GROUP T

SSV PART -1

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Contents:

1. The characteristics of the solar panel:

1.1 Solar panel

The Solar panel is the main source of our solar car and it will produce the current needed for the DC motor. Having a basic knowledge in understanding the uses of the solar panel helps to design a most efficient solar car. So we cannot be able to measure the behavior of the solar panel during the racing condition, so we just calculate the value of 'm' (diode factor) of solar panel in order to understand how it will perform.

Steps of procedure to calculate the m value:

We connected the solar panel to a voltmeter and an ammeter with a variable resistance, we placed our solar panel against a fixed lamp and adjusted the resistance (load)

An ideal solar cell model is been illustrated in figure 1.

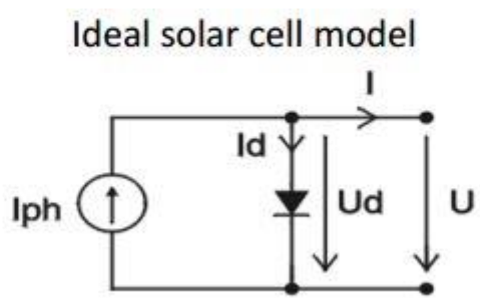


Figure 1

The following formula relates to an ideal solar panel that is an abbreviation of relativity:

$$I = Iph - Is(e^{\frac{U}{m*Ur}} - 1)$$

Iph – photocurrent

Is – reverse saturation current (A)

U – Diode voltage (V)

UT – thermal voltage (V)

m – Diode factor

When taking the solar panel and parallel resistance RS and RP the circuit that represents the real solar cell model shown in figure 2 is received

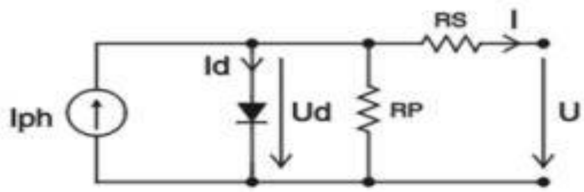


Figure 2: real solar panel circuit

The next formula represents the real solar panel circuit:

$$I = Isc - Is(e^{\frac{U}{m*N*Ur}} - 1)$$

I_{sc} – short circuit current (A)
I_s – saturation current (A): 1x10-8 A/m2
U – Output voltage (V)
Ur – thermal voltage (V): 25,7mV at 25°C
Ur = k x T/e
k – Boltzmann constant: 1.38 x 10-23J/K
T – Temperature (K)
E – Charge of electron (V): 1.6 x 10-19As
m – Diode factor: range of (1 – 5)
N – Number of solar cells in series: 16

Almost all these values are already defined because they're the solar panel's properties. The other parameters need to be calculated, these parameters are: the short circuit current Isc and the diode factor m.

The first parameter that is calculated is the short circuit current Isc. Measuring the current with a multi-meter when the solar panel is short-circuited gives the proper value.

I_{sc} = 0.41 A

To measure the second parameter an external variable resister was put into the circuit, a potentiometer like in figure 3 which is shown below

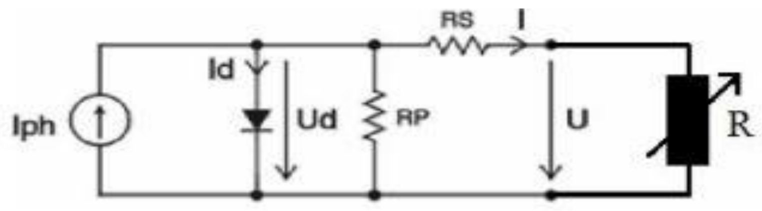


Figure 3: extensive circuit

With this circuit it is possible to measure the values of I and U for different values of the resistor. These different I and U values are plotted in a graph. Table 1 gives the values obtained with the experiment.

1.2) TABULAR REPRESENTATION OF EXPERIMENTAL VALUES:

TABLE:

Resistance (Ω)	Voltage(V)	Current (A)	Column4	m Values	Power(W)
96.88888889	8.72	0.09		1.229382208	0.7848
79.18181818	8.71	0.11		1.232738477	0.9581
66.92307692	8.7	0.13		1.239198453	1.131
54.0625	8.65	0.16		1.24098792	1.384
45.42105263	8.63	0.19		1.248411806	1.6397
39.04545455	8.59	0.22		1.269561004	1.8898
30.35714286	8.5	0.28		1.386015522	2.38
20.76923077	8.1	0.39		1.425820788	3.159
17.36585366	7.12	0.41		1.253314076	2.9192
16.65853659	6.83	0.41		1.202266171	2.8003
14.17073171	**5.81**	**0.41**		1.022718368	**2.3821**
10.97560976	4.5	0.41		0.79212266	1.845
9.292682927	3.81	0.41		0.670663852	1.5621
6.048780488	2.48	0.41		0.436547599	1.0168
1.609756098	0.66	0.41		0.091439748	0.2706
			AVERAGE	1.049412577	

Table 1: MEASURMENTS + CALCULATED VALUES

For each value of U and I the corresponding diode factor m is calculated with the formula of the real solar panel's circuit.

$$I = Isc - Is(e^{\frac{U}{m*N*Ur}} - 1)$$

By taking the average of the calculated values the overall value of the diode factor m is 1.0494. Figure 4 shows an example of an ideal voltage-current curve and power curve of the solar panel.

And we calculated the m value based on the formula below using known data

$$m = \frac{1}{N} * Ur * \ln(Isc - \frac{I}{Isc} + 1)/U$$

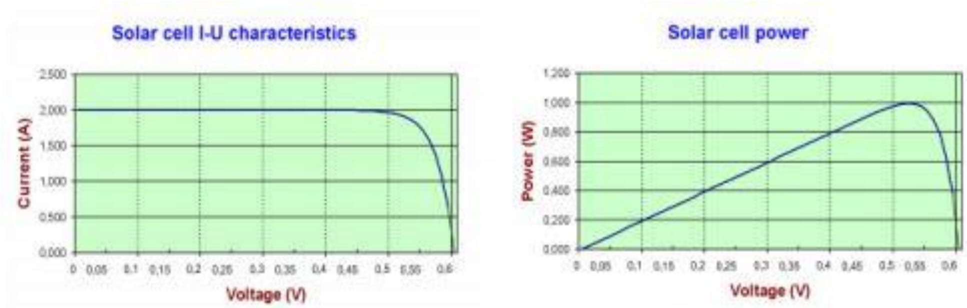


Figure 4: ideal graph for solar panel characteristics

Figure 5 and 6 show the graphs of the experimental measurements. The values aren't exactly the same as the ideal values due to systematic errors. The light source that provides power for the solar panel wasn't turned off between two measurements. This resulted in heating the solar panel which caused the value of Ur to increase and lower the current I and output voltage U.

