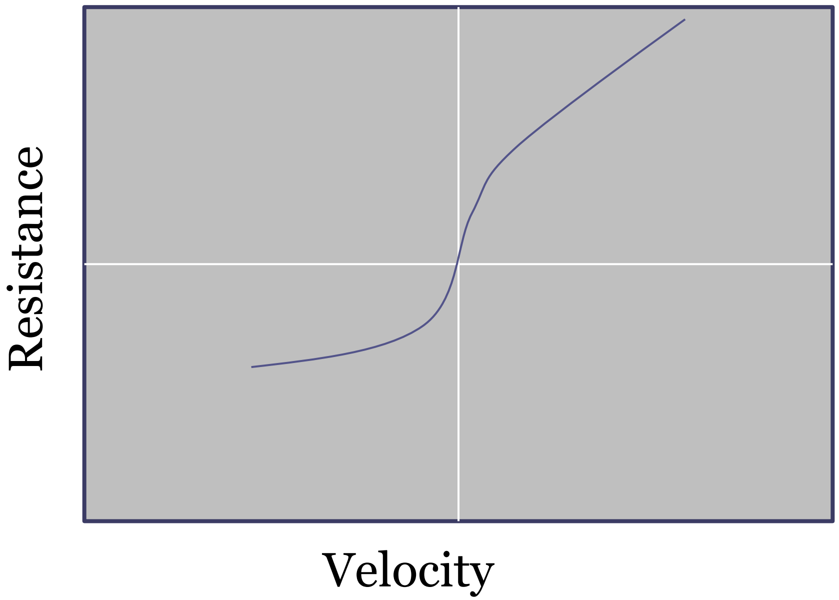
Linear

Non-linear

Asymmetric Response



Linear



Non-linear

Fourth order RK Method code:

- Mat-lab parameters:

```
function k1=k_function(d,p)
mu=200;
ku=400000;
ms=1500;
ks=44000;
cu=20;
cs1=4000;
cs2=3500;
```

- Road profile:

```
zr=0.05*(1-(1+(gama*omega*p))*exp(-gama*omega*p));
zv=0.05*(2*gama*omega*exp(-gama*omega*p)+gama^2*omega^2*p*exp(-gama*omega*p));
```

- Damping control:

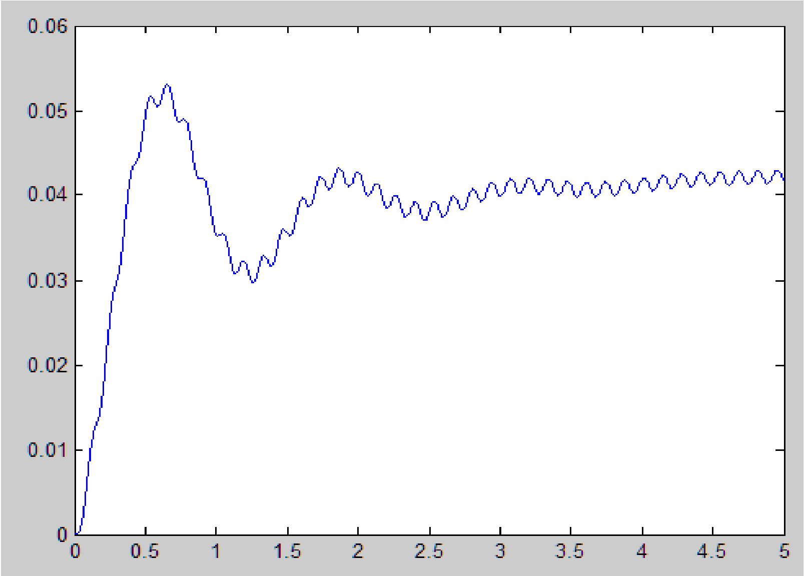
```
if((d(4)-d(2))>=0)
    fcs=cs1*(d(4)-d(2));
else
    fcs=cs2*(d(4)-d(2));
end
```

