ENGINEERING EXPERIENCE 4

PM14: Team Members

(Team leader)Praveen Saragadam

Surendra Botu

Sanjay Kandukuri

Anjali Nedunuri

Anoop Nuka

Chaitanya Keta

SSV Case I Report

1) Introduction:

In Engineering experience 4 we have to build a solar car, which can travel in a 10m race track and then hits a pétanque ball which weights 750g approximately. And the ball has to travel on the inclined plan. Moreover the movement of the car must be powered exclusively by the solar energy produced instantly by the solar panel consisting of 16 solar cells.

The race will cover a distance of 10 straight meters starting followed by a inclined slope, with an elevation. The solar car needs to use the solar energy efficiently and properly to remain stable during the drive. Given all the limitations we must be able to make our car produce the maximum power necessary to cover the given distance as fast as possible and hit the ball with maximum force so that it travels, up the inclined plane. The power used to propel the car should exclusively come from the solar panel. It must be ensured that the car has an optimal transmission ratio over the whole race; that the weight of the car is kept low and air and rolling resistance are minimalized. To make this project a success the group worked hard and made every possible effort to be active, innovative, precise and organized. Every one contributed equally in working with the project. We did a rigorous calculation work to have an accurate and correct outcome. The more accurate the calculations the better the car will behave to our expectations once built. We expect a good solar car as the end result.

The Race:

The race track consists of a flat part of 10 meter. At the end of the track is a board against, which the SSV comes to a stop. Behind the board is a ramp on which a ball can roll upwards (Figure 1). The goal is to have the SSV hit the ball through an opening in the board, rolling it as high as possible. The opening through which the ball can be pushed is at least 25 cm wide, starts 6 cm above the track and has a height of 6 cm. The ball rests in the middle of the track with its centre at a height of 86±3 mm with respect to the track. The course is checked by the organizers and cannot be adapted by the candidates. The location is the 'Martelarenplein' (at the train station of Leuven). The track will be approximately parallel to the ring of Leuven, running from the monument in the direction of the 'Tiensepoort'. Rubber subsoil will be laid down on the track. Every vehicle acquires a track of 30-40 cm wide. At the sides of each track, wooden beams of approximately 8 cm high will be mounted. The track, including the wooden beams at the side, is at least 60cm longer than 10m to enable the SSV's to be positioned entirely before the start line.

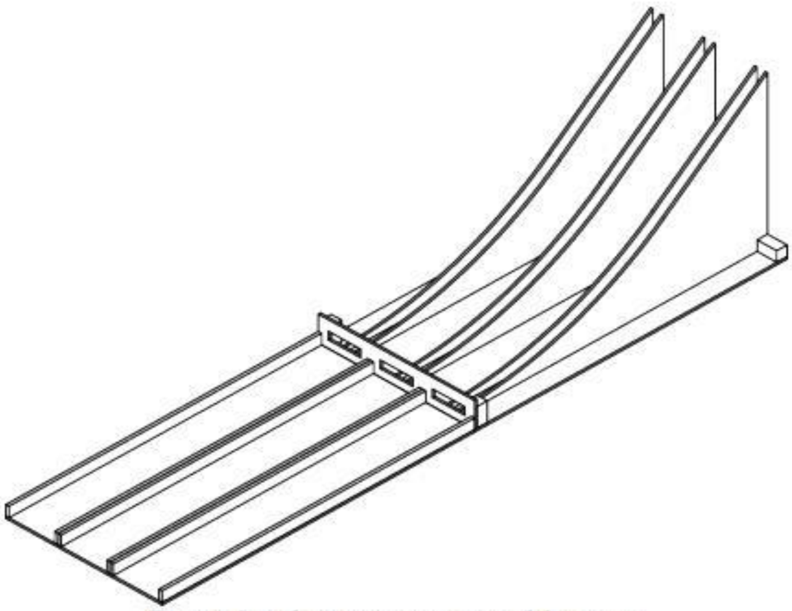


Figure 1: schematic overview of the ramp

Design:

The design is mainly focused at keeping the weight lower minimizing the drag force and at the same time strong so that it hits the ball harder up onto the inclined plane. The STAR SWIFT car weighs 1.4kg.

All vehicle parts are built out of materials with a fine strength and low density wood .The shape of the car s a simple "Rectangle" shaped. We will manage to cut and reshape in fablab KU Leuven. At the front of the car, we have put a wooden hitting element, to hit the ball. Driven four-wheel car. Mini disks are mounted double side by side for each wheel to increase stability while driving.

The angle of the solar panel with respect to the sun must be adjustable so that the light rays fall perpendicular to the solar panel to enable maximum power delivery from the solar panel;

we have made a stand for the solar panel which would be easier to put the solar panel, and also looks neat. The gears are made with help of 3D printing, in fablab. The gear box and transmission system will be simple by only using 2 small gears, and the gear ratio is achieved in 2 steps. The DC motor is also fixed in a box, so it does not move will drive .The same goes for the axel in the back. The engine will be fixed at the back through another supporting block with the same diameter.

PLAN OF APPROACH

1) Introduction:

In Engineering experience 4 we have to build a solar car, which can travel in a 10m race track and then hits a pétanque ball which weights 750g approximately. And the ball has to travel on the inclined plan. In order to start the whole project firstly plan of approach is needed to be made.

Plan of approach is one of the milestone products of the EE4 project. The Solar vehicle makes up propulsion with different types of courses in engineering (dynamics, material technology, statics, electricity etc.). The main desire of this project is to counterfeit the solar car with the highest possible team potential unto the race and following seminar containing the calculations and working.

1.1) Approval result and adjustments:

The POA will be submitted to the EE4-coach. This will be reviewed and final result is to be judged on drop or move forward. POA should be adjusted to meet the required standards and some errors would be seen and solved.

1.2) Points on the structure of planning:

The following steps have the description about the working plan on the SSV with precise calculations and simulation process proposed in the solution of our EE4 project.

2) EE4 project description:

The main motive of team is mainly focussed on getting the solar car to work with an innovative model and idea by excelling through the race and anticipating future model. Firstly the assembling of SSV parts like solar panel, engine, and body framework shows impact on the competition and well reliable automobile.

2 .1) Four E's of engineering : the project combines all the four E's:

Engineering, enterprising, educating and environmental.

Engineering:

This part has all the engineering parts of the project, which includes building, designing, calculation, simulating, testing, mechanical, and other engineering aspect

Enterprising:

Enterprising of a product play a very vital role in market. This part includes marketing of car or survey on it, creating publicity, p r i c e , work breakdown structure, Gantt chart, POA etc.

Educating:

This area includes seminars, reports which are written and research, and group meeting.

Environmental:

Is relatively straight forward as the source of energy is solar energy. There are no environmental constraints.

2.2) Client:

The customer of this project could be the member of the Group T Engineering College, Leuven. The experience could be gained by the engineering experience project given to the students. The team coach will always be a role as a contract during the project and do the needful.

2.3 contractors:

Contractor is the team of members who do the project in exchange of an output. TheFollowing are the details of team members' consisting7.

	Name:	Email:	Ph. No:
	Praveen saragadam	praveen kumar 2347@yahoo.com	0488967468
	Sanjay Kandukuri	sanjaykandukuri@in.com	0486375712
	Anjali Nedunuri	nanjali28@gmail.com	0486223021
	Surendra Botu	botu.surendraeme@gmail.com	0486375712
	Anoop Nuka	kinganoop11@gmail.com	0486060102
	Chaitanya Ketha	chaituidiot4u@gmail.com	

2.4) Aims/Objectives:

The main aim of this project is to place the working, balanced solar car by competing and completing the race with highest possible potential.

2.5) Problems:

There were many problems which occurred during construction of SSV, we had to change the whole model, as we took wrong measurements, and design and everything was totally change .Problems may occur in the SSV like air drag due to the uneven assembling of car frame and odd placing of solar panel in the angle which degrades the aerodynamic law. Sometimes, calculations have highest probability in countering the disputes in the SSV such as collusion with metal ball using the front bumper (billiards stick, spring system). So we had to change the front hitting element. Some internal problems could occur between the members due to language difference but although our team is of similar region have the strength in mutual understanding .keeping all the problems aside we got the end output very efficient and good one.

2.6) Anticipated result:

The expected results of the project would be good, efficient and successful as, cooperation and team work among the team is strong.

3) Management aspects:

3.1) Time management:

As a team of six members it was very important to manage time, according to the convincing of member, and for completion of a good SSV as expected.

The team members were conscious and ready to the deadline fixed by the leader. The members of the team must be regular and careful during work progress.

3.2) Quality management:

As quality of any product is the basic thing, so quality of the project should be carefully managed by sharing each other projects in order to obtain a refined quality.

3.3) Information management:

All The information can be found online where everyone can access it at any time. The administration will manage and organize the information.

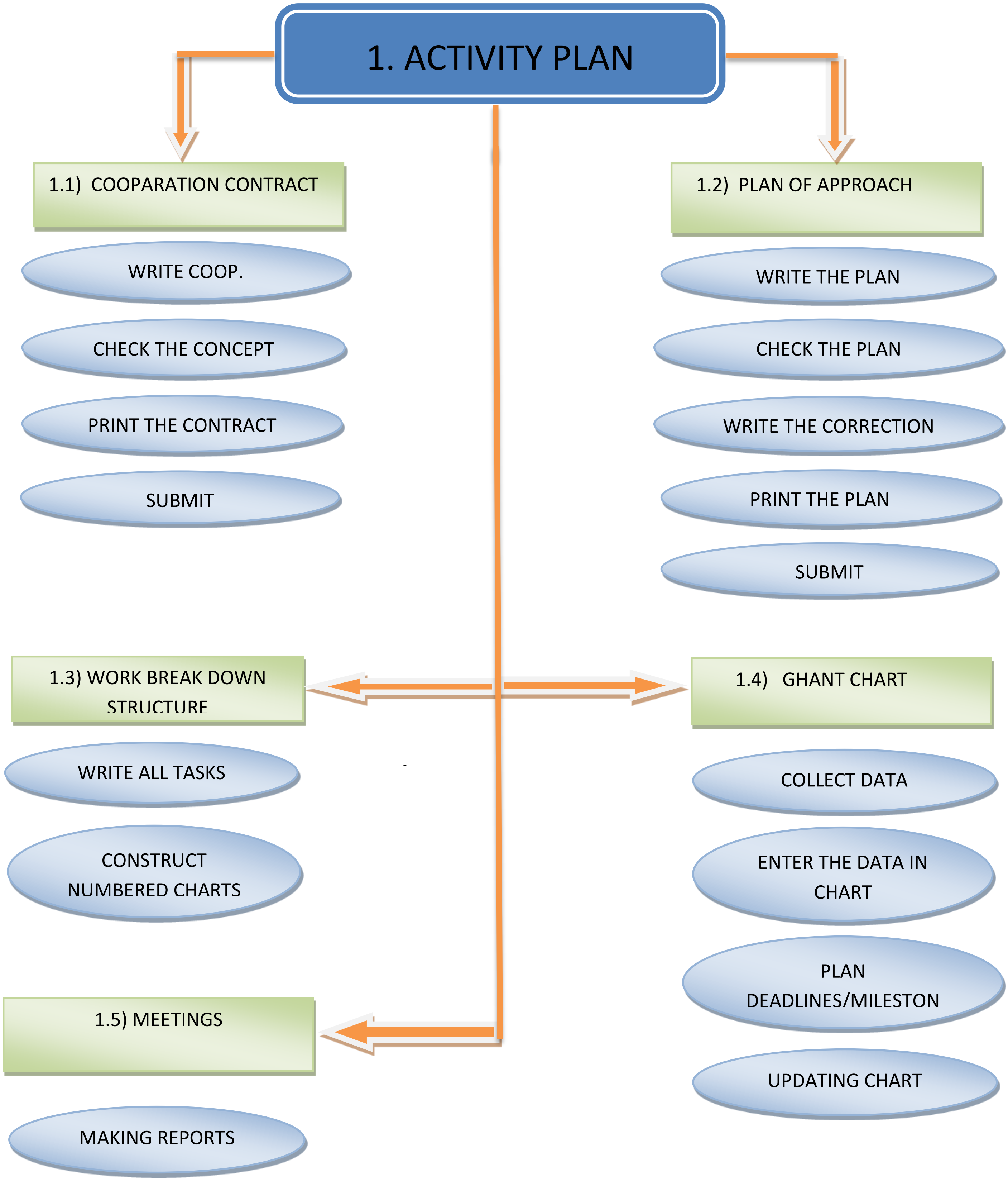
3.4) Organization management:

