Power Generation Using Speed Breakers

ME396 (ENGINEERING PRACTICUM)

GUIDED BY :- Dr. Somnath Sarangi and Dr. Chiranjit Sarkar

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Aim of the Project :

This project aims to conserve the power expended on speed bumps by redesigning them and converting mechanical energy into electrical energy.

Principle :

The vehicle acquires height as it moves over an elevation, resulting in an increase in potential energy.

Set up description :

The setup consist of following main components :

1.Speed Bump
2.Springs
3.Supporting Rods
4. Rack
5. Gears
6. Electric Motor
7. Shaft
8. Wall and Base

Solidworks Analysis

- When a Vehicle Passes over a speed bump the springs get compressed following which the rack moves vertically down, ultimately the linear motion is converted to rotational motion of the gear and shaft.
- One of the gears is meshed with the rack, while the other gear at the other end is connected with the dynamo. Ball bearings are present on the ends of the shaft, which supports the shaft at the ends and aids in rotation.
- The then obtained dynamo’s output is an A.C voltage which converts to a D.C. voltage for storage purposes.
- Using a step-up transformer a higher voltage is obtained and the circuit for conversion of A.C. to D.C. can be seen from below. We thus obtain a D.C. Voltage across the capacitor.

Features | Sketch | Markup | Evaluate | MBD Dimensions | SOLIDWORKS Add-Ins | Simulation | MBD | Analysis Preparation

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History
Sensors
Annotations
Solid Bodies(1)
Material <not specified>
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Top Plane
Right Plane
Origin
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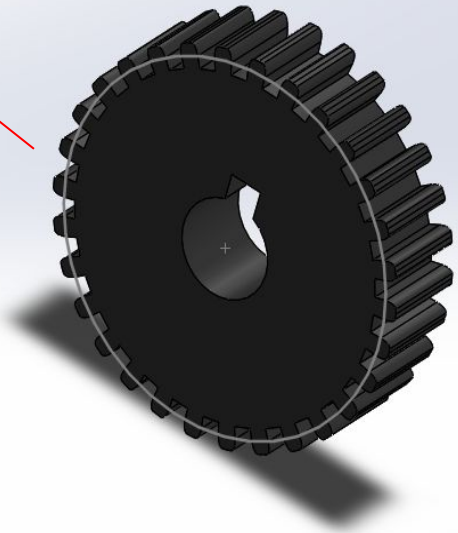
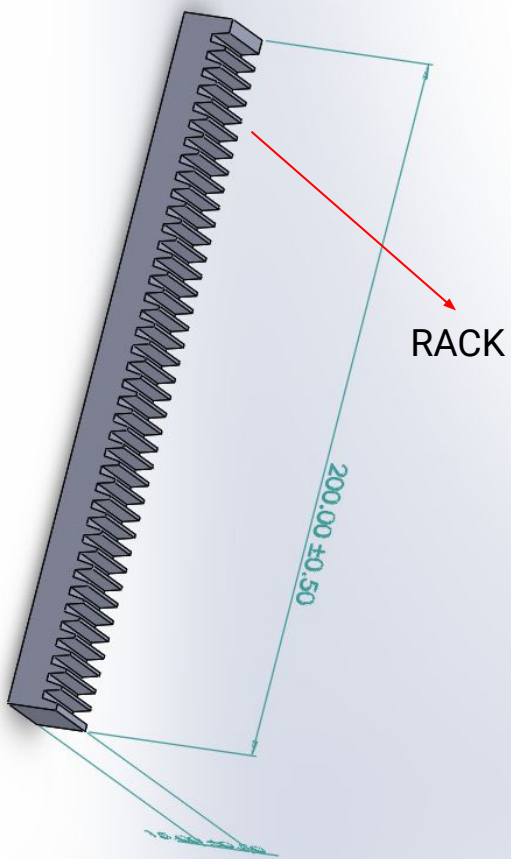
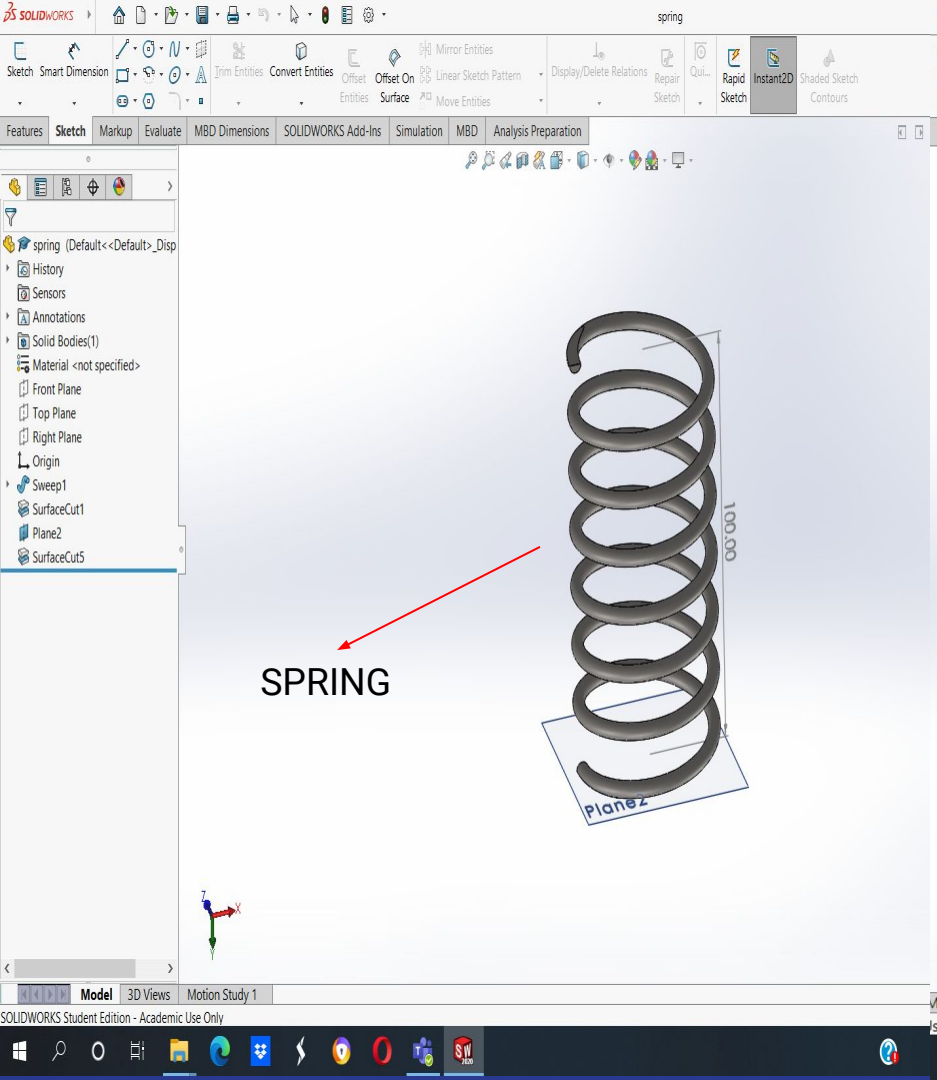
CirPattern1
Cut-Extrude1
Cut-Extrude2
Sketch4