1.3) GRAPHICAL Representation

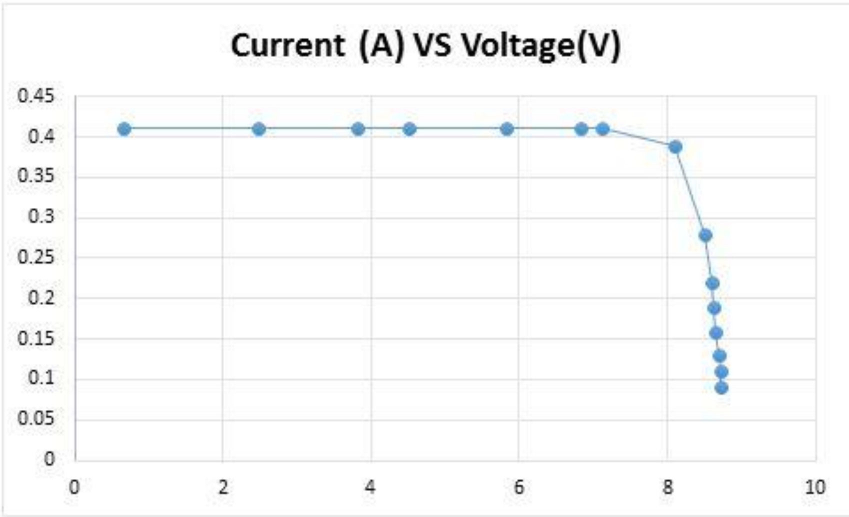


Figure 5: current VS voltage graph (measured values)

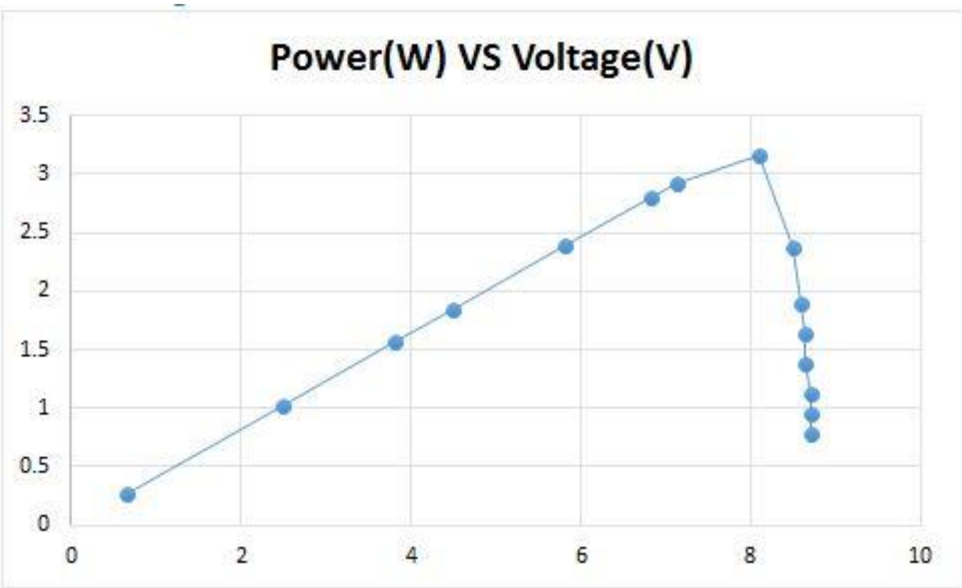


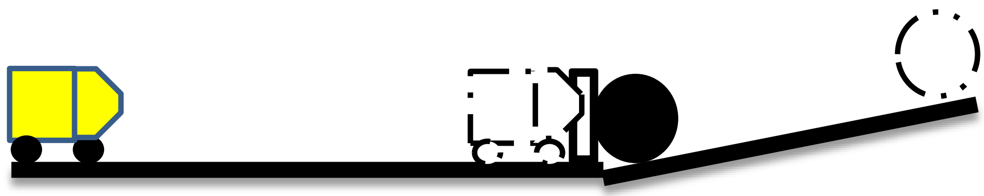
Figure 6: Power (W) VS Voltage (V)

2. Optimal Gear Ratio

2.1 Calculations

The behavior of SSV is simulated with 10 different gear ratios with 10 different masses and the data is tabulated below.

An efficient gear ratio could be found out using these plots with an efficient possible gears.



Race Track

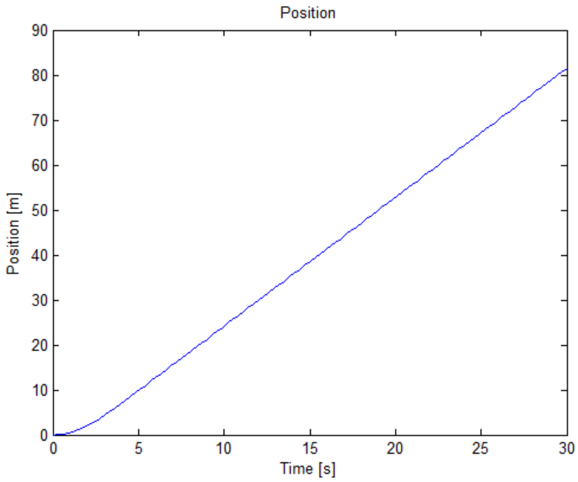
Table:

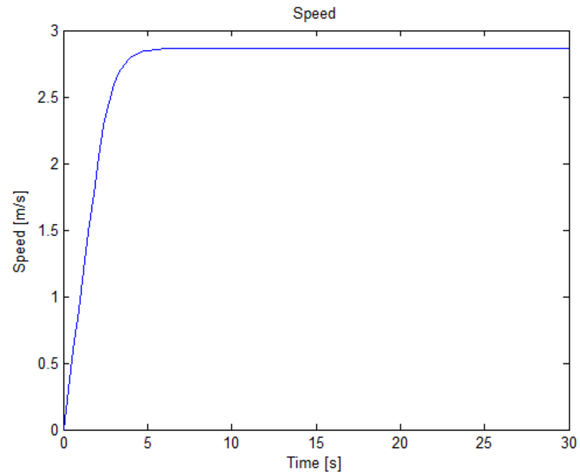
	Gear ratios	6	7	8	9	10	11	12	14	15	16
mass											
0.7		5.52	5.98	6.49	6.89	7.18	7.65	7.76	8.7	8.89	9.59
0.9		4.7	5.2	5.55	5.95	6.2	6.5	6.88	7.5	7.78	8
1		4.2	4.8	5.21	5.61	5.8	6.18	6.56	6.9	7.48	7.71
1.1		4.48	4.07	4.93	5.32	5.65	5.91	6.11	6.73	6.99	7.23
1.2				4.69	5.08	5.27	5.53	5.89	6.33	6.59	6.82
1.25				4.49	4.97	5.17	5.43	5.79	6.24	6.5	6.74
1.3				4.29	4.87	5.08	5.34	5.55	6.16	6.4	6.47
1.35					4.67	4.99	5.26	5.47	5.92	6.17	6.4
1.4					4.49	4.79	5.18	5.4	5.85	6.11	6.34
1.45					4.33	4.72	4.98	5.32	5.64	5.89	6.11
1.5					4.16	4.65	4.91	5.13	5.58	5.84	6.06
1.6						4.33	4.79	4.9	5.35	5.59	5.82

We choose gear ratio 12 and optimal mass of our SVV is 1.2kgs.