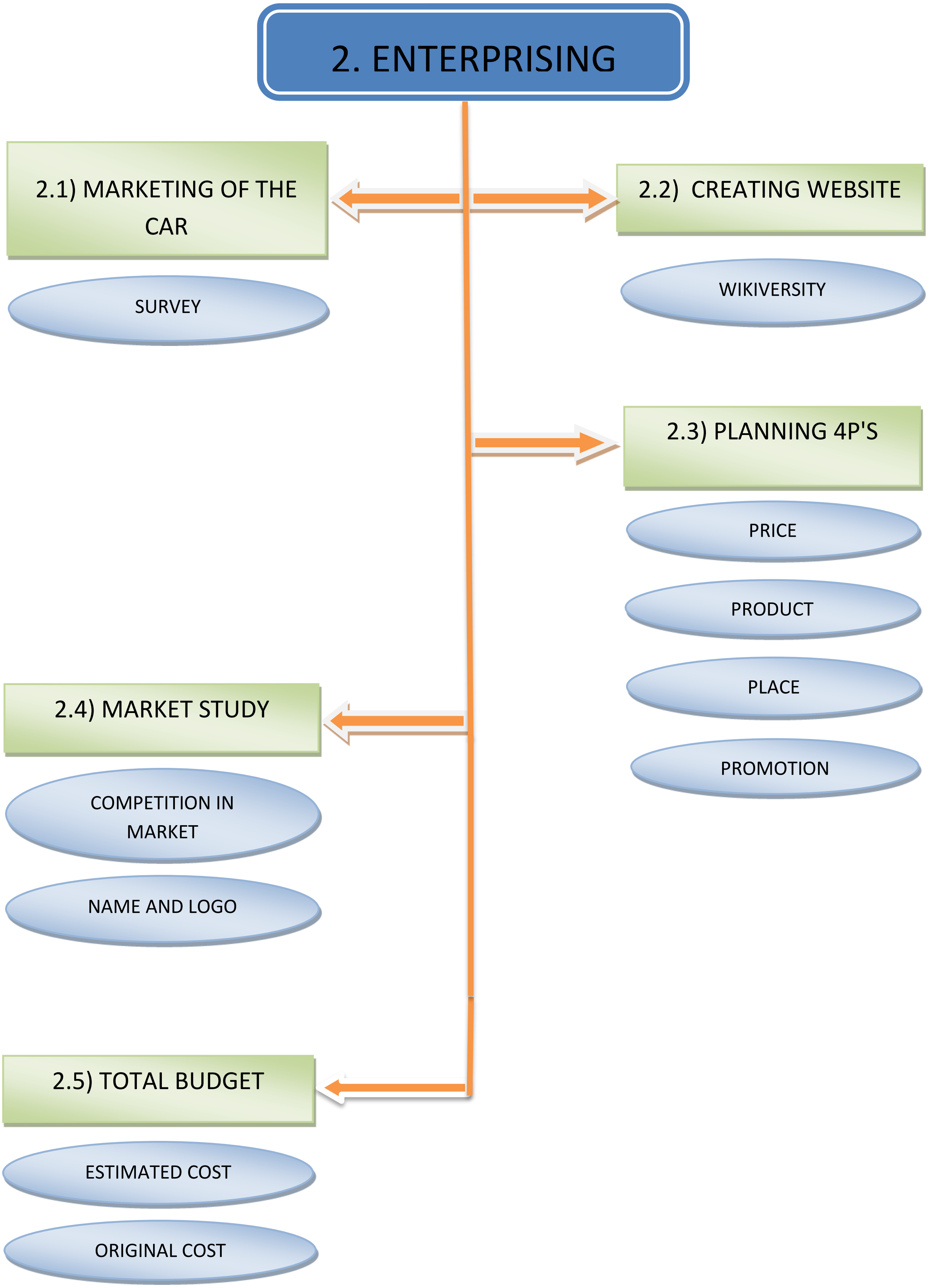
The members of the team should work together and if any difficult circumstances rise from any member then they will be executed or graded poorly. Late arrivals or agree working times will be penalized by the team in order to get a polished organization. For more details refer to the cooperation contract.

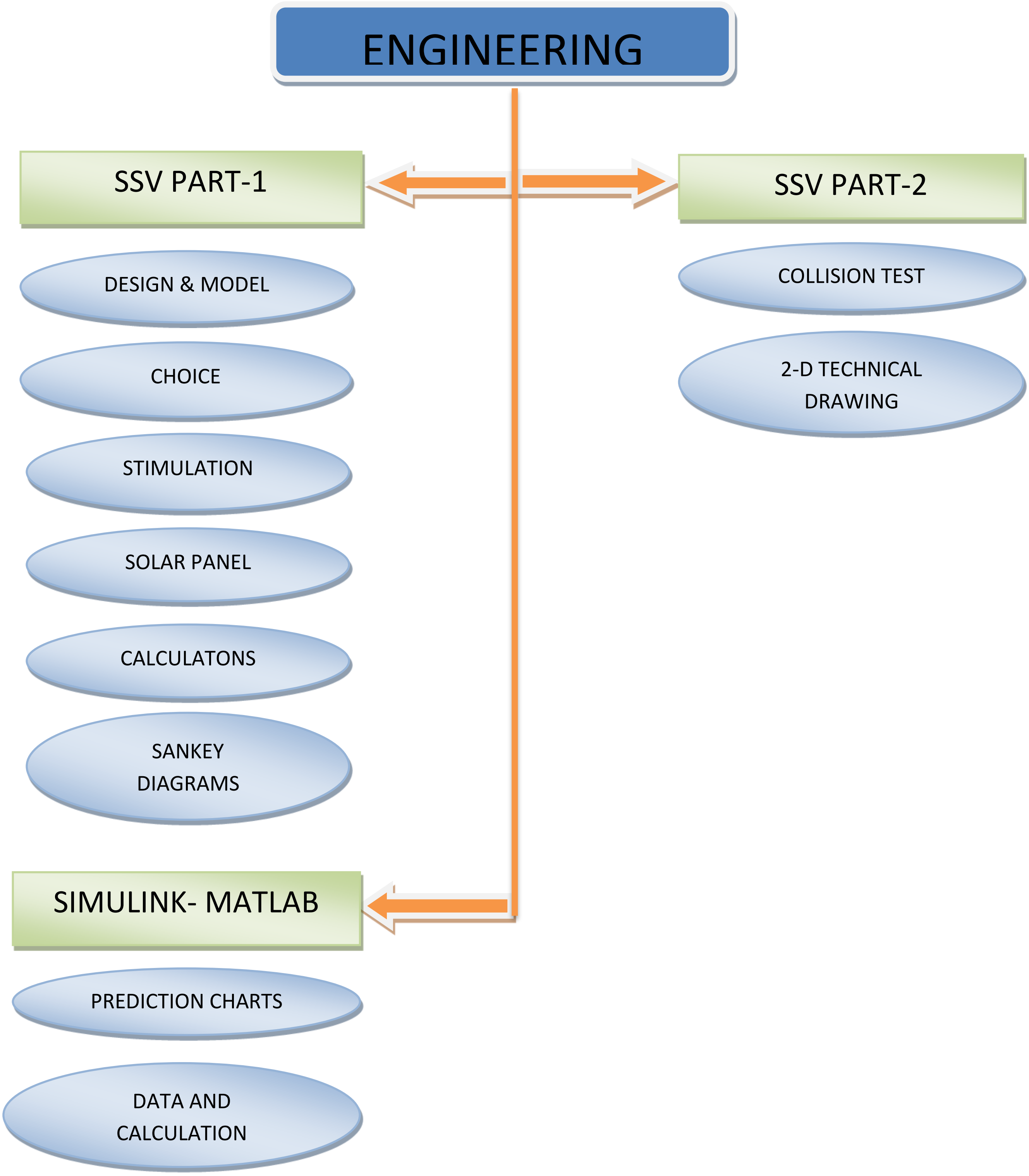
3.5) Money:

All the expenses and purchases of the project have been decided to divide equally on to team members. The total cost for the model is 35euros.

WORK BREAKDOWN STRUCTURE




2. ENTERPRISING
2.1) MARKETING OF THE CAR
SURVEY
2.2) CREATING WEBSITE
WIKIVERSITY
2.3) PLANNING 4P'S
PRICE
PRODUCT
PLACE
PROMOTION
2.4) MARKET STUDY
COMPETITION IN MARKET
NAME AND LOGO
2.5) TOTAL BUDGET
ESTIMATED COST
ORIGINAL COST


ENGINEERING
SSV PART-1
SSV PART-2
DESIGN & MODEL
CHOICE
STIMULATION
SOLAR PANEL
CALCULATONS
SANKEY DIAGRAMS
COLLISION TEST
2-D TECHNICAL DRAWING
SIMULINK- MATLAB
PREDICTION CHARTS
DATA AND CALCULATION

Project: EE4
Electromechanical
Engineering

GANTT CHART

Assignments		Weeks	Responsible	Hours / Men: Anjali	Sanjay	Anoop	Praveen	Chaitu	Surendra
1. ARRANGEMENT									
1.1. Ghantt Chart		1	Praveen	1	1	1	1	4	1
1.2. WBS		1	Anjali	5	5				
1.3. Plan of Approach		1	Sanjay	3	8	6		4	6
1.6. Logotype		1	Sanjay	1	1			2	2
1.7. Team Meeting		14	Praveen	3	3	4	4	3	4
2. ENTERPRISING									
2.1. Marketing	2.1.1. Wiki Page	14	Sanjay				20	5	7
	2.1.2. Business Plan	2	Anoop	4	1	3	2		1
	2.1.3. Market Analysis	2	Anoop	2		3		2	
2.2. Finances		2	Surendra		2		1	2	3
3. ENGINEERING									
3.1. Power	3.1.1. Engine	2	Praveen	2	3	4	3	2	3
	3.1.2. Transmission	2	Surendra		4	5	1	4	6
	3.1.3. Solar Panel	2	Praveen	2	2	2	3	2	2
	3.1.4. Electric Circuit	2	Surendra	1	3	4	3		4
3.2. Structure	3.2.1. Body	4	Praveen	6	10	6	7	5	6
	3.2.2. Drivetrain	2	Anjali	4		1	2	3	1
	3.2.3. Montage	1	Surendra	6	6	6	6	5	6
	3.2.4. wheels	1	Anoop	3	3	3	2	2	3
3.3. Optimization		3	Sanjay	12	12	12	12	10	12
3.4. Simulation	3.4.1. Simulink	1	Anjali	4	3	3		3	2
	3.4.2. Umicar	2	Anjali	4		4	2		
	3.4.3 SSV	1	Chaitu	5	5	4	5	4	5
4. CONCLUSION / OTHERS									
5.1. Test		2	Praveen	5	5	5	5	4	4
5.2. Final Report		3	Sanjay	10	10	9	9	9	9
5.3. Team Meeting		14	Praveen	3	3	4	4	3	4
5.4. Seminares		5		23	24	23	24	23	24
		Total Hour/Men		109	114	112	116	101	115

Academic Weeks: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Enterprising

Market research

Market research plays vital role in success of any product, our main focus is to give an ecofriendly product to the customers. So we mainly focus on the analysis of competitors, customers and suppliers. Based on these three analyses, we determine how we want join the market and promote our products. We have done a lots of research what customers need and expect, so based on the analysis we have made and launched our product.