GEAR





Model | 3D Views | Motion Study 1


spring
Sketch
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Trim Entities
Convert Entities
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Offset On Surface
Mirror Entities
Linear Sketch Pattern
Move Entities
Display/Delete Relations
Repair Sketch
Rapid Sketch
Instant2D
Shaded Sketch Contours
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Sketch
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MBD Dimensions
SOLIDWORKS Add-Ins
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History
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Annotations
Solid Bodies(1)
Material <not specified>
Front Plane
Top Plane
Right Plane
Origin
Sweep1
SurfaceCut1
Plane2
SurfaceCut5
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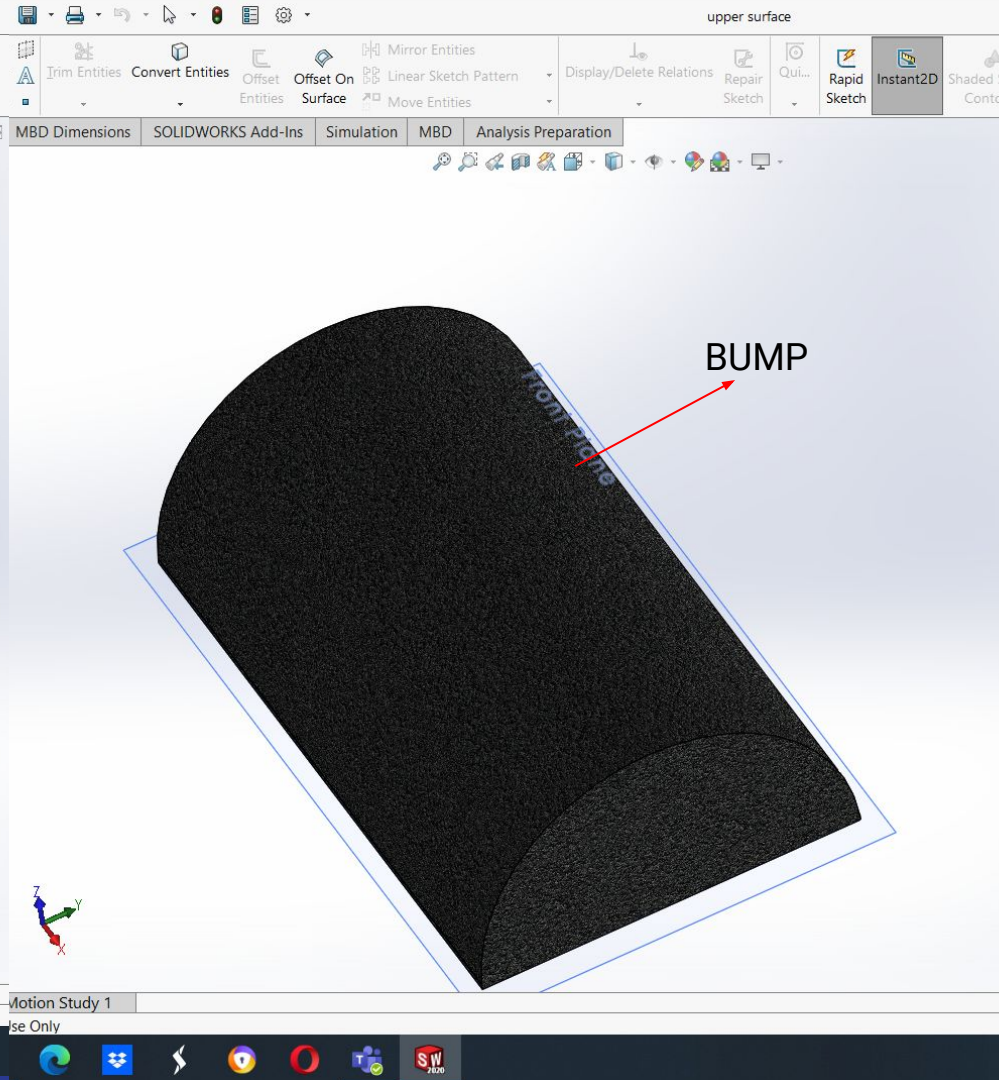
SPRING
Plane2
Model
3D Views
Motion Study 1
SOLIDWORKS Student Edition - Academic Use Only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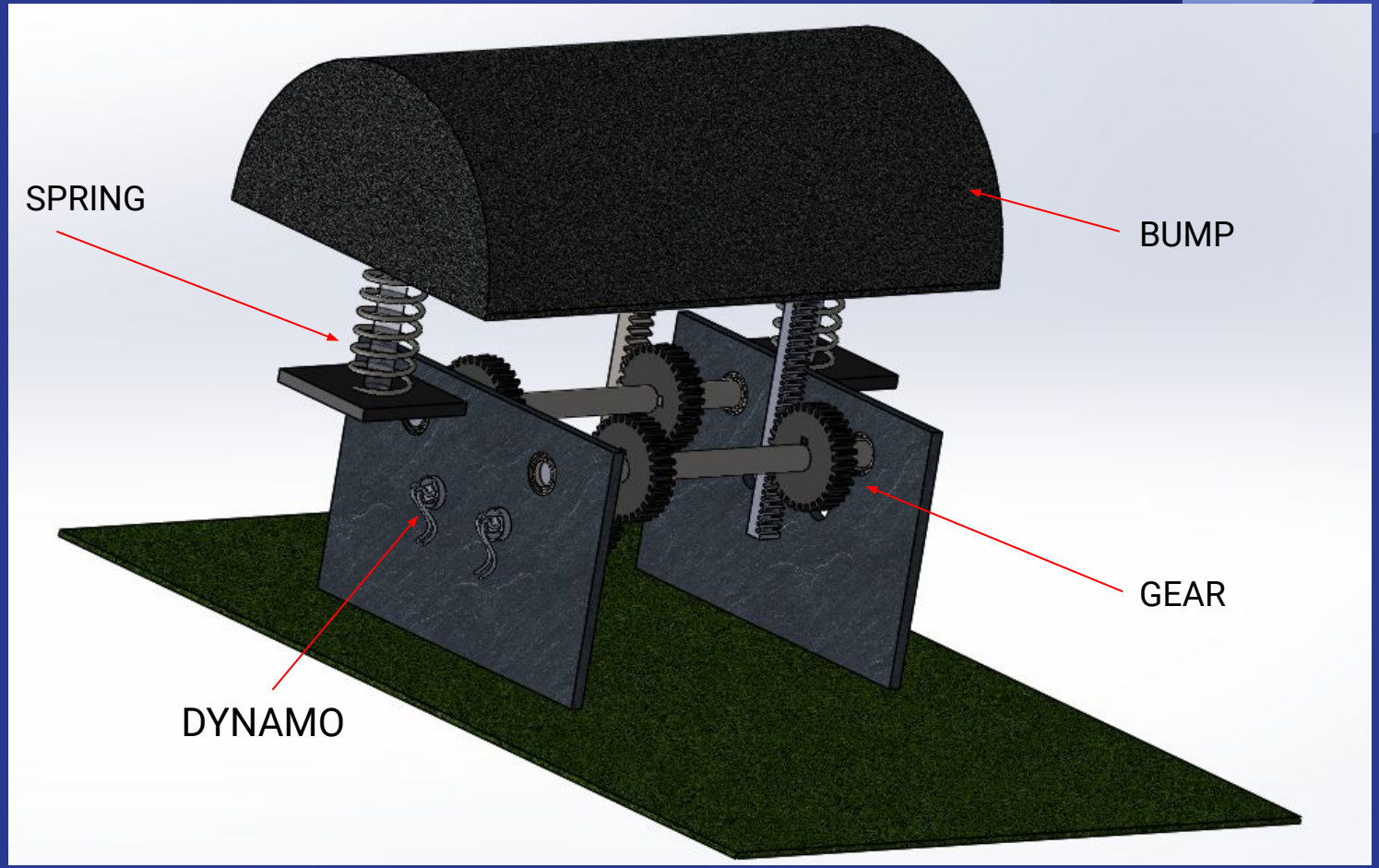
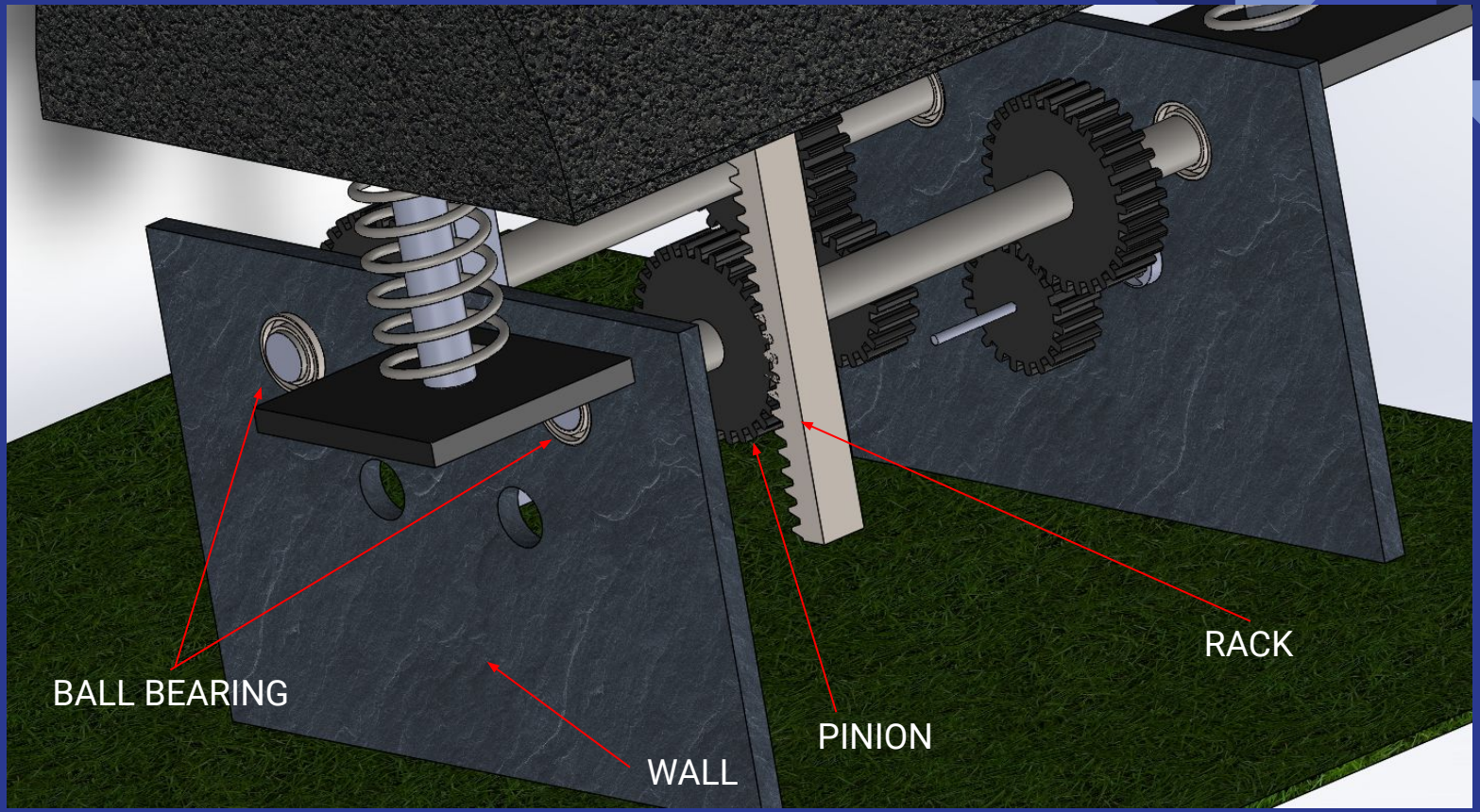
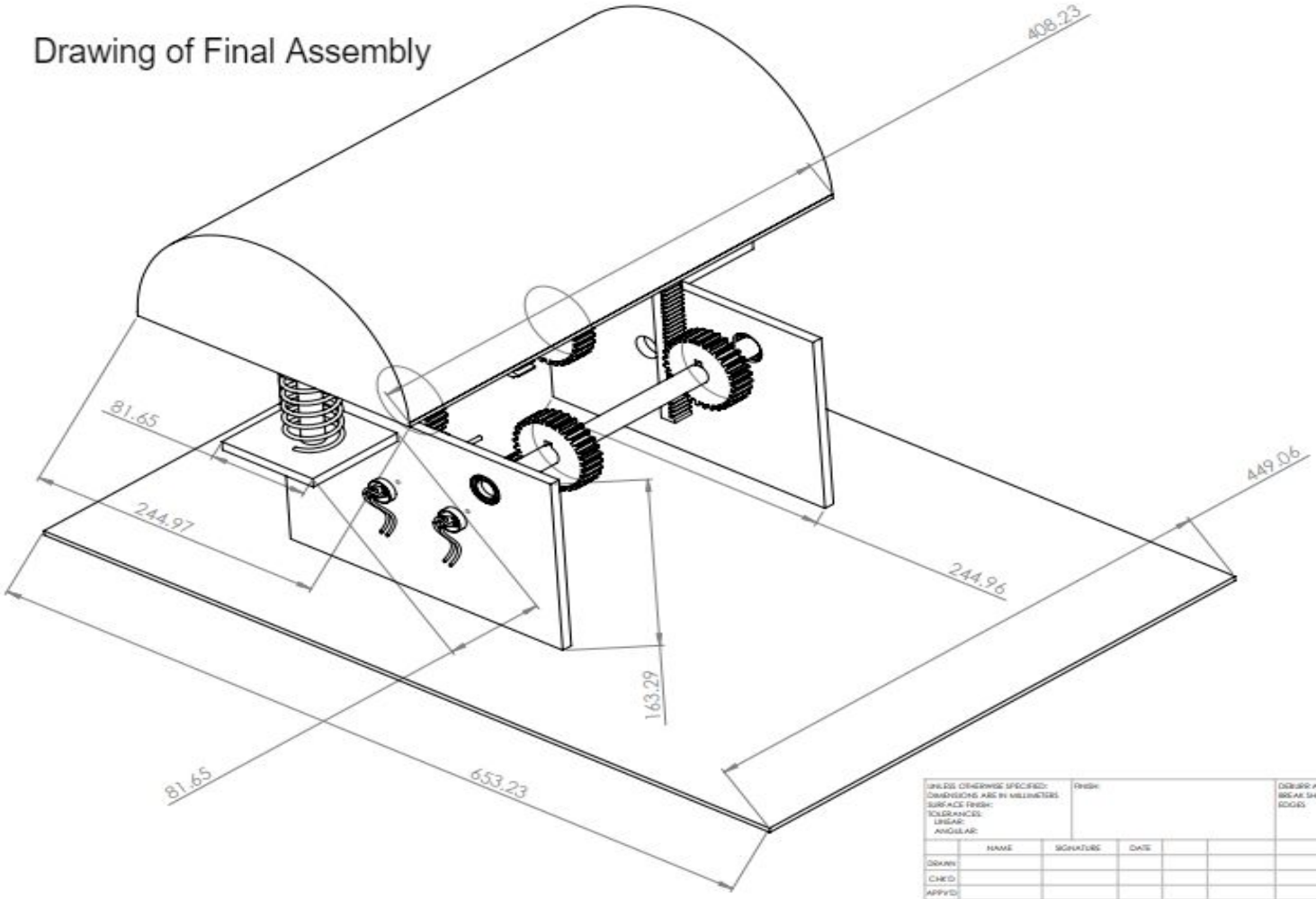
Move Entities
Display/Delete Relations
Repair Sketch
Rapid Sketch
Instant2D
MBD Dimensions
SOLIDWORKS Add-Ins
Simulation
MBD
Analysis Preparation
BUMP
Front Plane
Motion Study 1