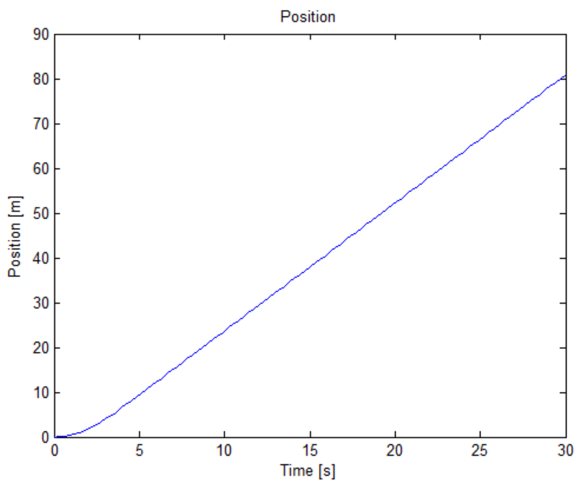
2.2 Displacement and Speed curves

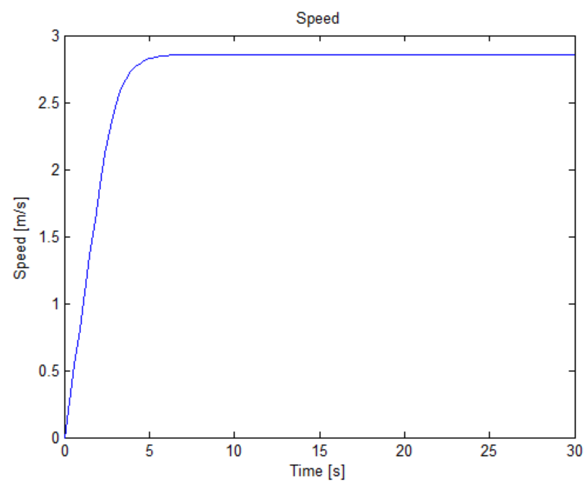
Gear Ratio 12 and 1.1kgs



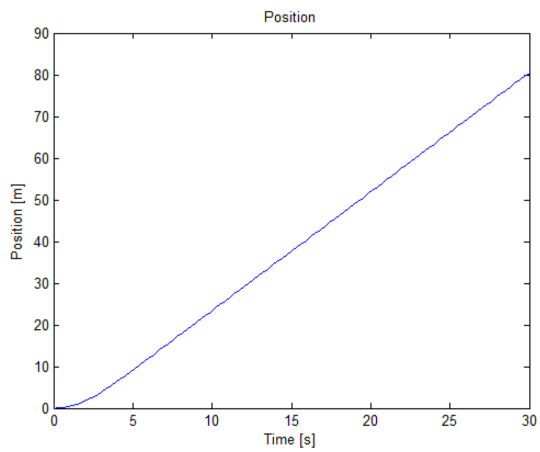


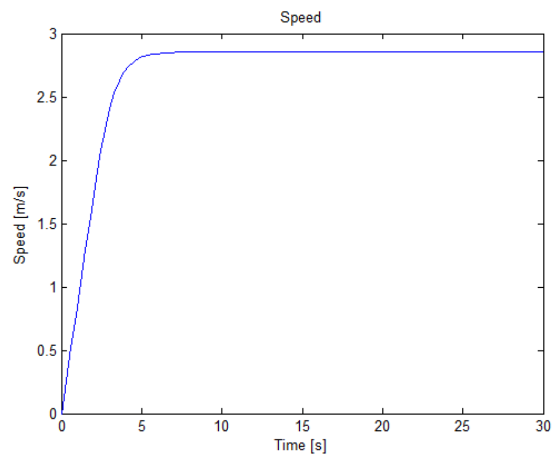
Gear Ratio 12 and 1.2 kgs



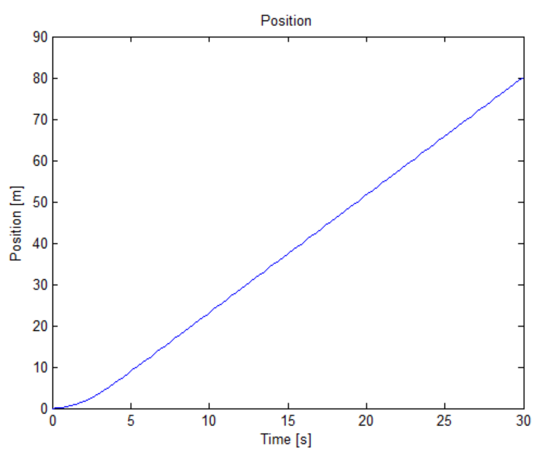


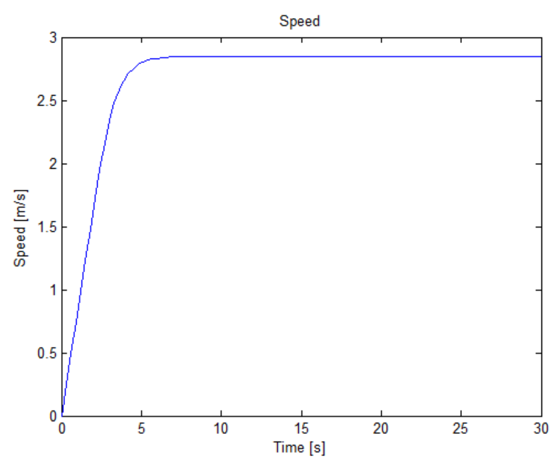
Gear Ratio 12 and 1.25 kgs



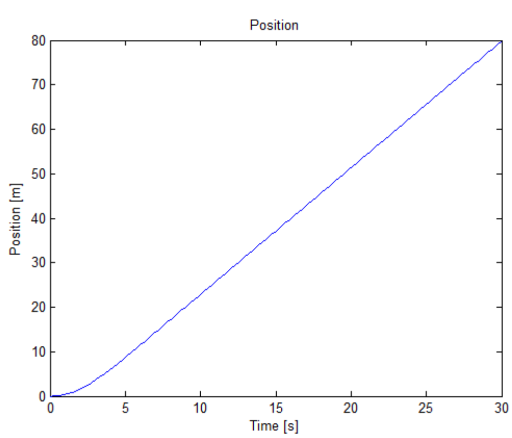


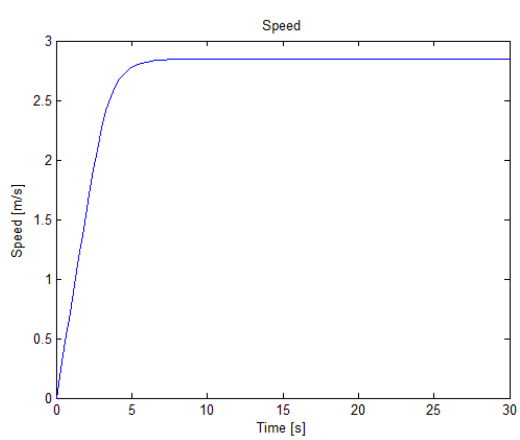
Gear Ratio 12 and 1.3 kgs



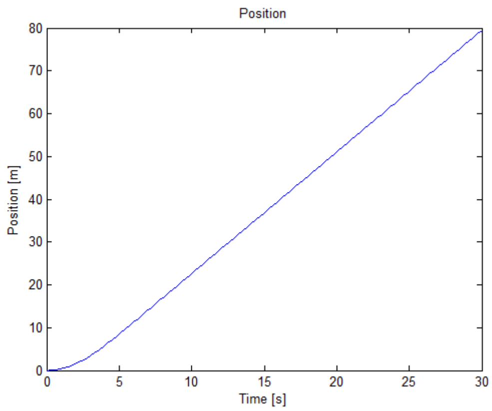


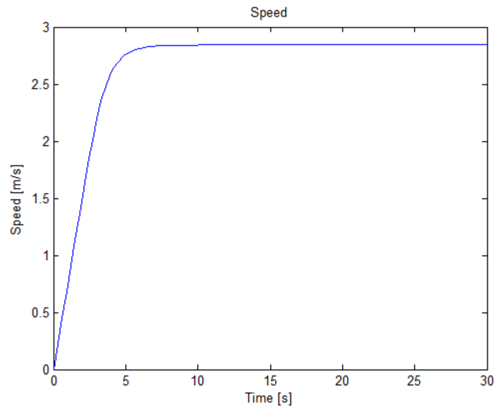
Gear Ratio 12 and 1.35kgs





Gear Ratio 12 and 1.4 kgs





3. Bisection Method

3.1. Idea:

Fact:

If f (x) is continuous on [a, b] and f (a) ∗ f (b) < 0, then there exists r such that f (r) = 0.

Idea:

The fact can be used to produce a sequence of ever-smaller intervals that each brackets a root of f (x) = 0:

Let c = (a + b)/2 (midpoint of [a, b]). Compute f (c).

- If f (c) = 0, c is a root.
- – If f (a)*f (c) < 0, a root exists in [a, c].
  – If f (c)*f (b) < 0, a root exists in [c, b].

In either case, the interval is half as long as the initial interval. The halving process can continue until the current interval is shorter than a given tolerance δ.

2. Algorithm