Competitor's

identification of competitors counts more, because we are playing in a competitive and technically fast growing world. To participate and compete in a market, we need to maintain our identification of being quality, brand, affordable and accessible.

Customers

our main focus is to give an ecofriendly product to the customers. solar car is one of the most eco friendly with good quality and affordable .The main customers are companies which are willing to produce solar car, instead of petrol and electric cars, And kids between above 10 years .

Suppliers

we need a lot of suppliers for the kit consists of many components. So we will have to deliver, dc motors, carbon rods, Plexiglas's, wheels, bearings, gears, wires, boxes and manuals solar panels. Later these packages we have circuit boards, switches, sensors and several sizes gears required.

Business plan preparation

Product:

The solar car will look like a kit that can be easily and quickly put together. This kit consists of a solar panel, a DC motor, balsa wood chassis, wheels, bearings, gears and necessary wires. To sell the model solar car we focus on the model construction. Selling cars powered by sunlight is a niche within the model construction. This part of the market is still relatively unexplored and therefore the prices based on the prices of the ordinary model construction. The basic model of the solar car costs € 80.WE are launching the product worldwide , and mostly in tropical country , where sun light is more compared to western countries .The product is found in 5 different attractive colors with combination of black (blue, red, yellow, green , white). And also looks has extra effects for better looking, like engraving of stars on the SSV.

Promotion:

Promotion plays a vital part in marketing of any product. Promotion of STARSWIFT will be done through the website of solar team, as well as in KU Leuven GROUP T. And also through events and *STARSWIFT Group T*, as the website of Group T. There can also be played on a commercial websites, as well as posters and advertisements .For commercials and market promotions we are also giving a 9 volt battery with the product.

Price:

Price is one of most important part in today's market, as it is a working model, so based on it we have fixed the price of the SSV. This includes the prices of all the materials, labour cost, and transportation cost. For the construction of our SSV it was necessary to buy some additional components. The frame was made with balsa wood bought from *fablab KU Leuven*.We also bought gears from a hardware shop in Leuven. We also brought some screws and bolts, 3mm wooden sheets for solar panel frame, glue. List of materials brought and there price given in the table below id the total price for SSV:

Material(component)	**Shop**	**Cost (euro)**
axes	Aitec heverlee	15.00
9mm Balsa wood	Fablab	15.00
3mm Balsa wood	fablab	4.00
Screws bolts and washers	Merkx(hardware shop)	15.00
Solar panel holder clips	Merkx(hardware shop)	4.00
Bearings and washers	ebay	4.00
paints	Merkx(hardware shop)	10.75
Transport charges	Transport charges	15.00
gears	Hardware shop(home flyers)	37.00
total		119.75

According to Belgian law, minimum wages for a labour is 8.56, so our wages were calculated based on it, hourly bases.

Names	Hours worked	Salary in total
Praveen kumar.s		
Anjali.N		
Anoop.N		
Chaitanya.K		
Sanjay.K		
Surendra.B		

As the total cost of product is 119.75.And also labour wages and taxes are separate. Finally the market price of the product is. It is very reasonable as it’s a very strong and classic model.

Process Report

Introduction

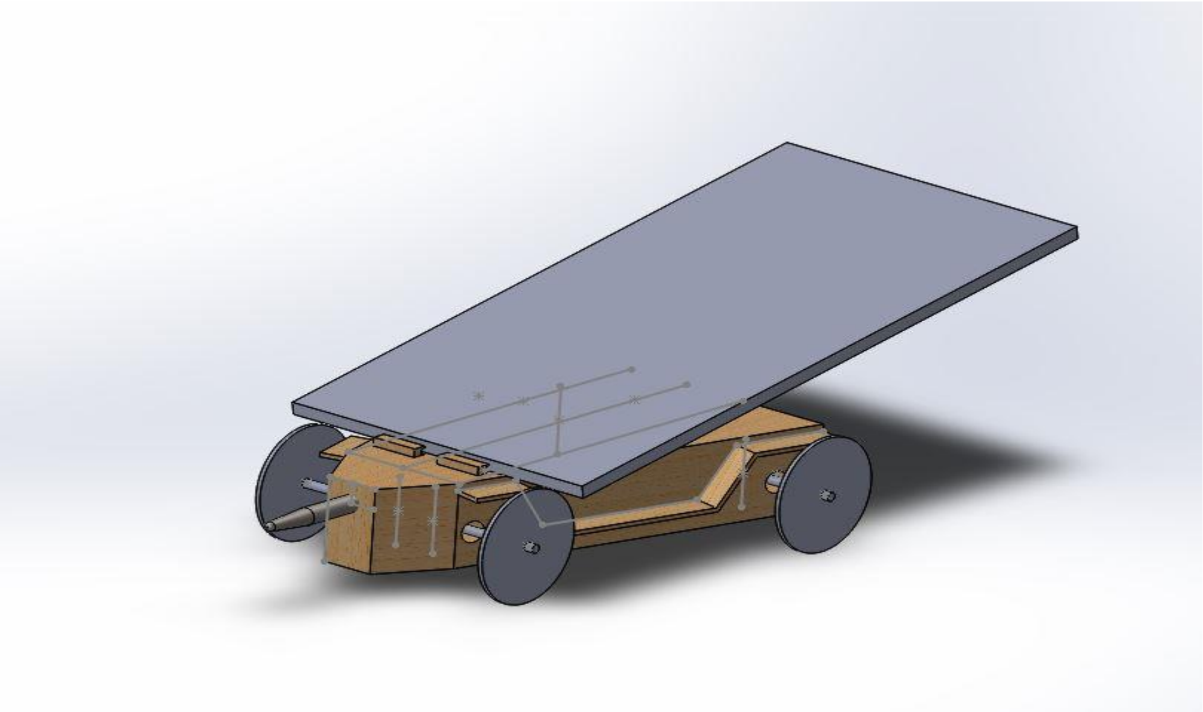
With process report we are trying to give an overview of our achievement and completion of our SSV.

Progress of the project

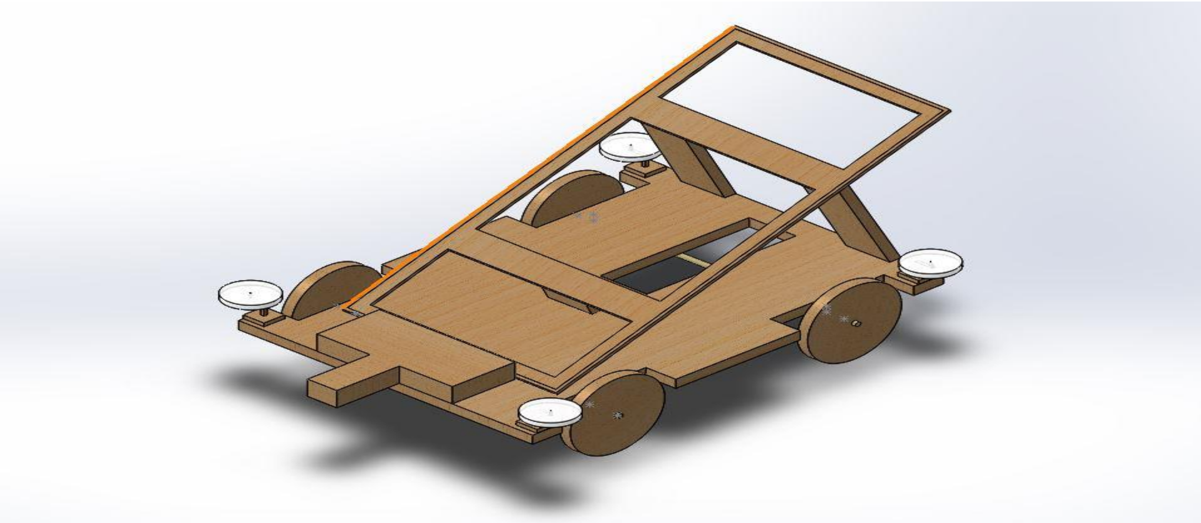
At the beginning of the project we have mainly been focused on the design of the SSV (chassis, mounting of the solar panel.) This was followed by the calculations and writing the report.

During the Easter holidays we worked on the design and realization of our solar car, but the model we made 1st was not appropriate. The 1st SSV was not efficient as we expected, it weight was very less. So In SSV part 2 we had to change the design, there were few difficulties faced by the team as the total design had to be changed and make a new SSV model. The new design was made simple and strong which should be capable of giving us better results during the race. After the trail collision we figured out some missing components for our SSV and minor mistakes and need to increase the height of the hitting components to have better contact surface during the collision. So we had to opt for another new model ,it was the 3rd SSV model , but it was prefect and output was as we expected , best looking , as well as hitting component , wheels and other minor problems we faced in 2nd model were modified in this 3rd model.

First car:



Second car:



Final Car:

Collaboration

everyone kept his personal deadlines so that no one left behind a bad impression. If someone had a question or problem he could immediately count on the cooperation of others. The coach also guided us a lot for the progress of the SSV. After a few discussions we quickly joined the most choices at a decision which everyone could find. We of course have to admit that not everything went was not smooth but still need to fight for it , there were many problems , but we had the guidance from the coach , team leader and cooperation among team member made it a good model .

Purpose of making our ssv :

STARSWIFT is an eco-friendly car, which runs with solar energy. We wanted to give the coming generations a model of solar car, with is most efficient, agile as well as good looking. As people now not only see its working but also looks of the SSV matter so, we made our model very creative and attractive, with black and red color .And star design on it .we made the solar car in ‘BATMAN MOBILE’ model , which will be very attractive in market .
With respect to the solar race, we took balsa wood for making the car, because it was cheaper, easy to cut and make, can hit the ball better than any other material and is also light weight.
The main aim of the solar car was to complete the race in less than 20 seconds and hit the metal ball as high as possible. To avoid breakage during the collision a metal surface is put in the front of hitting component. The weight of the solar car was made accurate so it runs with expected speed on the track .This was the main purpose of making our making our STARSWIFT.