Basic Results:

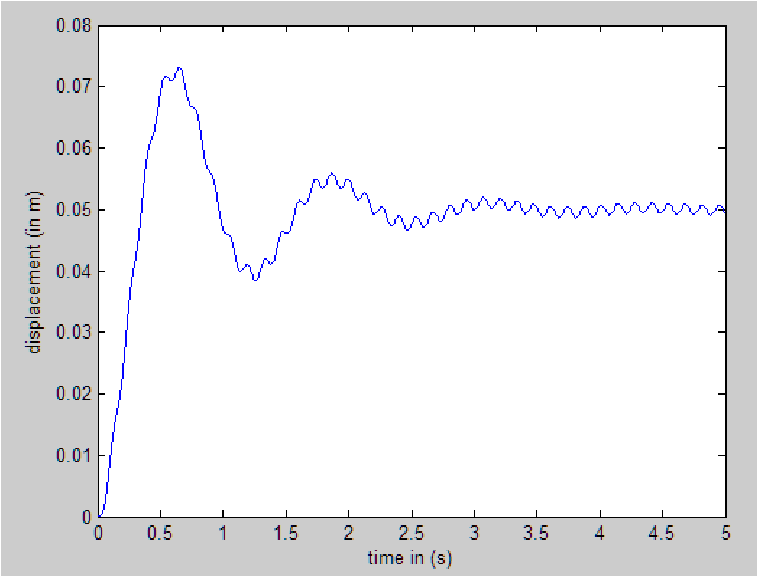
- Symmetric vs Asymmetric:
  1)Spring displacement is less in case of asymmetric damper model.
  2)Displcement settles at 0.5m.

Asymmetric settles earlier than symmetric damper model.

Asymmetric



Symmetric



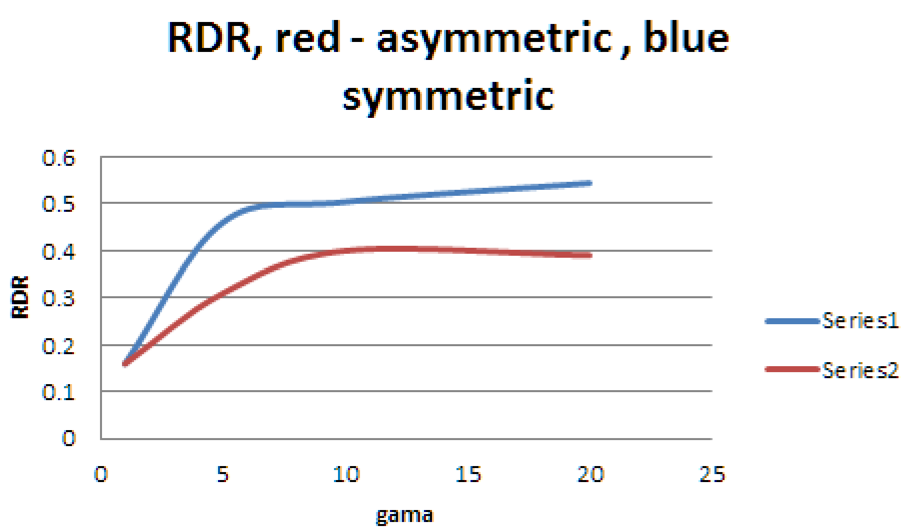
Comfort parameter (RDR)