Algorithm. Given f , a, b and δ, and suppose f (a)f (b) < 0:

```
c ← (a + b)/2
error bound ← |b − a|/2
while error bound > δ
  - if f (c) = 0, then c is a root,
    stop. else
        if f (a)f (c) < 0, then
          b ← c
        else
          a ← c
        end
    end

    c ← (a + b)/2
    error bound ← error bound/2
end

root ← c
```

When implementing this algorithm, avoid recomputation of values of function, and use sign [f (a)] sign (f (c)] < 0 instead of f (a) f (c) < 0 to avoid overflow and underflow.

3. Problem:

Here's an example of how to use the bisection method for following function:

f(x) = 0.5*Sin(0.5*x)*esin(0.33*x)

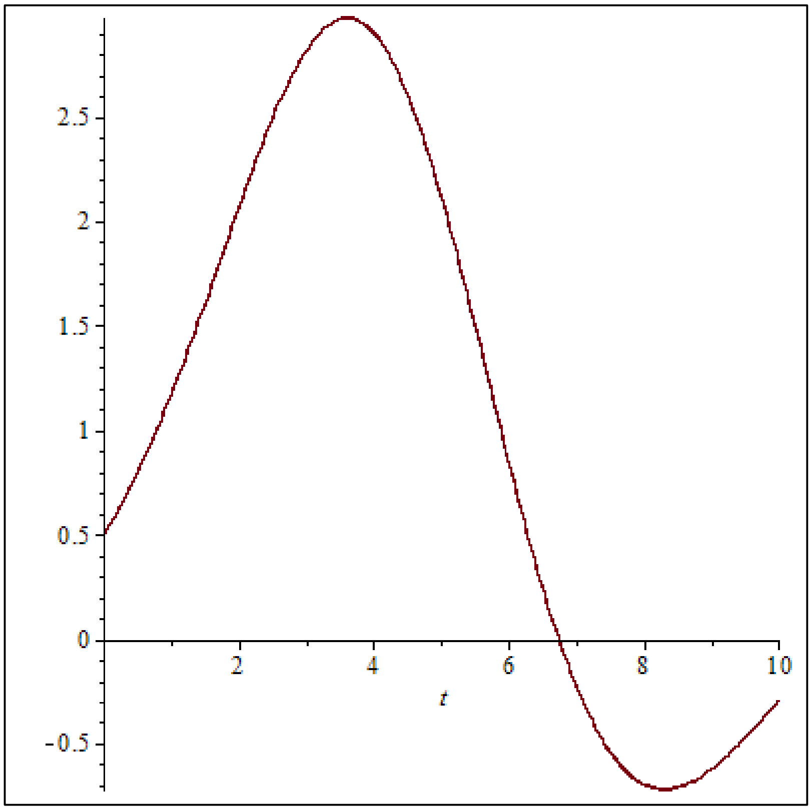


Figure: function f(x)

We have to find the root of this function for x-values between 0 and 10. To do this, we will evaluate the function at 5. For this function, y (5) equals 2.119362673. The function is descending so the value we search will be between 5 and 10. The next value we will calculate is7.5 because it is the average of 5 and 10.

When we look at the function value at 7.5 we can see that it is negative (0.53986265), so the zero we search will be between 7.5 and 5. We continued this method until we got about 4 zero digits. This should be reasonably accurate for most calculations.