SPRING
BUMP
GEAR
DYNAMO


BALL BEARING
WALL
PINION
RACK

Drawing of Final Assembly



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CHK'D								
APPV'D								
MFG								
Q.A.				MATERIAL:			DWG. NO. Final assembly	A3

Taking ABCD as the car frame,

N is the reaction from the speed bump on the front wheels.
N1 is the reaction from the ground.
Balancing net moment on car about CD we get

$$2*N*b=M*g*b/2*\cos(\beta)$$

$$2*N=M*G*\cos(\beta)/2$$

Now practically beta is very small approx to 5 to 10 degree eleven at the top of the bump.
So,

$$2*N=M*g/2$$

Now considering the FBD of speed bump

Here , $\theta h-\theta=\alpha$

Net Vertical force=$2N\cos(\theta h-\theta)$

$$\theta=\frac{Vt}{R}$$

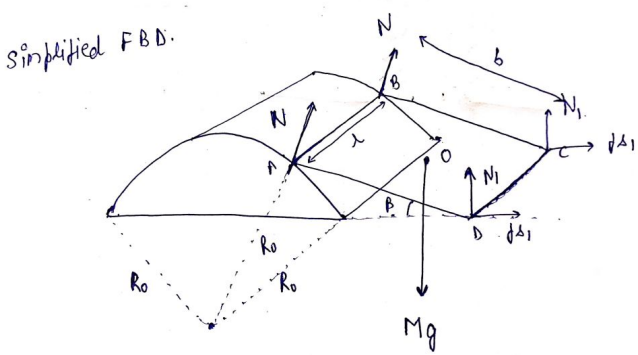
Here V is the speed of car or vehicle
R is the radius of curvature of the bump.

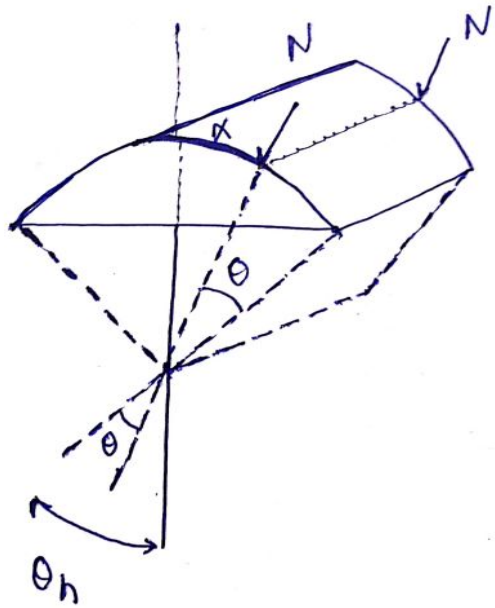
$$Fv=M*g*\cos(\theta h-\frac{Vt}{R})/2$$

So now we can write the equation of motion of a car or vehicle under these assumptions.
Now we can write equation of motion of speed bump under following loading conditions as

From Diagram,

$$\left(\quad Fv+mg-keq*x=m*\frac{d^2x}{dt^2} \right)$$





$$\left(\frac{Mg\cos(\theta h - \frac{Vt}{R}}{2} + mg - keq * x = m\frac{d^2x}{dt^2} \right)$$

Now since Rack is directly connected to the speed bump, the rack also gets displaced by distance x rotating the gear in contact.Assuming the radius of gear to be r1.

We can write $\left(r1 * \frac{d\phi}{dt} = \frac{dx}{dt} \right)$

Here $\frac{d\phi}{dt}$ is the angular velocity of the shaft.

Now the other end of the shaft also has gear connected with a third gear which runs the motor.

So we have ,

$$\frac{d\phi}{dt} * R_2 = \left(\frac{d\phi}{dt}\right)motor * R_3$$

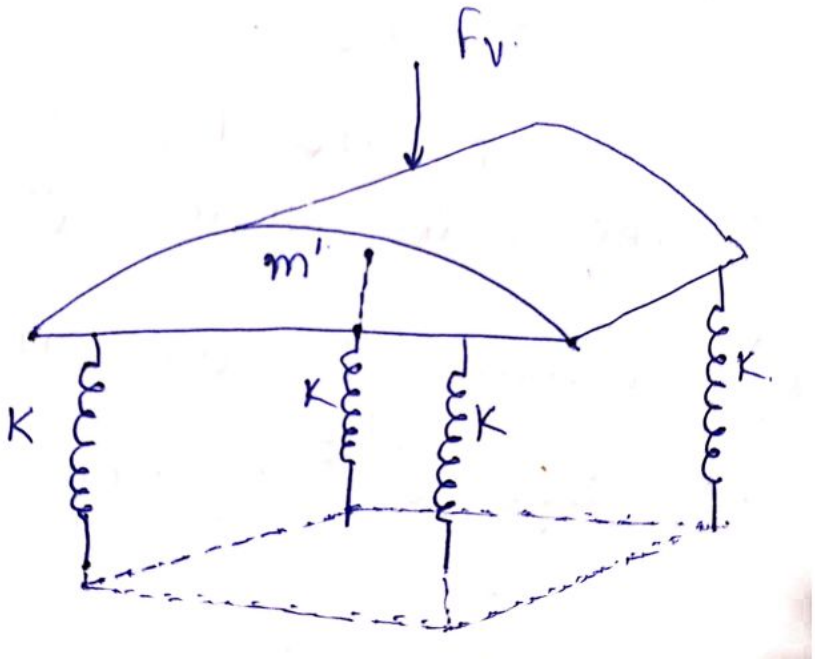
$$\left(\frac{d\phi}{dt}\right)motor = \frac{d\phi}{dt} * \frac{R_2}{R_3}$$

$$\left(\frac{d\phi}{dt}\right)motor = \frac{d\phi}{dt} * \frac{N_2}{N_3}$$

Here N_2 and N_3 are the teeths on the gear R_2 and R_3.

Hence by controlling $\frac{N_2}{N_3}$ we can have control over the angular velocity of the motor.

Now considering the simple circuit of motor
From Diagram,
During the intermediate stage,



Magnetic flux through the coil =B.dA

$\phi = B*ab\cos\delta$

Now according to faraday's law

$-\frac{d\phi}{dt} = emf = -B*ab*\frac{d\cos\delta}{\delta dt}*\frac{d\delta}{dt}$