RACE STRATEGY:

Conclusion

we conclude that generally things went good. This project is a proof that a group of people can work together in terms of organization and efficiency but all the members need to understand and cooperate with the other team members for the best results. We were in semifinals in the solar car race, which was a good result as we expected, our car hit the ball to 18.9 inches. The team spirit, zeal and guidance of coach gave a good output.

SSV PART-1

Table of Contents

SSV PART-2

SSV Case I Report

1.Introduction:

In Engineering experience 4 we have to build a solar car, which can travel in a 10m race track and then hits a pétanque ball which weights 750g approximately. And the ball has to travel on the inclined plan. Moreover the movement of the car must be powered exclusively by the solar energy produced instantly by the solar panel consisting of 16 solar cells.

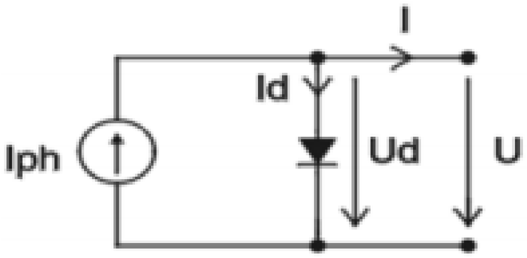
The race will cover a distance of 10 straight meters starting followed by an inclined slope, with an elevation. The solar car needs to use the solar energy efficiently and properly to remain stable during the drive. Given all the limitations we must be able to make our car produce the maximum power necessary to cover the given distance as fast as possible and hit the ball with maximum force so that it travels, up the inclined plane. The power used to propel the car should exclusively come from the solar panel. It must be ensured that the car has an optimal transmission ratio over the whole race; that the weight of the car is kept low and air and rolling resistance are minimalized. To make this project a success the group worked hard and made every possible effort to be active, innovative, precise and organized. Every one contributed equally in working with the project. We did a rigorous calculation work to have an accurate and correct outcome. The more accurate the calculations the better the car will behave to our expectations once built. We expect a good solar car as the end result.

2. Solar panel and DC motor characteristics:

2.1 Characteristics of Solar panel:

To get good advantages of the SSV from the solar panel it's evident to know the complete characteristics and working of the solar panel. Solar panel is considered as the heart of the SSV as the DC motor is powered by the solar panel.

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



The formula that relates to an ideal solar panel is

$$I = I_{Ph} - I_S\left(e^{\frac{U}{m*U_r}} - 1\right)$$

IPh – photocurrent , I_s – reverse saturation current (A)

U – Diode voltage (V) , UT – thermal voltage (V) , m – Diode factor

When considering the serial and parallel resistance Rs and RP into account, the circuit that represents the real solar cell model shown in figure 2 is received.

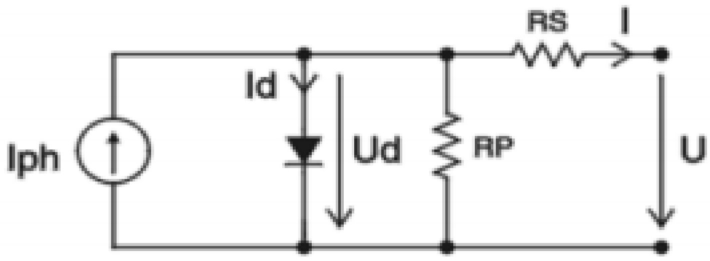


Figure 2: real solar panel circuit

This formula below represents the real Solar panel circuit:

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

I_{sc} – short circuit current (A) , Is – saturation current (A): 10^{-8} A/m2

U – Output voltage (V) , Ur – thermal voltage (V): 25,7mV at 25°C

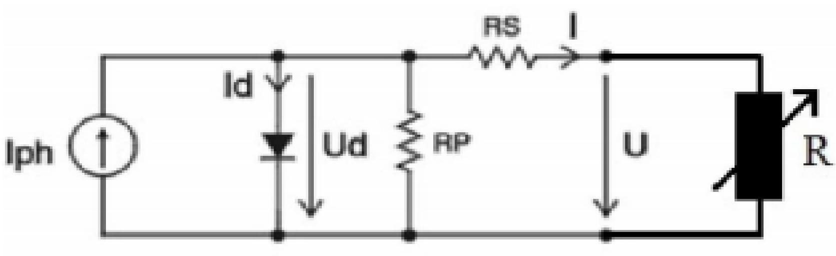
$U_r = k * \frac{T}{e}$ k – Boltzmann constant: 1.38□10-23 J/K , T – Temperature (K), e – charge of electron (V): 1.6□10-19 As

m – Diode factor: range of 1 – 5, N – number of solar cells in series: 16

These values are already defined from the solar panel's properties. The parameters which need to be calculated are: the short circuit current I_{sc} and diode factor m.

The first parameter that is calculated is the short circuit current I_{sc}. Measuring the current with a multi-meter when the solar panel is short-circuited gives the proper value.
I_{sc} = 0.44A

To measure the second parameter an external variable resistor was put into the circuit, a potentiometer like in figure 3.



Firstly, we have calculated diode factor by placing solar panel under a high voltage lamp and optimizing the measurements by adjusting the resistor. Since the resistor was been moved inaccurate way the measurements aren't accurate. So we will take an optimal graph during our other calculation of work. So the maximum power of the solar panel can be calculated.

In order to obtain a better performance of our SSV, some accurate measurements were necessary. Firstly, we have calculated diode factor by placing solar panel under a high voltage lamp and optimizing the measurements by adjusting the resistor. Since the resistor has been moved inaccurately, measurements obtained are not accurate. So we will take an optimal graph during our other calculations of work. So the maximum power of the solar panel can be calculated. We did several calculations by using solar panel and motor equations.

2.2 For solar panel:

By using this formula we can calculate the diode factor for measured point.

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

Short circuit current: I_{sc}= 0.44,   Open circuit voltage: V_{oc}= 8.87

Diode factor: m= 1.156 , The working point: $U_s \cdot I_s$ = 8.87 · 0.38 = 3.37

To conclude the diode factor of solar panel, we have to measure the voltage and current with fluctuating resistance at room temperature.so that we get the diode factor m for each resistance.

V (voltage)	I (current)	Power (P=V*I)	Diode Factor (m)
0.53	0.43	0.2279	0.093294447
2.66	0.42	1.1172	0.445862842
4.17	0.42	1.7514	0.698965433
5.72	0.41	2.3452	0.932706916
6.95	0.41	2.8495	1.133271515
8.87	0.38	3.3706	1.382113041
8.89	0.37	3.2893	1.371681526
8.92	0.36	3.2112	1.364748173
8.98	0.33	2.9634	1.346942247
9.01	0.32	2.8832	1.344228078
9.09	0.28	2.5452	1.332644004
9.14	0.25	2.285	1.326234685
9.16	0.23	2.1068	1.321246793
9.18	0.22	2.0196	1.320488136
9.21	0.19	1.7499	1.314861561
9.22	0.17	1.5674	1.310368984
9.29	0.14	1.3006	1.312237652
9.3	0.12	1.116	1.308744223
9.31	0.09	0.8379	1.303392713
			Average: 1.156

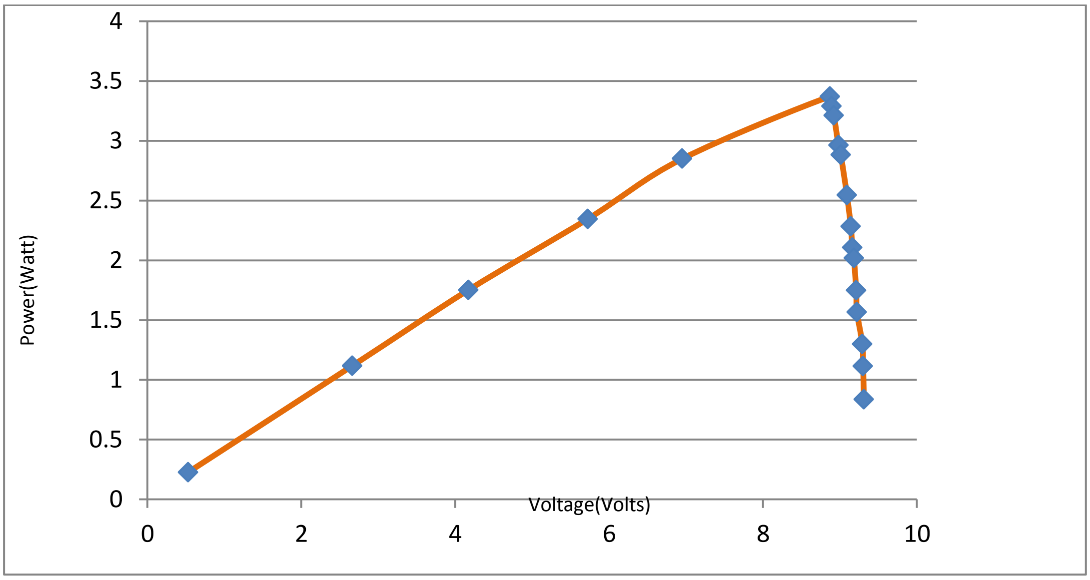
Table 1: Diode Factor

By using following formula we can calculate the diode factor for each measured point. After taking the averages of all diode factors we got the diode factor 1.156.

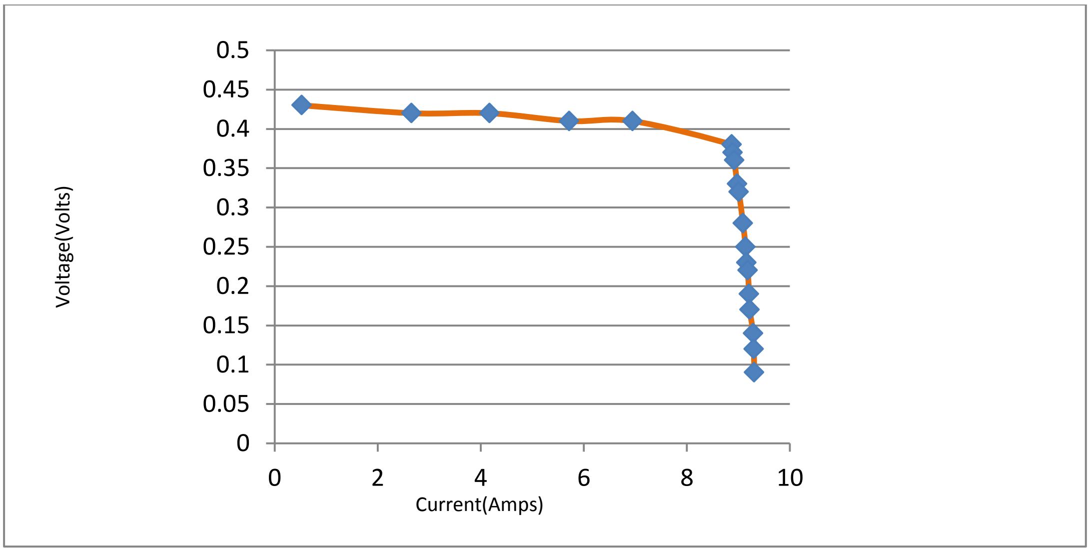
Procedure:

We are altering the resistance and current on the solar panel, in that we would measure the various voltages. By applying the formula on excel sheet we have to calculate the diode factor m. The adjusted current with its corresponding voltage given us then the power consumed.