Given function:

$$fx = \frac{1}{2} * \sin(\frac{1}{2}*x\ )*e^{\sin\left(\frac{1}{3}x\right)}$$

But $x = (0,10)$

$$=> \quad f0 = \frac{1}{2} * \sin(\frac{1}{2}*0)*\ e^{\sin\left(\frac{1}{3}*0\right)}$$

= 0

$$=> \quad f10 = \frac{1}{2} * \sin\left(\frac{1}{2} * 10\right) * e^{\sin\left(\frac{1}{3}*10\right)}$$

= 0.0461

Root will lies between '0' and '10'

Root= $\frac{0+10}{2} = 5$

Again

$$=> \ f5 = \frac{1}{2} * \sin\left(\frac{1}{2} * 5\right) * e^{\sin\left(\frac{1}{3}*5\right)}$$

= 2.119362673

$$=> \ f5 * f10 = 0.0461 * 2.119362673$$

= 0.0978196 $>$ 0

Function is descending. So, root lies between '5' and '10'.

Average = $\frac{5+10}{2} = 7{,}5$

Again

$$=> f7.5 = \frac{1}{2} * \sin\left(\frac{1}{2} * 7.5\right) * e^{\sin\left(\frac{1}{3}*7.5\right)}$$

= -0.5398626500

=>$f7.5 * f5 =$ (-0.5398626500)*(0.0461)

= -0.024887668165 < 0

So, root lies between '5' and '7.5'.

$$\text{Root} = \frac{5+7.5}{2} = 6.25$$

Again,

$$=> \quad f6.25 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.25\right) * e^{\sin\left(\frac{1}{3}*6.25\right)}$$

= 0.5396629439

$$=> f6.25 * f7.5 = (0.5396629439) * (-0.5398626500\ )$$

= -0.2913438670006553 < 0

So, root lies between '6.25' and '7.25'.

$$\text{Root} = \frac{6.25+7.5}{2} = 6.875$$

Again,

$$=> \quad f6.875 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.875\right) * e^{\sin\left(\frac{1}{3}*6.875\right)}$$

= -0.1180946389

$$=> f6.25 * f6.875 = (0.539662943) * (-0.1180946389\ )$$

= -0.0637313003812963<0

So, root lies between '6.25' and '6.875'.

$$\text{Root} = \frac{6.25+6.875}{2} = 6.5625$$

Again

$$=> \quad f6.5625 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.5625\right) * e^{\sin\left(\frac{1}{3}*6.5625\right)}$$

= 0.1852658234

$$=> f6.5625 * f6.875 = (0.1852658234) * (-0.1180946389\ )$$

= -0.0218789005149342<0

So, root lies between '6.5625' and '6.875'.

Root = $\frac{6.5625+6.875}{2} = 6.71875$

Again

$$=> \quad f6.71875 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.71875\right) * e^{\sin\left(\frac{1}{3}*6.71875\right)}$$

= 0.0264994375

$$=> f6.71875 * f6.875 = (0.1852658234) * (-0.1180946389\,)$$

=-0.0218789005149342 < 0

So, root lies between '$6.71875'$ and '6.875'.

Root = $\frac{6.71875+6.875}{2} = 6.796875$

Again

$$=> \quad f6.796875 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.796875\right) * e^{\sin\left(\frac{1}{3}*6.796875\right)}$$

= -0.0476390705

$$=> f6.71875 * f6.796875 = (0.1852658234) * (\,-0.0476390705)$$

= -0.0088258916221931 <0

So, root lies between '$6.71875'$ and '$6.796875'$

Root = $\frac{6.71875+6.796875}{2} = 6.7578125$

Again

$$=> \quad f6.7578125 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.7578125\right) * e^{\sin\left(\frac{1}{3}*6.7578125\right)}$$

= -0.011022272

$$=> f6.71875 * f6.7578125 = (0.1852658234) * (-0.011022272)$$

= -0.0020420502978188< 0

So, root lies between '$6.71875'$ and '$6.7578125'$

$$\text{Root} = \frac{6.71875+6.7578125}{2} = 6.73828125$$

Again

$$=> \quad f6.73828125 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.73828125\right) * e^{\sin\left(\frac{1}{3}*6.73828125\right)}$$

= 0.0076265302

$$=> f6.73828125 * f6.7578125 = (0.0076265302) * (-0.011022272)$$

= -0.00008406169028 <0

So, root lies between '$6.73828125'$ and '$6.7578125'$

$$\text{Root} = \frac{6.73828125+6.7578125}{2} = 6.748046875$$

Again

$$=> \quad f6.748046875 = \frac{1}{2} * \sin\left(\frac{1}{2} * 6.748046875\right) * e^{\sin\left(\frac{1}{3}*6.748046875\right)}$$

= -0.0017260214

Now this method is used to approximate the current of the solar panel while the acceleration is calculated with these equations:

$$a(t) = -gC_{rr} + \frac{I(t) \times E(t)}{M \times v(t)} - C_w A\rho \times \frac{v^2(t)}{2M}$$

$$E(t) = K_e \times \omega = C_e \times \varphi \times 60 \times v(t) \times \frac{gear\ ratio}{2\pi r}$$

$$I(t) = I_{sc} - I_s \left(e^{\frac{E(t)+I(t)R}{m*N*U_r}} - 1 \right)$$

This last equation is the one where the bisection method is needed. It isn't possible to simplify the equation where I(t) equals a constant. Instead, a function f (I(t)) is created and equalized with zero.

4. Assumptions:

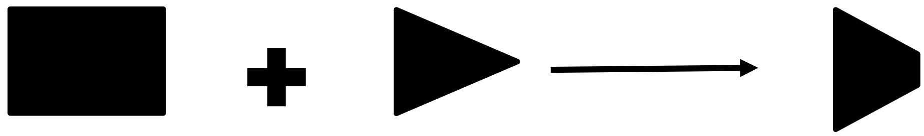
- ***Assumptions in Solar Panel,*** It is assumed that the solar panel produces a peak Open circuit voltage of 9.6 V while the short circuit current being 1.03 Amp. It is also assumed that the peak power output is 7.5 Watts. It is not constant as the power generated from the solar panel is dependent on the intensity of the incoming sunlight.

E = A * r * H * PR

E = Energy from solar panel
A = Area of solar panel
H = Solar radiation (kW/mt^2)

Form this equation it is clear that the energy output from the solar panel is directly proportional to the Solar Radiation (Intensity of sunlight).