$=B*ab*\sin\delta*\frac{d\delta}{dt}$

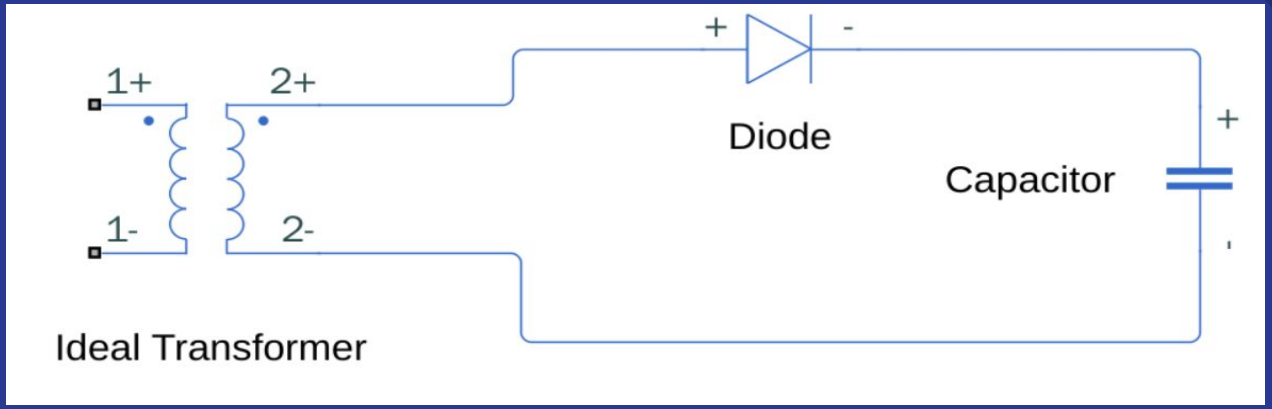
But $\frac{d\delta}{dt}$ is angular velocity of motor

$$\frac{d\delta}{dt} = \left(\frac{d\phi}{dt}\right)motor$$

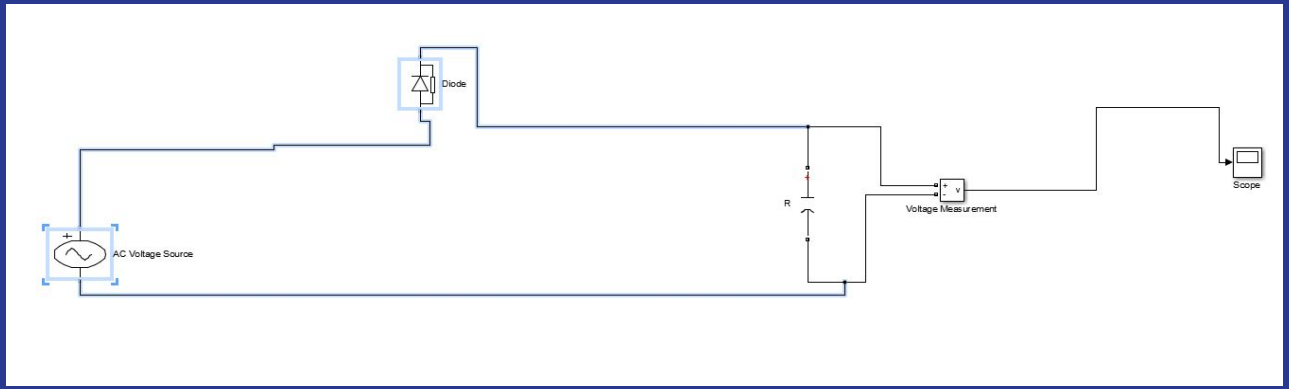
$emf = B*ab*\sin(\delta)*\left(\frac{d\phi}{dt}\right)motor$

Now this analysis was done considering single coil,assuming N number of turns

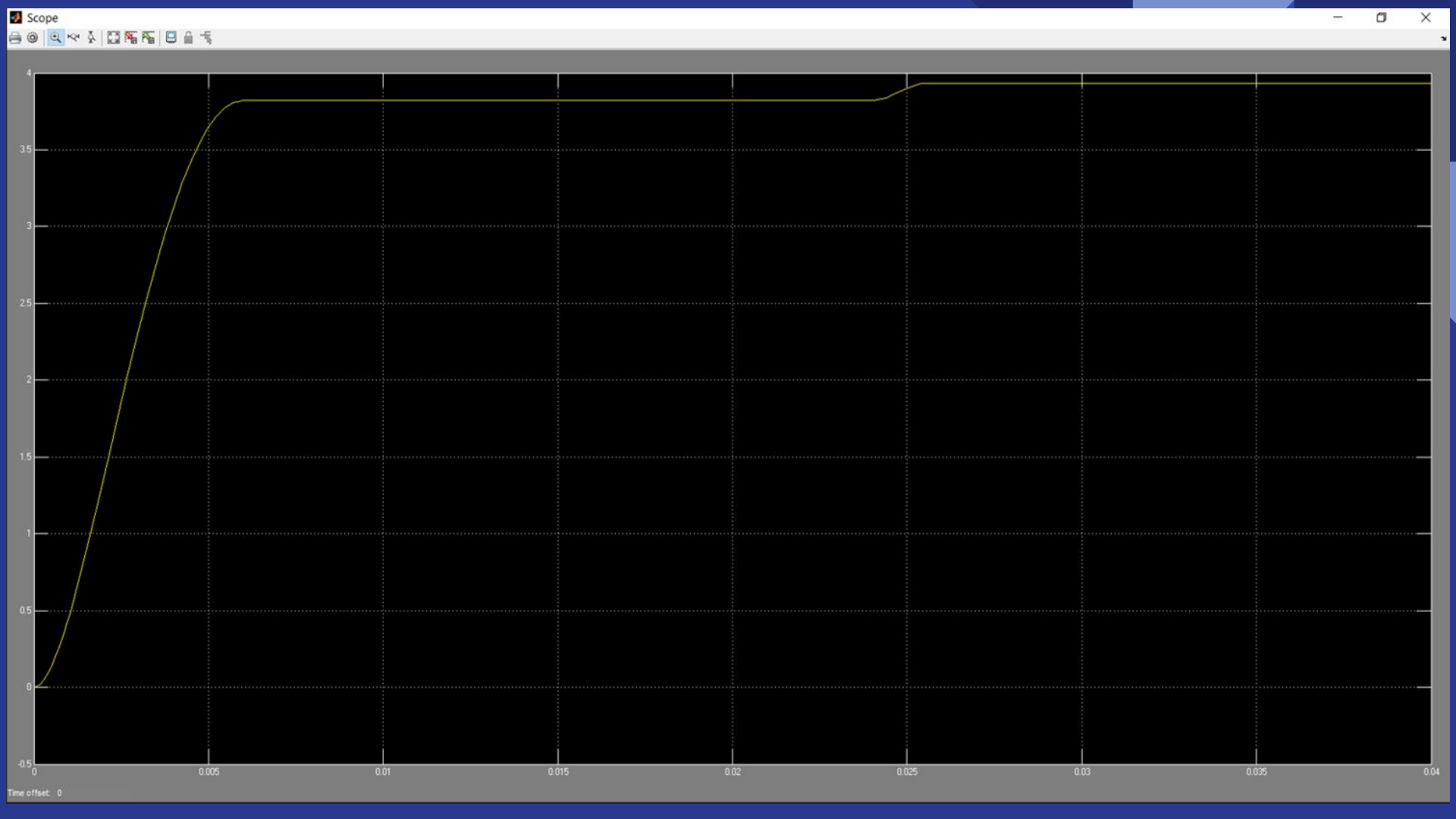
We get $emf = N*B*ab*\sin\delta*\left(\frac{d\phi}{dt}\right)motor$



Once the Capacitor attains the charge corresponding to the maximum voltage, the diode will no longer be forward biased and it will turn off for the remaining time and we obtain the peak value of input voltage as D.C voltage.



This is a Half wave rectifier Circuit. It is also known as the Ideal Peak detector Circuit. In the positive half cycle of the input voltage , the diode is forward biased and turns on because of which the capacitor starts following the input voltage and gets charged to the maximum value of the input voltage.