2.3 Accurate result:



Graph 1: Power x Voltage



Graph 2: Voltage x Current

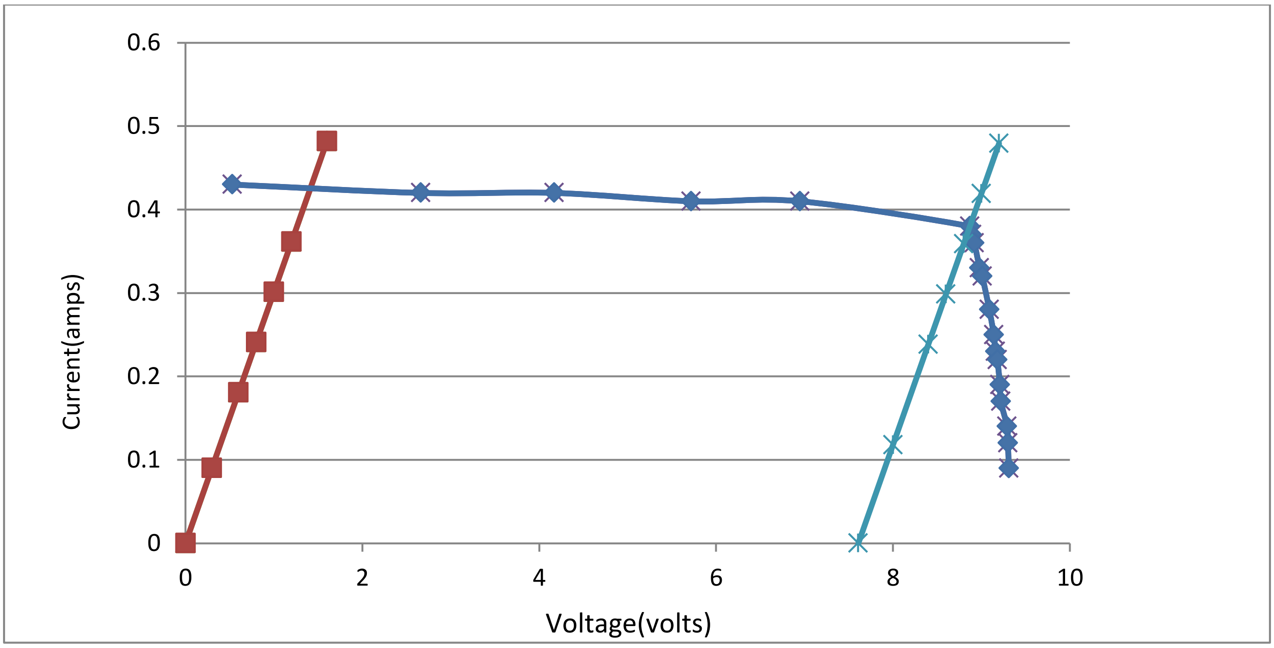
Ps: Values on Voltage and Current where obtained based on calculations and graphical analyses exposed bellow.

2.4 For motor:

U = IR + (n/1120)

V(line 1)	I(line1)		V(line 2)	I(line 2)
0	0		7.6084	0
0.3	0.090361446		8	0.117952
0.6	0.180722892		8.4	0.238434
0.8	0.240963855		8.6	0.298675
1	0.301204819		8.8	0.358916
1.2	0.361445783		9	0.419157
1.6	0.481927711		9.2	0.479398

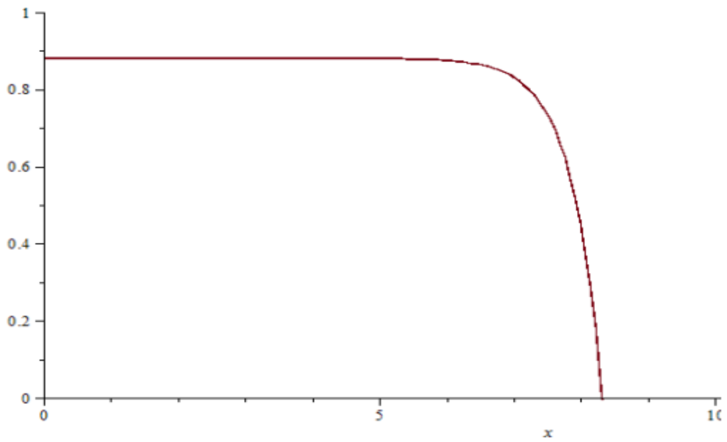
Table 2: Voltage and Current



Graph 3: Current x Voltage

In this picture we can easily see the maximum power. At this point the voltage is around 6.8V and the maximum power is 3.370W

2.5 Optimal Result:



The observation which we found under the lamp may differ from the values obtained from the sunlight as both of them vary in their intensities.

2.6 Error approximation for diode factor:

For every m value we have subtracted the average diode factor in order to obtain the error approximation for diode factor.

$$Standard\ Deviation = \left[\frac{1}{n}\sum(x_i - x_{mean})^2\right]^{\frac{1}{2}}$$

D1 = 0.0933 – 1.156 = -1.0627

D2 = 0.4459 – 1.156 = -0.7101

D3 = 0.699 – 1.156 = -0.457

D4 = 0.9327 – 1.156 = -0.2233

D5 = 1.1333 – 1.156 = -0.0227

D6 = 1.3821 – 1.156 = 0.2261

D7 = 1.3717 – 1.156 = 0.2157

D8 = 1.3647 – 1.156 =0.2087

D9 = 1.3469 – 1.156 =0.1909

D10 = 1.3442 – 1.156 =0.1882

D11 = 1.3326 -1.156 = 0.1766

D12 = 1.3262 – 1.156 = 0.1702

D13 = 1.3212 – 1.156 = 0.1652

D14 = 1.3205 – 1.156 = 0.1645

D15 = 1.3149 – 1.156 = 0.1589

D16 = 1.3104 – 1.156 = 0.1544

D17 = 1.3122 – 1.156 = 0.1562

D18 = 1.3087 - 1.15 = 0.1527

D19 = 1.3034 – 1.156 = 0.1474

We have calculated a sequence of diode factor by error and approximation method and now final factor can be calculated by using above formula:

=

$$\left[\frac{1}{n}\sum (x_i - x_{mean})^2\right]^{\frac{1}{2}}$$

$$\left(\frac{(D1)^2 + (D2)^2 + (D3)^2 + (D4)^2 + (D5)^2 + (D6)^2 + (D7)^2 + (D8)^2 + (D9)^2 + (D10)^2 + (D11)^2 + (D12)^2 + (D13)^2 + (D14)^2 + (D15)^2 + (D16)^2 + (D17)^2 + (D18)^2 + (D19)^2}{19}\right.$$

$$\left[\frac{((-1.0627)^2+(-0.7101)^2+(-0.457)^2+(-0.2233)^2+(-0.0227)^2+(0.2261)^2+(0.2157)^2+(0.2087)^2+(0.1909)^2+(0.1882)^2+(0.1766)^2+(0.1702)^2+(0.1652)^2+(0.1645)^2+(0.1589)^2+(0.1544)^2+(0.1562)^2+(0.1527)^2+(0.1474)^2)}{19}\right]^{1/2}$$

$= [2.26405/19]^{1/2}$

$= (0.1191)^{1/2}$

Diode Factor = 0.145±

Optimal gear ratio:

Choosing the right gear ratio is essential for a good performance of the SSV. Gears are used to connect the DC motor with SSV's wheels in order to transform rotation into motion .The velocity and acceleration of the SSV is closely related with gears ratio. Since the calculation of optimal gear ratio depends on many variables, we made use of MATLAB to better solve this problem. To specify the properties of our vehicle and the track in MATLAB following variables were needed:

In order to move the SSV we need to attach the gears to the DC motor through an axel. Speed of the SSV can determined with the ratio of these gears and this plays a very prominent role in the building of the SSV .MATLAB was used to calculate the ratio depends on many variables. This software helps us for a simulation of the displacement speed curves of our vehicle. The variables below give the description of our SSV.

SOLAR PANEL :-
Short circuit current (A) 0.88 Saturation current(A) 1*10-8 Thermal Voltage(V) 0.0257 Diode factor 1.156 Number of solar cells in series 16
DC-Motor :-
Terminal resistance(OHM) 3.32
Ce 8.9285*10-4
Gravitational force(N/Kg) 9.81

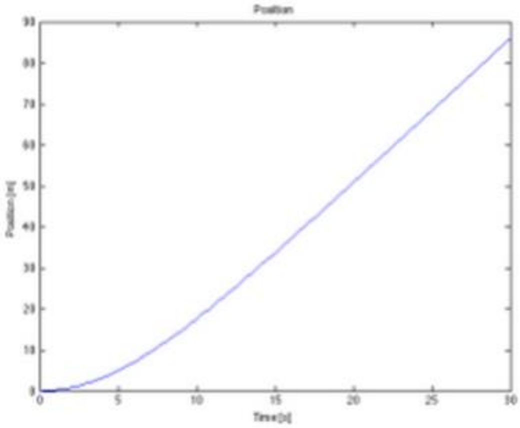
Drag coefficient 0.897 Density of air(Kg/m3) 1.293
Frontal Surface area 0.0786
SSVMass(Kg) 1.4 Wheel radius(m) 0.04 Gear ratio Variable(5-9.5)

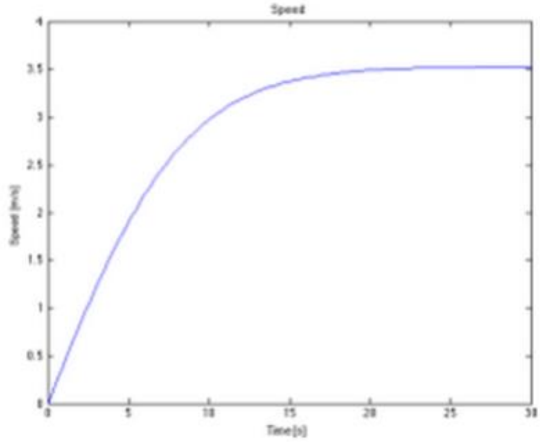
Few values are found by measuring the solar panel characteristics and using some realistic values for our car's weight, drag coefficient, frontal surface, etc. Of course these values can be slightly different with our real car. Properties for the track, the motor, the surroundings and the solar panel are given.

When we use the very small gear ratio, the car will accelerate fast but will have a low top speed .Very high gear ratio means a slow acceleration but a high top speed. It was necessary to find a good value between these two extremes to have a decent acceleration and a top speed high enough so the car would need minimal time to finish the 10 meter track.

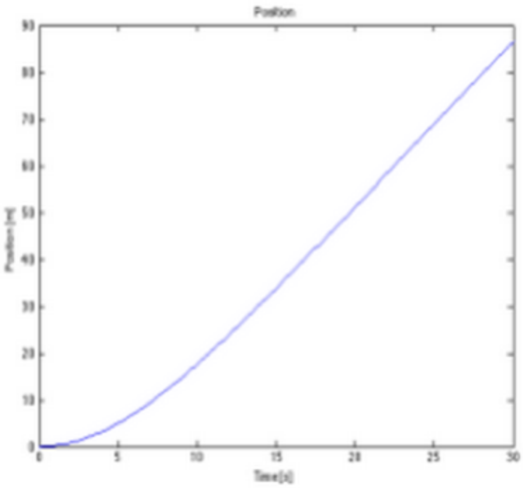
The gears were evaluated between 5 and 9.5 with different assumptions of the mass SSV with the help of MATLAB. The graphs below represent the speed, time and position of the SSV with different combinations of mass SSV and gear ratios. There is also a curve with the race times for the different gear ratios given for a solar panel of 16 cells.