- ***Assumptions in skeletal structure,*** the drag coefficient of the SSV depends the shape of the solar car. Our conceptual model has a structural shape like :

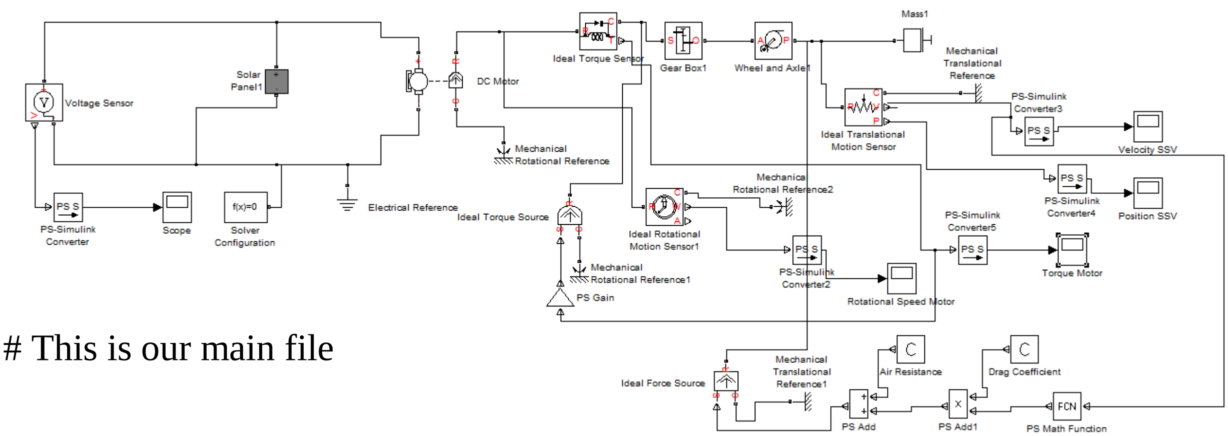


- ***Assumption in radius of gear,*** The radius of the gear is assumed to be 40 mm in diameter (20 mm in radius) as it has no negative effects on the design of SSV
.
- ***Assuming the optimal Gear ratio,*** for this SSV we consider the Optimal Gear ratio as '6' because the speed is controllable (125.4 mts/sec) and the race time is also low 0.07974 sec. If a high gear ratio gives a less race time but provides an uncontrollable speed and it also increases the size the gear which is inconvenient in the design of SSV.

Assumptions	Assumed Value
Power output from Solar Panel	7.5 Watts
Drag Coefficient of SSV	0.75
Radius of Gear	20 mm.
Optimal Gear Ratio	6
Approximations	Assumed Value
Acceleration due to Gravity	10 mts/sec^2
Pi Value	3.14

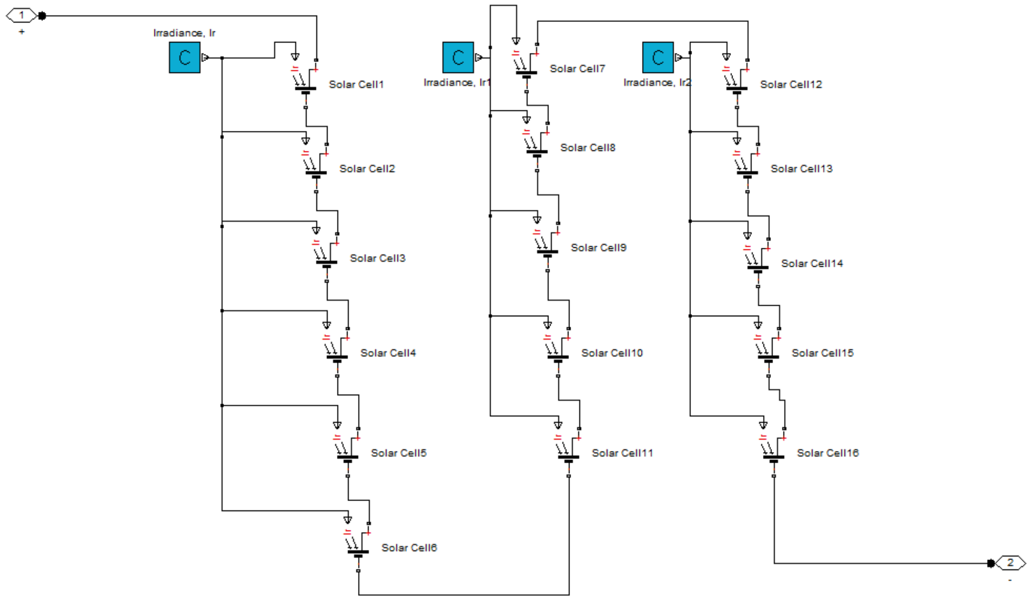
Case Simulink :

To make our car runs more faster and in higher efficiency, we simulate our in the software "MATLAB 2010"
In the circuit, we make the electrical part on the left, the mechanical mart one the right. Between is the "bridge"-- DC motor.



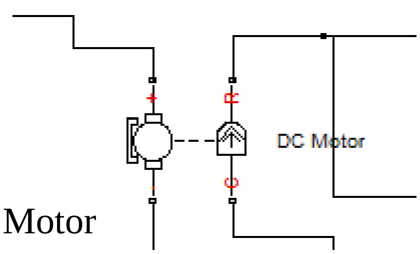
This is our main file

The first part is the Solar Panel. The solar panel is the combination of 16 solar sell that connected in series.
Here is the parameter that we calculated measured and will be used during the simulation.
Short-circuit current, Isc: 0.9 A
Open-circuit voltage, Voc: 9.6 V
Irradiance used for measurements, Ir0: 800 W/m^2
Quality factor, N: 1.05



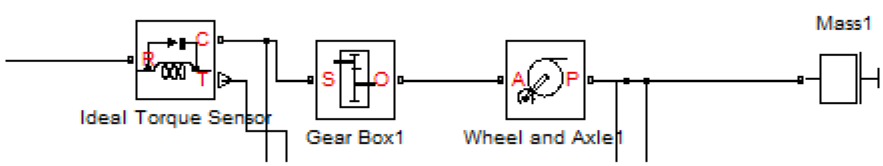
16 Solar Cells Connected in Series

The second important part is the "bridge" DC motor, which is connected in parallel with the solar panel. Here is the parameter that will be used inside the DC Motor.
Armature resistance: 3.32 Ohm
Armature inductance: 0.22 mH
Back-emf constant: 0.000893 V/rpm
Rotor inertia: 4.10 g*cm^2
Rotor damping: 1e-08 N*m/(rad/s)
Initial rotor speed: 0 rpm



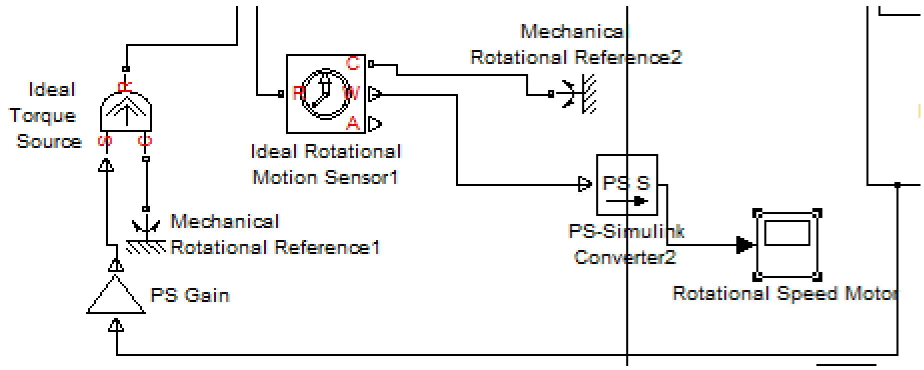
DC Motor

The third part is the gearbox, axel and wheel and the mass.
When simulation, the following parameter will be used.
Gear ratio: 6
Wheel radius: 0.04 m
Mass: 1.2kg