Scope
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Time offset: 0

Position vs Time

HOME PLOTS APPS EDITOR PUBLISH FILE VERSIONS VIEW

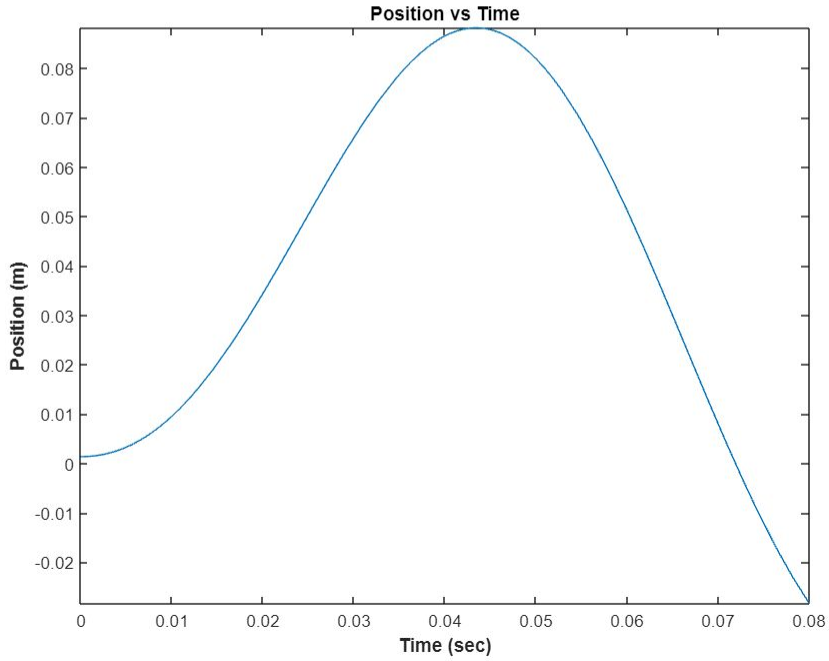
New Open Save — FILE
Go To Find Bookmark — NAVIGATE
Refactor — CODE
Run Section Section Break Run and Advance Run to End — SECTION
Run Step Stop — RUN

/ › MATLAB Drive ›

untitled.m

```
1  syms x(t)
2  Dx = diff(x,t) ;
3  D2x = diff(x,t,2) ;
4
5  m = 18 ;          % kg (Mass of bump)
6  M = 1300 ;        % kg (Mass of car) (Indian SUV / Sedan)
7  g = 9.81 ;        % m/s^2 (Acceleration due to gravity)
8  V = 5.556 ;       % m/s (Speed of car at approach)
9  R = 0.1625 ;      % m (Radius of bump)
10 Keq = 129295.8 ;  % N/m (Equivalent spring constant)
11 theta_h= (67.38*pi)/180 ;
12
13 ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;
14
15 cond1 = x(0) == (m*g)/Keq;
16 cond2 = Dx(0) == 0;
17
18 conds = [cond1 cond2];
19 uSol(t) = dsolve(ode,conds);
20 % display (uSol)
21 vel = diff(uSol,t);
22
23 figure(1);
24 fplot(uSol, [0,0.08]);
25 title('Position vs Time');
26 xlabel('Time (sec)', 'fontweight','bold');
27 ylabel('Position (m)', 'fontweight','bold');
28
29 figure(2);
30 fplot(vel, [0,0.08]);
31 title('Velocity vs Time');
32 xlabel('Time (sec)', 'fontweight', 'bold');
33 ylabel('Velocity (m/s)', 'fontweight', 'bold');
```

Figure 1 | Figure 2 | Figure 3 | Figure 4 | Figure 5



COMMAND WINDOW

UTF-8 CRLF script Ln 1 Col 1

Velocity vs Time

HOME PLOTS APPS FIGURE

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FILE TEXT STYLE LINE STYLE TOOLS FORMAT

/ › MATLAB Drive ›

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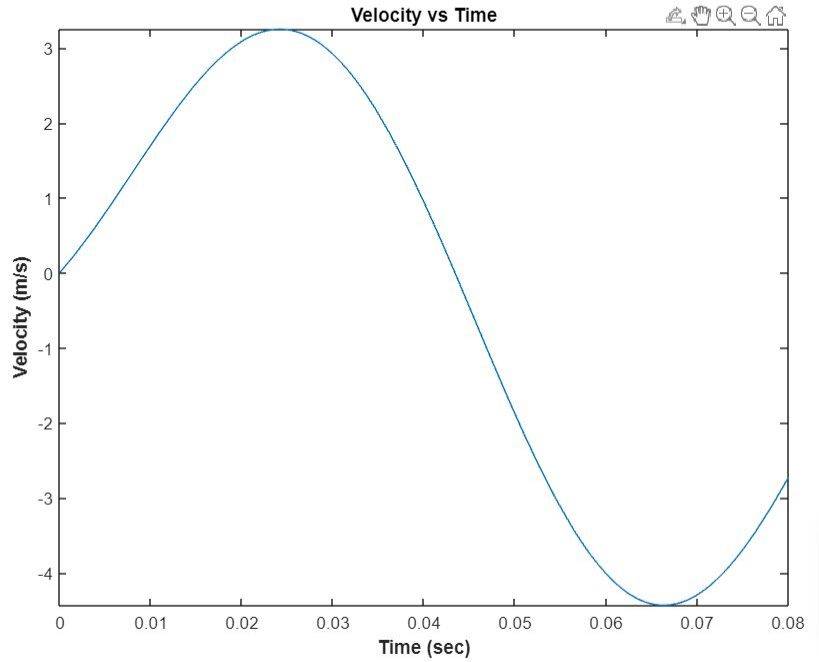
9   R = 0.1625 ;      % m (Radius of bump)
10  Keq = 129295.8 ;  % N/m (Equivalent spring constant)
11  theta_h= (67.38*pi)/180 ;
12
13  ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;
14
15  cond1 = x(0) == (m*g)/Keq;
16  cond2 = Dx(0) == 0;
17
18  conds = [cond1 cond2];
19  uSol(t) = dsolve(ode,conds);
20  % display (uSol)
21  vel = diff(uSol,t);
22
23  figure(1);
24  fplot(uSol, [0,0.08]);
25  title('Position vs Time');
26  xlabel('Time (sec)', 'fontweight','bold');
27  ylabel('Position (m)', 'fontweight','bold');
28
29  figure(2);
30  fplot(vel, [0,0.08]);
31  title('Velocity vs Time');
32  xlabel('Time (sec)', 'fontweight', 'bold');
33  ylabel('Velocity (m/s)', 'fontweight', 'bold');
```

Figure 1 | Figure 2 | Figure 3 | Figure 4 | Figure 5



COMMAND WINDOW

Omega of shaft vs Time

HOME PLOTS APPS FIGURE

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FILE TEXT STYLE LINE STYLE TOOLS FORMAT

/ › MATLAB Drive ›

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V = 5.556 ;       % m/s (Speed of car at approach)
R = 0.1625 ;      % m (Radius of bump)
Keq = 129295.8 ;  % N/m (Equivalent spring constant)
theta_h= (67.38*pi)/180 ;

ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;

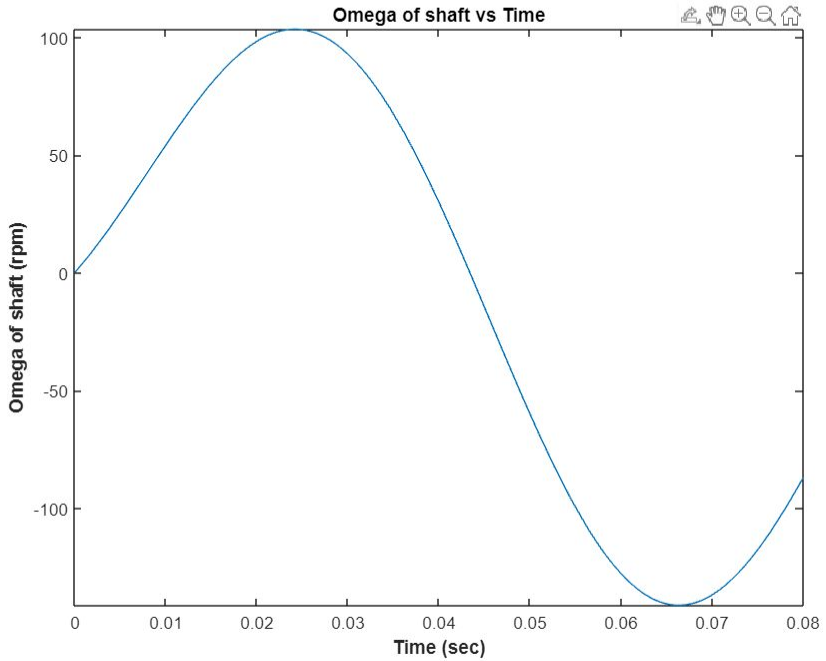
cond1 = x(0) == (m*g)/Keq;
cond2 = Dx(0) == 0;

conds = [cond1 cond2];
uSol(t) = dsolve(ode,conds);
% display (uSol)
vel = diff(uSol,t);

figure(1);
fplot(uSol, [0,0.08]);
title('Position vs Time');
xlabel('Time (sec)', 'fontweight','bold');
ylabel('Position (m)', 'fontweight','bold');

figure(2);
fplot(vel, [0,0.08]);
title('Velocity vs Time');
xlabel('Time (sec)', 'fontweight', 'bold');
ylabel('Velocity (m/s)', 'fontweight', 'bold');
```