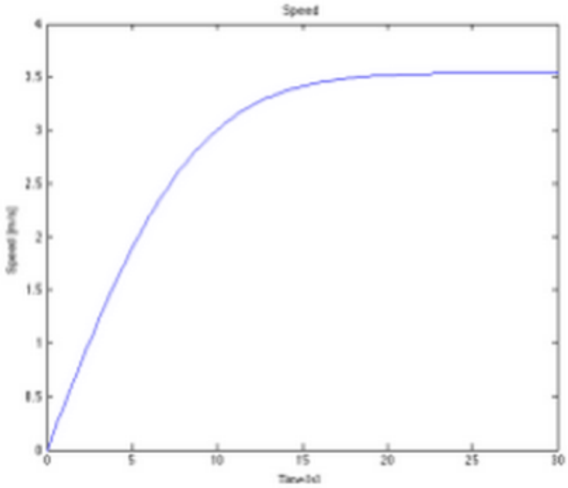
SSV with mass = 1.3kg and Gear ratio = 7.5



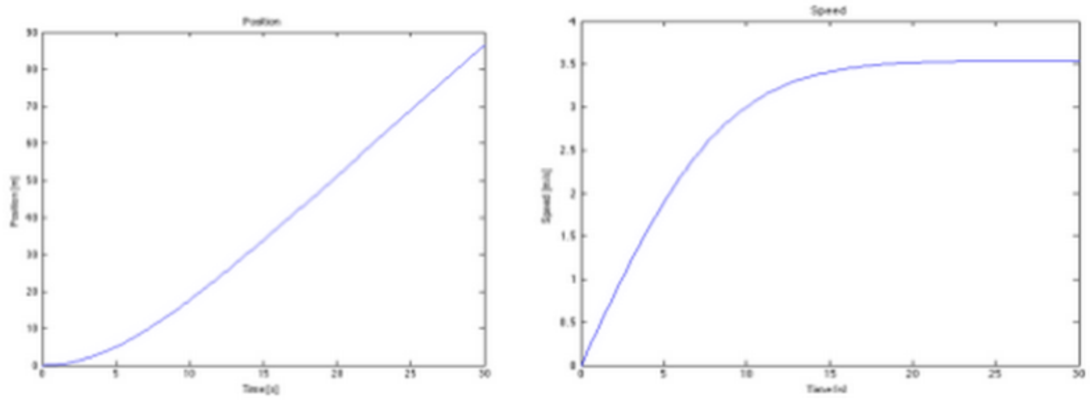


SSV with mass = 1.4kg and Gear Ratio = 8





SSV with mass = 1.5Kg and Gear ratio = 8.5



This Curve shows that the power produced by the DC motor is not completely sufficient to move the SSV, which need to collide the ball at the end of the track of length 10m. As the mass of the car is bit high and we are looking for bigger gear ratio.

After taking the several measurements with the combination of different mass of the SSV and the Gear ratio we derived several displacement curves shows the race time. Within 4.62Seconds the SSV will reach the end of the track and hit the ball.

Secondly the very suitable gear ratio for the car is 7.5 or 8 which brings advantage to us by accelerating the car with the mass of 1.3Kg approx. This is because the motor will be able to push the SSV to the extreme level. But still there will be slight changes in the mass of the real SSV but not in the change of the Gear ratio. For the best result for our SSV, We choose 8 as our gear ratio with the solar panel consisting of 16 solar cells.

Optimal mass:

we have consider the moment of the **SSV** hits the ball and the ball is taken as a system, so assume an ideal elastic collision occurred .In order get the optimal mass from the elastic collision equation

Momentum equation

$M_{ini,SSV} . M_{ini,SSV} + M_{ini,ball} . V_{ini,ball} = M_{end,SSV} . V_{end,SSV} + M_{end,ball} . V_{end,ball}$

therefore $V_{end,ball} = [(M_{ini,ball} - M_{ini,SSV}) . v_{ini,ball} + 2M_{ini,SSV} . V_{ini,SSV}] / (M_{ini,SSV} + M_{ini,bal})$

Form the wheel: power $(p) = \tau_w . w_w$, torque is the function of force and radius is f.r_w.Insert torque equation to the power and we get f.$r_w w_w$

=F.v_w [Therefore F=m.a]

=ma.v_w [Derivative of velocity $\frac{dv}{dt} = a$ (acceleration)

=m.$\frac{dv}{dt}.v_w$

Therefore, p=m.$\frac{dv}{dt}.\frac{ds}{dt}.v_w(v_w = v)$ Apply integration to the power in order to get initial velocity of the ssv.

$$\int_0^s pds = \int_0^v m.v^2.dv$$

$$\text{p.s}=[mv^3/3]_0^v$$

$$\text{v}=(\frac{3.p.s}{m})\,{}^1\!/_3 = v_{in}, ssv$$

We know that, final velocity of ball, $v_{fin,ball}$,m->M_{ssv}

$V_{end,ball}$=[($M_{ini,ball}$-$M_{ini,SSV}$)* $V_{ini,ball}$+2$M_{ini,SSV}$*$V_{ini,SSV}$]/($M_{ini,SSV}$+$M_{ini,bal}$)

From the collision system, $V_{ini,ball}$ =0,

$$v_{end,ball} = \frac{2M_{ssv}+v_{in,ssv}}{M_{ssv}+M_b} = \frac{2M_{ssv}}{M_{ssv}+M_b}\left(\frac{3ps}{M_{ssv}}\right){}^1\!/_3$$

$$v_{end,ball} = \frac{2(3M_{ssv}^2.ps)^1/_3}{m_{ssv}+m_b}$$

For maximum speed, we have to differentiate the $v_{end,ball}$

$$\frac{dv_{end,b'}}{dm_{ssv}} = 2(3ps)1/3\left[\frac{(M_{svv}+M_b).\frac{2}{3}M_{ssv}{}^{-\frac{1}{3}} - M_{svv}{}^{\frac{2}{3}}}{(M_{svv}+M_b)^2}\right] = 0$$

$$\frac{2}{3}M_{svv}^{\frac{-1}{3}}(M_{svv}+M_b)=M_{svv}^{\frac{2}{3}}$$

$$2(M_{svv}+M_b)=3M_{svv}$$

$$M_{svv}=2M_b.$$

Optimal mass is obtained when the mass of ball is twice that of the mass of ssv .

Maximum Height:- We have to determine the max. height with KE and PE .

From the definition

$$KE_{initial}+PE_{initial}=KE_{final}+PE_{final}$$

$$\frac{\mathrm{Mboule}*\mathrm{Vi}^2}{2}+(\mathrm{MBoule}*\mathrm{g}*\mathrm{height})=\frac{\mathrm{Mboule}*\mathrm{Vf}^2}{2}+(\mathrm{MBoule}*\mathrm{g}*\mathrm{height})$$

Initial height=0 and final velocity =0,
Then equation becomes

$$\frac{\mathrm{Vi}^2}{2}=(\mathrm{g}*\mathrm{height})$$

$$height=\frac{\mathrm{Vi}^2}{\mathrm{g}*2}$$

we can assume there is no energy loss during the collision, that means ball will reach the maximum height and we couldn't consider the frictional force. When car hits ball force of the car will transmit to the ball and it will reaches the max. height

Bisection method:

3.1 Practice example:

Bisection method is used in order to get approximate values which is closer to the zero digit number .Initially we can calculate the roots of the following equation by using bisection method in between interval x=0……10

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

From the above equation we have find the values of x from 0 to 10.up to the value y(5) values increase and then it decreases until y(10).So we have calculate the y(7.5),because it is the average of 5 and10 but y(7.5) got negative .In order to that take average values until we find the zero digits Now, we will calculate the value of y(5), since this is the average of the interval. This gives us:

$$y(5) = \frac{1}{2} + \sin\left(\frac{5}{2}\right) * e^{\sin(\frac{5}{3})} = 2.119362673$$

Next we have to calculate the y(7.5) ,at this point y values are slightly decreasing

$$y(7.5) = \frac{1}{2} + \sin\left(\frac{7.5}{2}\right) * e^{\sin(\frac{7.5}{3})} = -0.5398626500$$

From the above two values we can calculate that y(x) is zero between x=5 and x=7.5, so now we will calculate of this interval:

$$y(6.125) = \frac{1}{2} + \sin\left(\frac{6.125}{2}\right) * e^{\sin(\frac{6.125}{3})} = 0.6926260906$$

$$y(6.125) = -0.0620287511$$

$$y(6.125) = 0.2867889120$$

From that we will continue the solution until the zero digits value

$$y(6.25) = \frac{1}{2} + \sin\left(\frac{6.25}{2}\right) * e^{\sin(\frac{6.25}{3})} = 0.5396629439$$

$$y(6.875) = \frac{1}{2} + \sin\left(\frac{6.875}{2}\right) * e^{\sin(\frac{6.875}{3})} = -0.1180946389$$

$$y(6.71875) = \frac{1}{2} + \sin\left(\frac{6.71875}{2}\right) * e^{\sin(\frac{6.71875}{3})} = 0.0264994375$$

$$y(6.7578125) = \frac{1}{2} + \sin\left(\frac{6.7578125}{2}\right) * e^{\sin(\frac{6.7578125}{3})} = 0.757812$$

$$y(6.73828125) = \frac{1}{2} + \sin\left(\frac{6.73828125}{2}\right) * e^{\sin(\frac{6.73828125}{3})} = 0.0076265302$$

Using these values, we find a value as close as to zero.

$$y(6.745361328) = \frac{1}{2} + \sin\left(\frac{6.745361328}{2}\right) * e^{\sin(\frac{6.745361328}{3})} = 0.0008403303$$

3.2 Numerical Approximation applied to SSV:

AS of we know that race track consists of 10meters.so, we will calculate displacement s(t), velocity v(t), back emf E(t) and terminal current I(t)

Main equation - energy equation

Let us take the solar car hits the ball as the system, many equations are involved in this system

Kinetic energy (Ek): Mv2(t)/2

Dissipated power (P=F ×v(t)): MgCrr × v(t) ; CwAρ × v3(t)/2

Input work (W=UIt): E(t)I(t) × dt

Energy equation:

a(t) = – g · Crr + I(t) × E(t)/(M × v(t)) - CwAρ × v2(t)/2M

Two constraints:

Motor: E(t) = Ke × ω = CE.Φ × 60 × v(t) × gear ratio /(2πr)

Solar panel:

I(t) = Isc – Is(eU(t)/(mNUr) – 1) = Isc – Is(e(E(t)+I(t)R)/(mNUr)-1)

Step 1: State the initial conditions:

So we have solar panel and SSV parameters in that to determine the design of our vehicle

g = 9.81N/kg; Crr = 0.012; CE.Φ = 8.9285e-4V/rpm;

r = 0.04m; π = 3.14; M = 1kg; Cw = 0.5; A = 0.02; ρ = 1.293kg/m3

3.3 Solar panel parameters:

I(t) = Isc – Is(e(E(t)+I(t)R)/(mNUr) – 1)

Isc = 0.88A; Is = 1e-8 A/m²; m = 1.1; N = 16; Ur = 0.0257V; Ra = 3.32Ω

From initially we considered these values given below

Time interval (T): 0.1s, Testing gear ratio: 10, Initial condition (at t = 0s):

s(0) = 0; v(0) = 0; I(0) = 0.88A

3.4 Numerical approximation method:

Step 2: solve the energy equation

a(0) = – g · Crr + I(0) × E(0)/(M × v(0)) - CwAρ × v2(0)/2M

During each time interval (T, 0.1s), the acceleration remains constant!!!