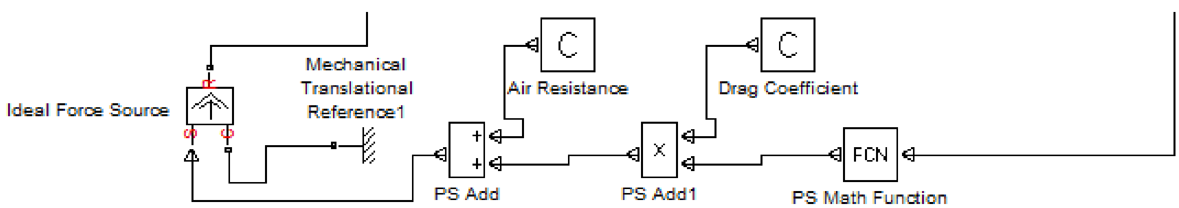


There are of course some loses in the motor. So we add a gain to reduce the torque -20%

Gain:



The fourth part is the different force in Different situation. Of course that there is no force when the car stands still. The force is as follows.
Rolling resistance, Crr: 0.012 N
Air resistance, Cw: 0.5

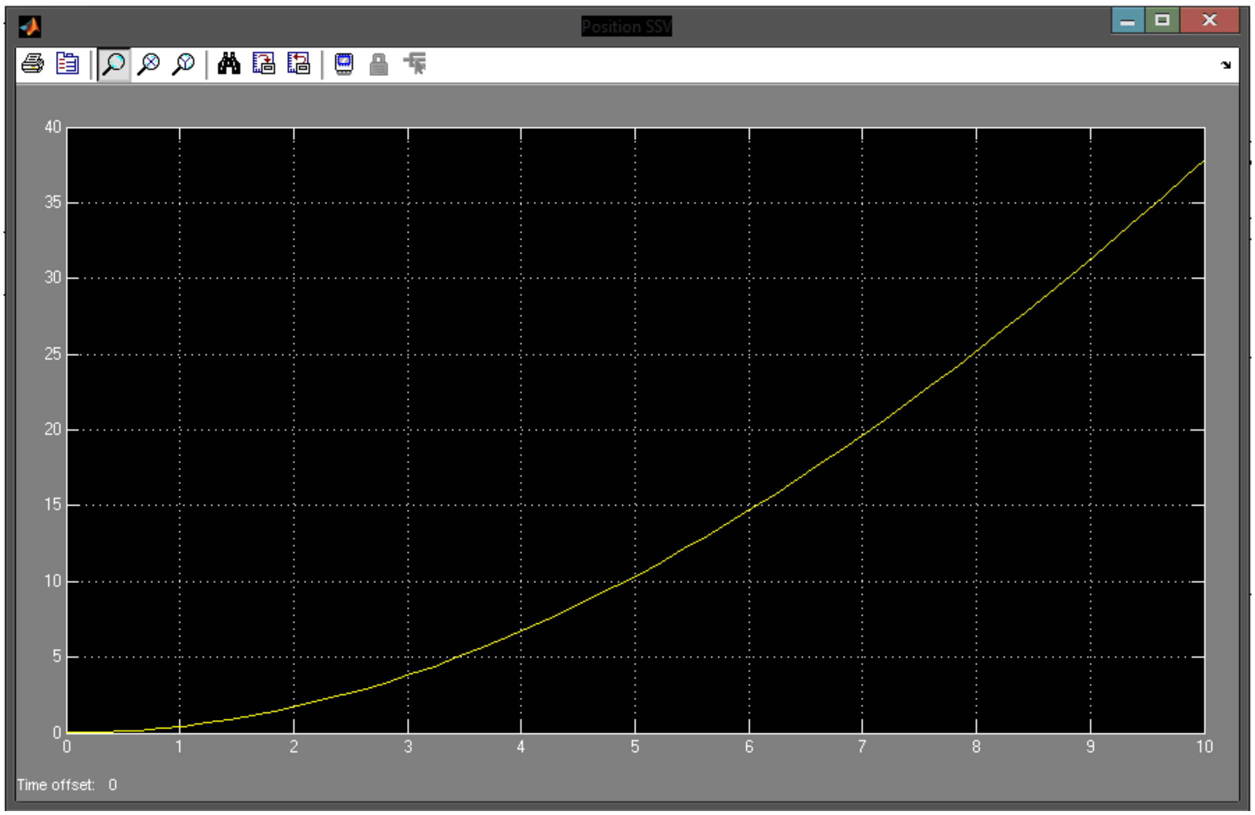


Ideal Forces

Here are the simulation result:

1. Displacement:

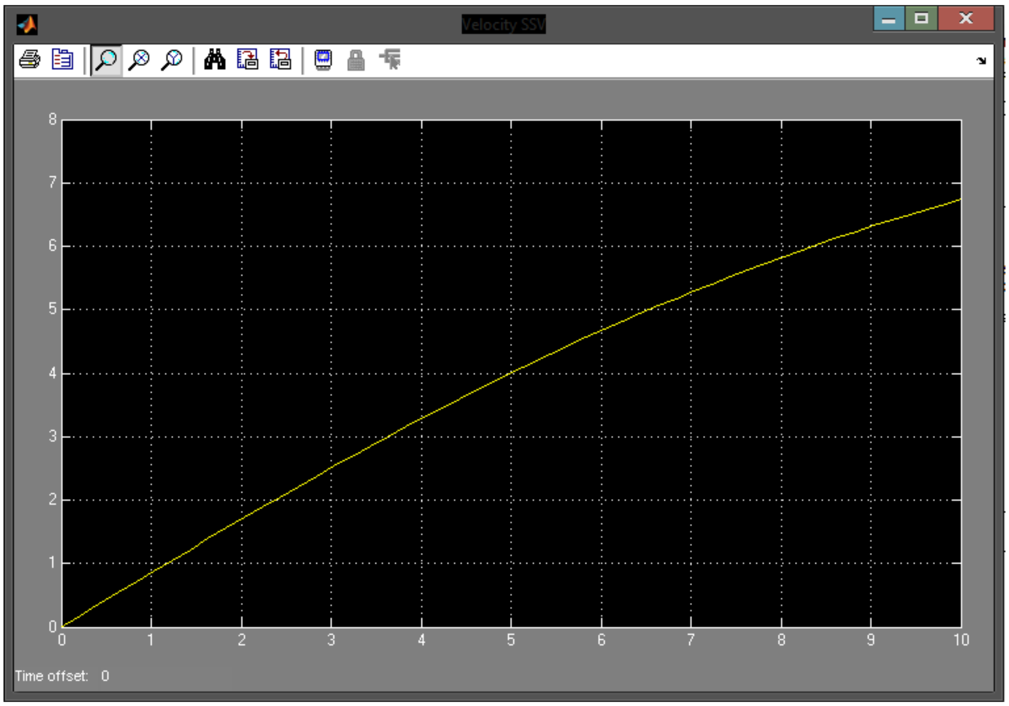
The displacement will first be increased with a curve. The car Stops after it hits the ball. Our car will reach the ball around 5 sec.