Figure 1 | Figure 2 | Figure 3 | Figure 4 | Figure 5



COMMAND WINDOW

Omega(Dynamo) vs Time

HOME PLOTS APPS FIGURE

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FILE TEXT STYLE LINE STYLE TOOLS FORMAT

/ › MATLAB Drive ›

untitled.m

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V = 5.556 ;       % m/s (Speed of car at approach)
R = 0.1625 ;      % m (Radius of bump)
Keq = 129295.8 ;  % N/m (Equivalent spring constant)
theta_h= (67.38*pi)/180 ;

ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;

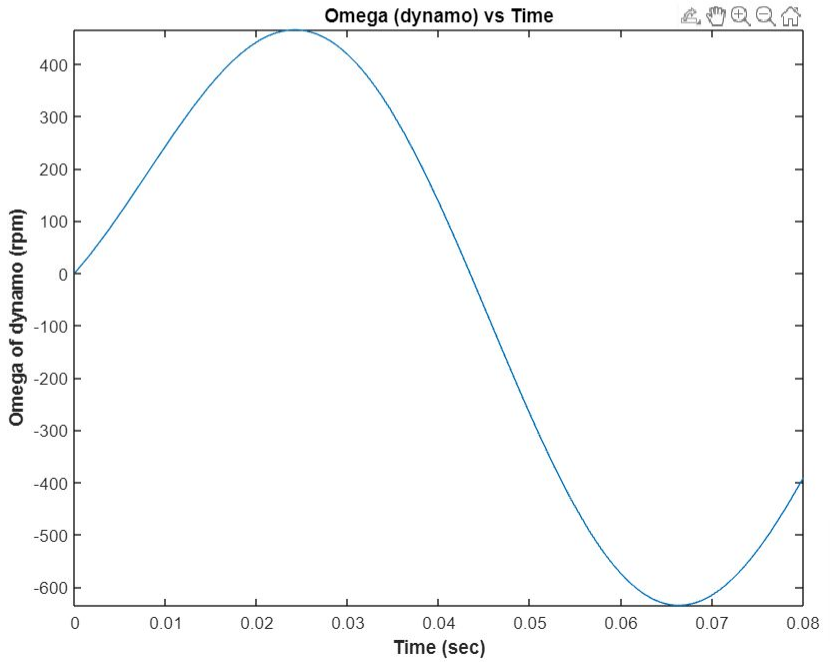
cond1 = x(0) == (m*g)/Keq;
cond2 = Dx(0) == 0;

conds = [cond1 cond2];
uSol(t) = dsolve(ode,conds);
% display (uSol)
vel = diff(uSol,t);

figure(1);
fplot(uSol, [0,0.08]);
title('Position vs Time');
xlabel('Time (sec)', 'fontweight','bold');
ylabel('Position (m)', 'fontweight','bold');

figure(2);
fplot(vel, [0,0.08]);
title('Velocity vs Time');
xlabel('Time (sec)', 'fontweight', 'bold');
ylabel('Velocity (m/s)', 'fontweight', 'bold');
```

Figure 1 | Figure 2 | Figure 3 | Figure 4 | Figure 5



COMMAND WINDOW

Generated EMF vs Time

HOME PLOTS APPS FIGURE

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/ › MATLAB Drive ›

untitled.m

```
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V = 5.556 ;       % m/s (Speed of car at approach)
R = 0.1625 ;      % m (Radius of bump)
Keq = 129295.8 ;  % N/m (Equivalent spring constant)
theta_h= (67.38*pi)/180 ;

ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;

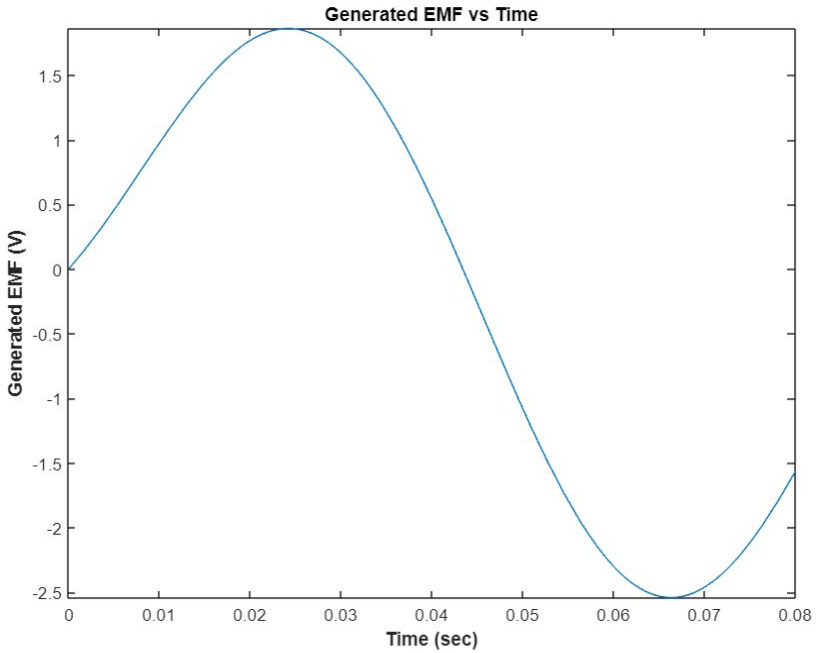
cond1 = x(0) == (m*g)/Keq;
cond2 = Dx(0) == 0;

conds = [cond1 cond2];
uSol(t) = dsolve(ode,conds);
% display (uSol)
vel = diff(uSol,t);

figure(1);
fplot(uSol, [0,0.08]);
title('Position vs Time');
xlabel('Time (sec)', 'fontweight','bold');
ylabel('Position (m)', 'fontweight','bold');

figure(2);
fplot(vel, [0,0.08]);
title('Velocity vs Time');
xlabel('Time (sec)', 'fontweight', 'bold');
ylabel('Velocity (m/s)', 'fontweight', 'bold');
```

Figure 1 | Figure 2 | Figure 3 | Figure 4 | Figure 5



CURRENT FOLDER | WORKSPACE | COMMAND WINDOW

Stepped up EMF vs Time