Step 3: calculate the initial condition for the next time interval

v(0.1) = a(0) × T

s(0.1) = v(0) × T + a(0) × T 2/2

E(0.1) = CE.Φ × 60 × v(0.1) × gear ratio /(2πr)

I(0.1) = Isc – Is(e(E(0.1)+I(0.1)R)/(mNUr) – 1) -» I(t) = f(I(t))

Secondly we have to state the initial conditions. At the start of the race our car's

Displacement and speed will both be zero. The current at this point is equal to the Short-circuit current:

s(0) = 0 m, v(0) = 0 m/s and I(0) = ISC = 0.88 A

3.5 Numerical approximation method:

Step 2 (!): iterate the energy equation

a(0.1) = – g · Crr + I(0.1) × E(0.1)/(M × v(0.1)) - CwAρ × v2(0.1)/2M

Step 3 (!): iterate the initial condition for the next time interval

v(0.2) = v(0.1) + a(0.1) × T

s(0.2) = s(0.1) + v(0.1) × T + a(0.1) × T 2/2

E(0.2) = CE.Φ × 60 × v(0.2) × gear ratio /(2πr)

I(0.2) = Isc – Is(e(E(0.2)+I(0.2)R)/(mNUr) – 1)

Assumptions and Approximate value:

We had considered some of the assumptions and approx. regarding the calculations

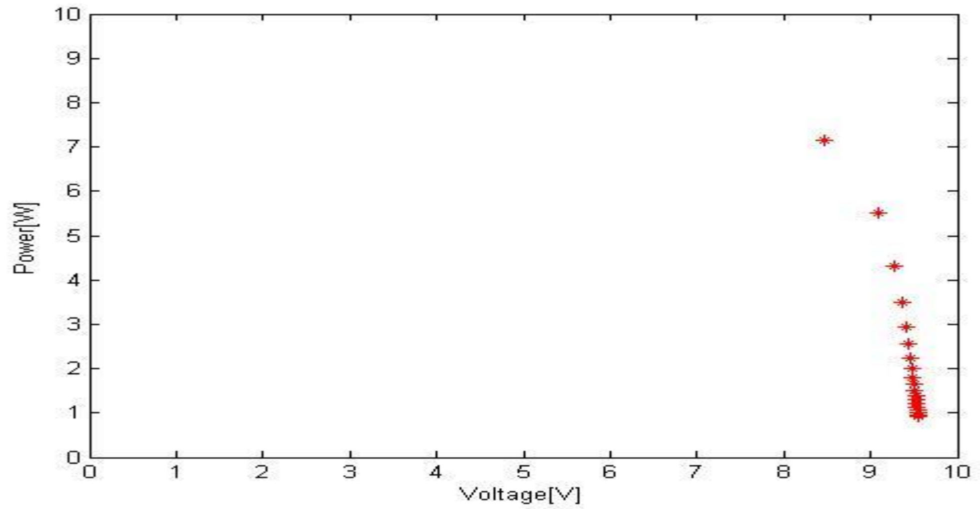
Assumptions	Approx. Value
Area (A): 820 .10^{-2} m	Area (A): 728 . 10^{-2} m
Maximum power (p): 5.42 W	Maximum power (p): 3.370 W
Gear ratio: 5	Gear ratio: 8

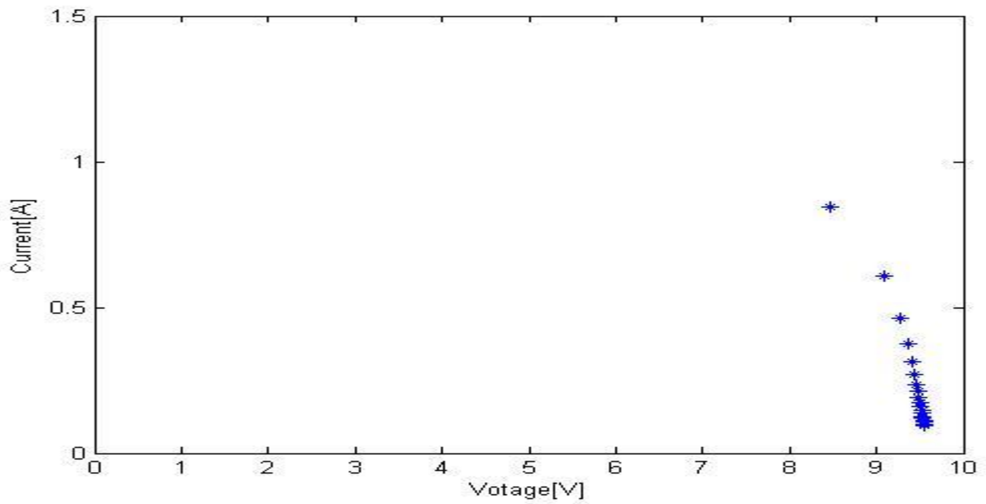
The calculated values have been sorted in approximates and assumption so that the SSV can be compared and simulated at high performance.

Area has high priority in making the race agitate so the area is considered to be 820 $.10^{-2}$mm. To get the maximum speed the SSV need to be modified using dynamics and area, so by optimizing it to 728 $\cdot 10^{-2}$ the speed can be maintained.

The gear ratio have been judged first to be 5 since the position of the SSV is high at that point but when we compare it to the speed and with position, then the ratio is set to be 10 in order to complete the 8 meter race track.

The maximum power need to be optimized according to the environmental and race conditions since it is dependent of the solar energy which is not constant every time. So the final value is considered to be 3.37 W since this is taken at room temperature with the source as lamp but when the SSV is put on the track then the value may differ.





Modelling is a method of solving problems, in which the system under study is replaced by a simple object that describes the real system and is called a model.

Simulation is used when conducting experiments on a real system would be impossible or impractical, because of the high cost of prototyping and testing, or because the fragility of the system will not support extensive tests, or because of the duration of the experiment in real time is impractical.

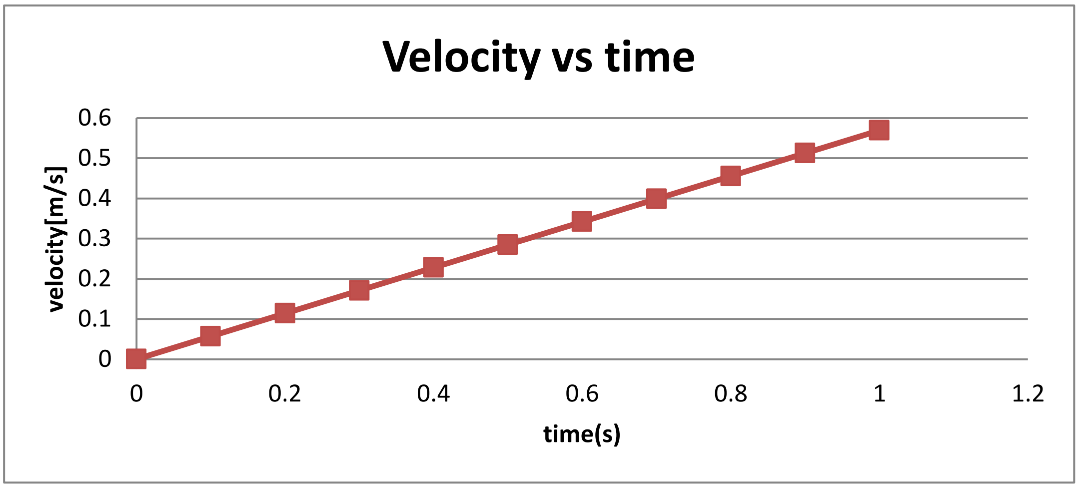
This helps us to find the analytical design of the SSV with the all the given properties of the Solar panel and DC motor through which we can extract the gear ratio , mass , time ,and speed , which suites to our SSV to the best .Which we found from MATLAB and create a prototype with approximation. This helps in saving time searching the material and developing something that will work after spending a lot of money.

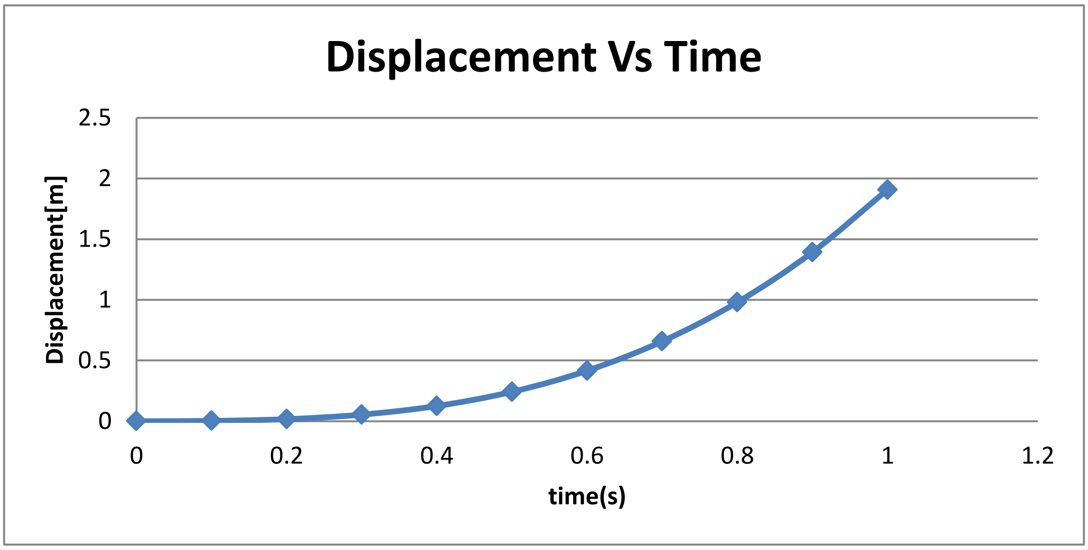
The equations which are obtained from the analytical calculations help to find optimal values. The found optimal values are used in the Simulink and MATLAB to get the accurate optimal gear ratio which is suitable for our SSV. The accurate values help us to find the exact time taken, speed of the SSV. The mass of SSV preferred is doubled as of the ball , which leads to the selection of gear ratio 8 .When the collision of the SSV with the ball takes place the distance travelled by the ball is high.

s(t)	v(t)	E(t)	a(t)
0	0	0	5.70E-01
2.85E-03	5.70E-02	0.13353983	0.569742245
1.71E-02	1.14E-01	0.267072101	0.56966337
5.41E-02	1.71E-01	0.400585885	0.569534317
1.25E-01	2.28E-01	0.534069422	0.569352979
2.42E-01	2.85E-01	0.667510459	0.569118698
4.16E-01	3.42E-01	0.800896587	0.56882869
6.58E-01	3.99E-01	0.934214745	0.568485913
9.80E-01	4.55E-01	1.067452565	0.568084755
1.39E+00	5.12E-01	1.200596364	0.567625357
1.91E+00	5.69E-01	1.333632493	0.56710215

T	E(t)	I(t)	f(I(t))
1.0000000000	1.3336324925	0.0000000000	-0.4399992310
		0.44	0.0000091808
		0.22	-0.2199972601
		0.33	-0.1099949661
		0.385	-0.0549931974
		0.4125	-0.0274920961
		0.42625	-0.0137414813
		0.323125	-0.1168701526
		0.3265625	-0.1134325602

		0.35578125	-0.0842129519
		0.384140625	-0.0558526042
		0.405195313	-0.0347970922
		0.364160156	-0.0758337736
		0.345361328	-0.0946331955
		0.350571289	-0.0894230759
		0.367355957	-0.0726378657
		0.386275635	-0.0537175150
		0.375217896	-0.0647756559
		0.4399999	0.0000090808
		0.45	0.0100096940





SSV PART-2

6.Collision Test and results: -

Testing the stability, strength and force transformation of our SSV helps us to redesign or change minor things in our design for better results during the race. During this trail test the ball has been placed with a pendulum of same mass. It was hung with supports and for the results during the impact and for the procedure sensors have been fixed to them. The model number of our sensor is PCB 200C20, and its sensitivity is 56.2mV/kN.