- RDR is defined as:

$$RDR = |(z_s - z_r)/z_{r,\max}|_{\max}$$

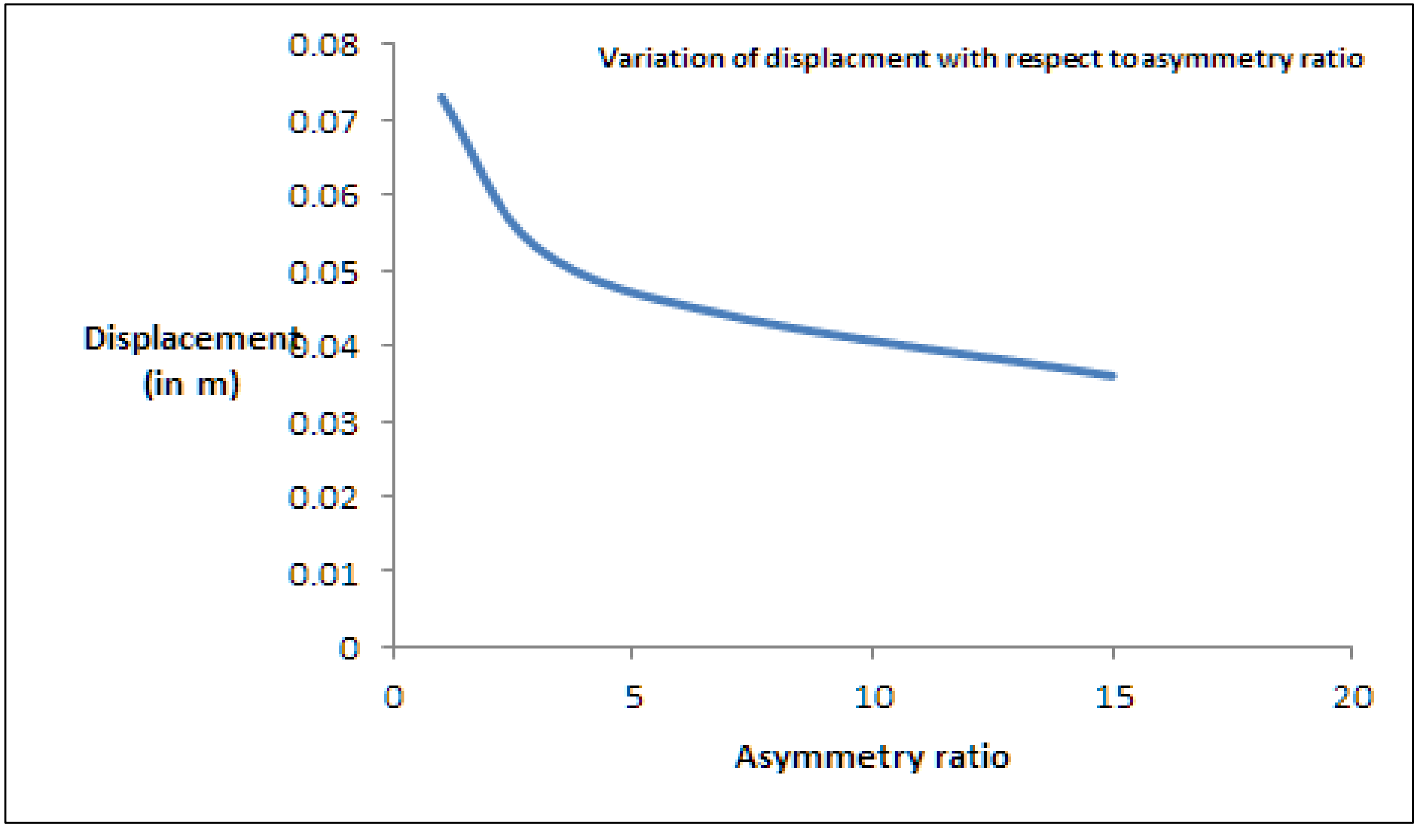
where, Zs = displacement of spring

Zr=Road displacement



Lower RDR implies lower spring deflection leading to better comfort.

Effect of Asymmetry Ratio



Conclusion

- asymmetrical system characteristics, tends to have a smoother and more progressive performance.
- This happens because the damping forces are lower during the first half-cycle, when the impacts occurs.
- This tendency increases with larger severity of impacts, indicating the advantage of the asymmetrical system over the symmetrical one in these conditions which ultimately improves the rider comfort.

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