```
syms x(t)
Dx = diff(x,t) ;
D2x = diff(x,t,2) ;

m = 18 ;           % kg (Mass of bump)
M = 1300 ;         % kg (Mass of car) (Indian SUV / Sedan)
g = 9.81 ;         % m/s^2 (Acceleration due to gravity)
V = 5.556 ;        % m/s (Speed of car at approach)
R = 0.1625 ;       % m (Radius of bump)
Keq = 129295.8 ;   % N/m (Equivalent spring constant)
theta_h= (67.38*pi)/180 ;
Ns = 45;           % Number of secondary coil turns in transformer
Np = 15;           % Number of primary coil turns in transformer

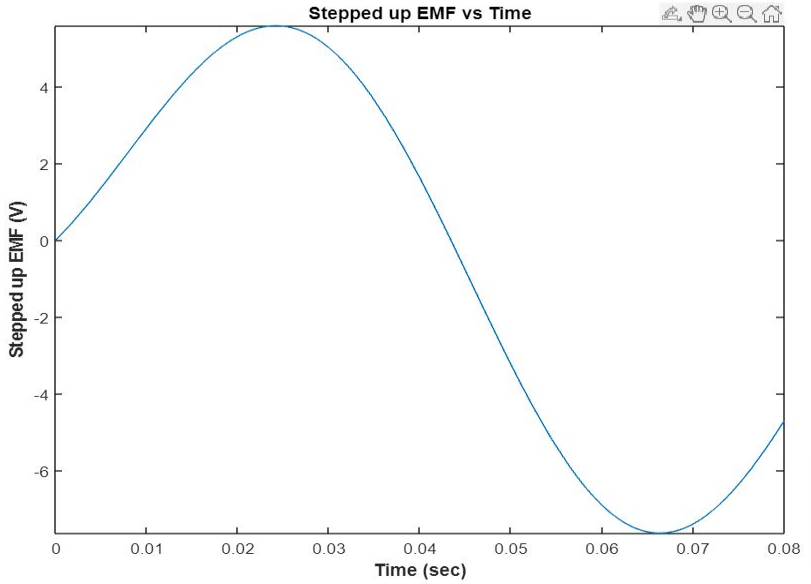
ode = (m)*diff(x,t,2) == (M*g)/2*cos(theta_h-(V*t)/R) + m*g - Keq*x ;

cond1 = x(0) == (m*g)/Keq;
cond2 = Dx(0) == 0;

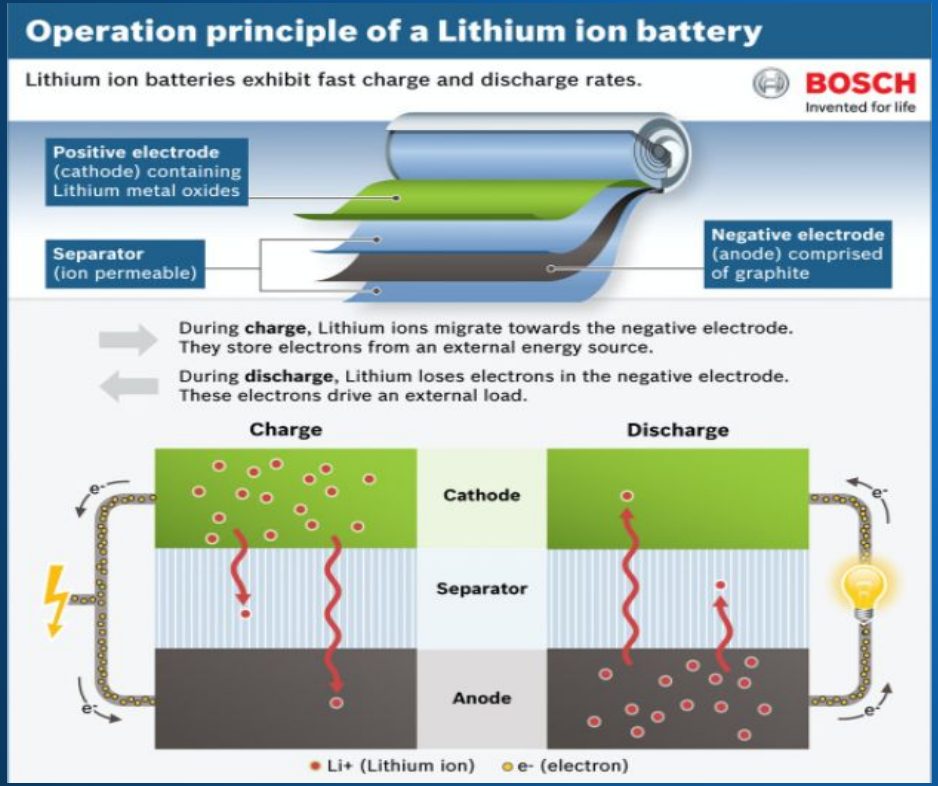
conds = [cond1 cond2];
uSol(t) = dsolve(ode,conds);
% display (uSol)
vel = diff(uSol,t);

figure(1);
fplot(uSol, [0,0.08]);
title('Position vs Time');
xlabel('Time (sec)', 'fontweight','bold');
ylabel('Position (m)', 'fontweight','bold');

figure(2);
fplot(vel, [0,0.08]);
title('Velocity vs Time');
```



Energy storage



- The positive electrode is typically made from a chemical compound called lithium-cobalt oxide (LiCoO2) or lithium iron phosphate (LiFePO4), negative electrode is generally made from carbon (graphite).
- The electrolyte is a lithium salt in an organic solvent.

Benefits over usual battery

	Lithium-ion battery	Lead-acid battery
Average cost per kWh of capacity	$137	$100-300
Specific energy (W.h/kg)	120-260	35-40
Materials	Scarce	Toxic
Direct current round trip efficiency (%)	85-95	70-90
Self discharge	Negligible	High

Energy Storage

- We are using a rechargeable lithium-ion battery consisting of power-generating compartments i.e. cells having three components - electrolyte, positive and negative electrode.
- The positive electrode is typically made from a chemical compound called lithium-cobalt oxide ($LiCoO_2$) or lithium iron phosphate ($LiFePO_4$), negative electrode is generally made from carbon (graphite).
- The electrolyte is a lithium salt in an organic solvent. Non-aqueous electrolyte is typically used, and a sealed container rigidly excludes moisture from the battery pack.
- The non-aqueous electrolyte is typically a mixture of organic carbonates such as ethylene carbonate or diethyl carbonate.

Energy Storage

- The salt is almost always lithium hexafluorophosphate (LiPF6), which combines good ionic conductivity with chemical and electrochemical stability.
- Energy density and power density are some of the parameters measuring watt-hours per kilogram and the amount of energy the battery can store with respect to its mass respectively.
- Lithium-ion batteries have several advantages over competing battery technologies. Compared to lead acid batteries, current lithium-ion batteries although having higher cost, the advantages outweigh the cost, such as better safety characteristics, higher energy density and power delivery characteristics.
- If, in addition to cost improvements, the energy density is increased, the batteries could be used for electric vehicles and power tools, and essentially any other application.

Practical Scope

- This project has wide ranging applications especially with the rising popularity of Electric Vehicles. The electricity shortage in India is rising day by day, along with the ever rising population. Also, usually, the location of speed breakers is near a populated area/ school/ village etc.
- Hence, the transportation will be for a very short distance which will ultimately lead to very less power loss. The generated energy can be used in various ways, some of which include a simple charging booth for travelers to charge their electric vehicles.
- This will also promote the usage of Evs in India, because the people now are hesitant to buy the cars for lack of widespread charging ports. Also, the places near settlements can be provided with electricity for light usage. Thus, summing things in short, this project has a vision to utilize the currently untapped energy and make this world a cleaner and greener place.

Thank You