Displacement Graph

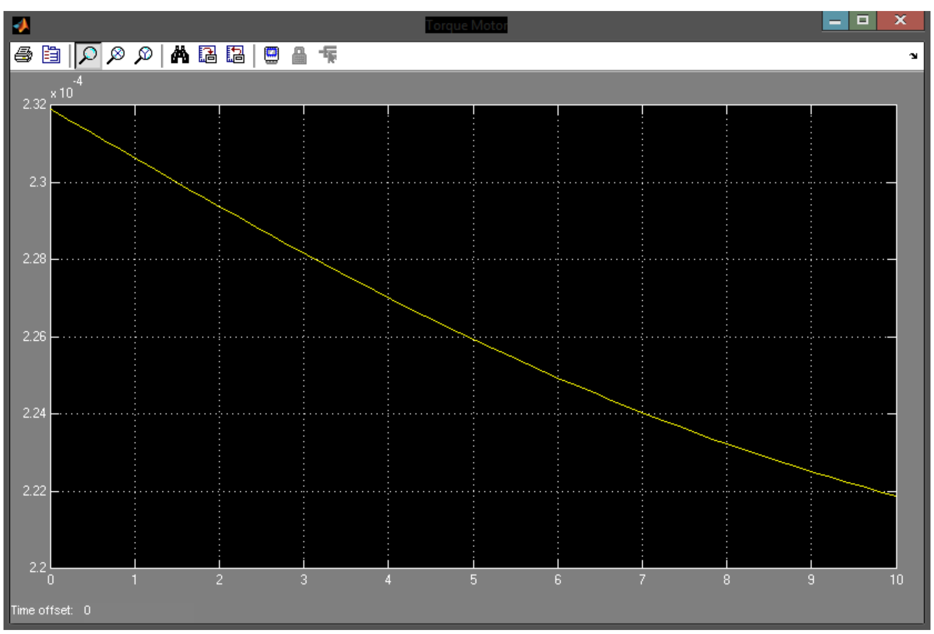
2. Velocity:

The velocity will increase until the vehicle reaches the ball. At the point, that means the vehicle hits the ball, the speed is around 4m/s.



Velocity Graph

3. Torque:

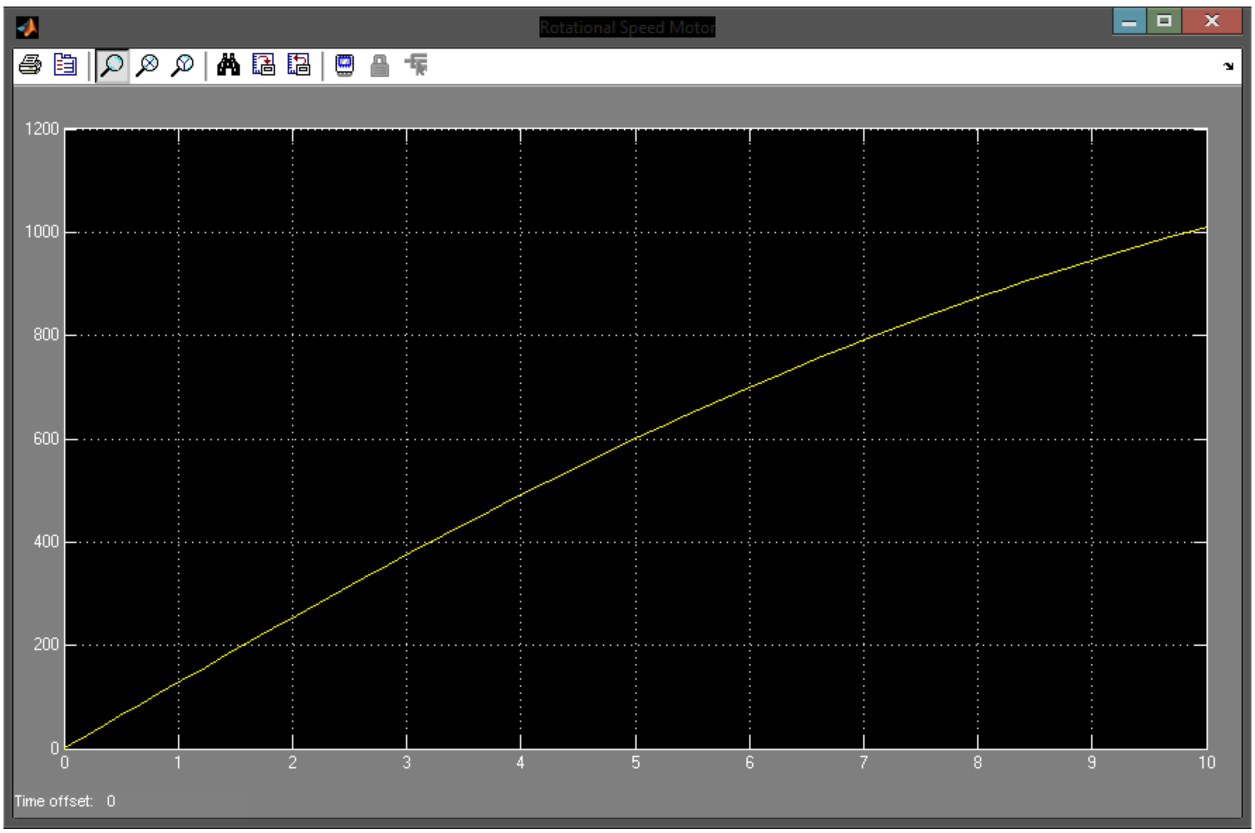


#Torque Graph

The torque will increase immediately when the current goes through the DC motor. And with the speed increases, the torque will decrease. After hitting the ball, the speed will keep 4m/s, also the torque will keep a constant value.

4. Motor Rotational Speed:

Rotation of the DC motor will increase until reach the break point. As soon as our car reach the ball, the rotational speed will keep around 600 rad/s, which is the max rotational speed.



#Rotational Speed Graph