So,Sensitivity = $\frac{Voltage}{Force}$

And

$$F = \frac{U}{sensitivity \bullet amplification} = \frac{U}{56.2 \times 100}[MN] = \frac{U}{5.62}[kN]$$

Then, we can calculate the forces impact on our SSV every time. The table below shows the tests results of our SSV

Potential energy = $mg\Delta h$, Mass 'm' = 0.735g , Gravitational force 'g' = $9.81_{m/sec}{}^{2}$

$\Delta H = H_{2\_}H_1$

Test	voltage(V)	Force (N)	height(cm)	Potential Energy(J_	velocity(m/s)	velocity car	delta h(m)
1	0.3182	56.619	15.1	0.0216	0.242610799	0.2972	0.003
2	0.4312	76.726	15.2	0.0288	0.280142821	0.3432	0.004
3	0.9318	165.8	16	0.0865	0.485221599	0.5944	0.012
4	1.7178	305.66	17.8	0.2163	0.767202711	0.9398	0.03
5	2.5331	450.73	19.8	0.3605	0.990454441	1.2133	0.05

6	4.1051	706.36	31.6	1.9581	**2.10451411**	2.3981	0.15

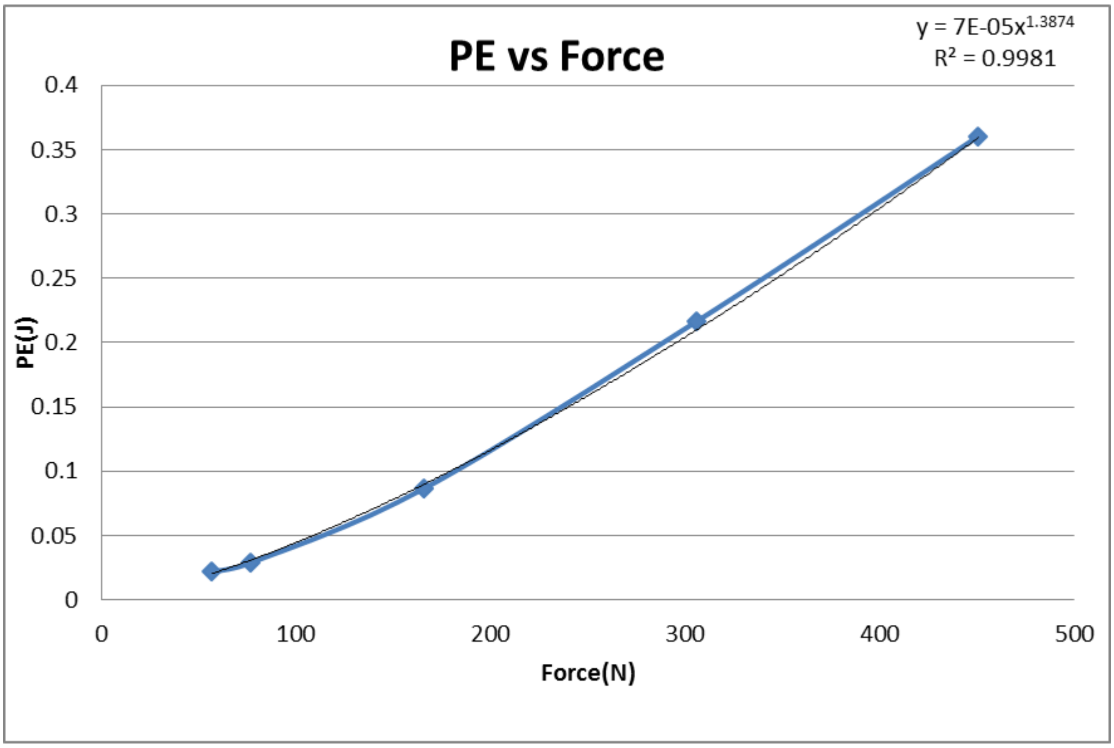


Figure 1: The graph below shows the Potential energy vs. Forces.

During the test 1 our Voltage results were amplified by a factor of 10 for better results

After the impact the SSV moved 198cm away from the impact point.

The test two was amplified by a factor of 100 and for further tests too.

This impact pushed the SSV for a distance of 119cm

The two impacts before we are done from very low heights of pendulum but they made good results and this test we raised the pendulum to height of 16cm the SSV travelled 38cm away from the starting point.

The impact was unfortunately was not at the right point of contact. This resulted in physical damage to the SSV and loss of control.

Test four was made from more height of approximately 17.8 -18cm.

The impact was a good and the result was appropriate by pushing the SSV to a distance of 56.2cm from the starting point.

The last one was made with the height 19.8 to check for high Voltage and force transformation and this resulted in moving of our SSV for 105cm from the impact point.

However, these results and tests proves that the SSV need a longer start-up, and thus the collusion will be harder and making the ball have more rolling efficiency and go high. Impact with a steel ball is a very big crash this brings a minor changes in the design of our SSV for more stability, Strength and better efficiency. Our assumption during that the ball will get a height. IN spite of being so accurate with the calculations and assumptions, there are always huge chances of things going wrong during the run and by hitting the ball at poorly. By choosing the manner in which the car runs effectively against the cell there are many more similarities with the real race.

This trail collision test was made in a shade and our SSV needs to use artificial source of battery to run, which produces more power to the battery and but during the race the power efficiency can be a bit low but it helped us to understand more about collision.

7. Sankey calculations:

Energy consumption of the ssv is shown in Sankey diagram. Solar panel supplies the input and output having some energy losses.

Energy losses can be calculated in given below.

Power of the sun:

Power of sun per square meter Area= 800 W/m2

Area of solar panel = 0.21*0.297=0.0623m2

Power absorbed by solar panel= 800*0.0623= 49.34Watt

Case 1: let us take the ssv reaches the maximum speed Vmax=2.1

Electric power (Solar panel):

Maximum velocity v_{max} = 2.1m/s

P = power, v = linear velocity, Cw = friction coefficient, A = frontal surface, ρ = density of air, m = mass, g = gravity constant (9, 81 m/s^2), v = linear velocity

Crr = rolling resistance coefficient, R=3.32 ohm.

Back emf, E= 60*Ce*vmax*ratio/ (2*Pi*r)

= 3.589V

From the formula, I = Isc-Is*(exp ((E+I*R)/ (m*N*Ur))-1

I = 0.8762 A

Terminal voltage U = E+I*R

=6.499 V

Electric power supplied by solar panel = U*I

=5.694 W

The Mechanical Power:

Mechanical power loss in armature resistance =R* I^2

= 2.548 W

Loss of efficiency in motor:

Efficiency in motor=0.7

Motor power lost due to efficiency =0.3*5.694

=1.7082 W

Power delivered to shaft= Motor power –Heat loss - Efficiency loss

=5.694-1.708-2.548 =1.438 W

Loss in Air resistance:

Power loss due to air drag/ resistance, $F_w = \frac{1}{2}(Cw)(A)(\rho)(v^2)$

=0.176 N

Loss in Air friction:

Power loss due to air friction = $F_w (v_{max})$

=0.176*2.1

=0.4696 W

Rolling Resistance:

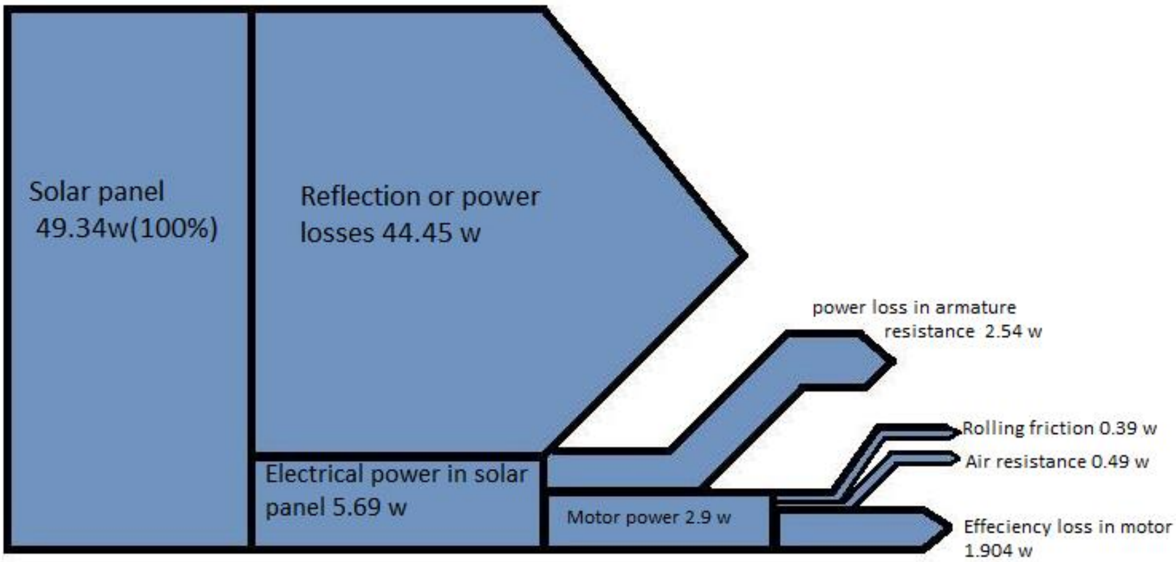
$F_r = \mu(m)(g)$

$= 0.012*1.5*9.8$

$=0.1764$ N

Power loss in rolling friction = $F_r\,(v_{max})$

$=0.1764*2.1 =0.384$ W



Case 2: In this case we have to consider the half of maximum speed (V_{half})

Electric power (Solar panel):

Velocity $\mathbf{V_{half}}$ = 1.05m/s

Back emf, E= 60*Ce*V_{half}*ratio/ (2*Pi*r)

= 1.79

From the formula, I = Isc-Is*(exp ((E+I*R)/ (m*N*Ur))-1

I = 0.8797 A

Terminal voltage U = E+I*R

=4.710 V

Electric power supplied by solar panel = U*I

=4.144 W

The Mechanical Power:

Mechanical power loss in armature resistance =R* I^2

= 2.569 W

Loss of efficiency in motor:

Efficiency in motor=0.7

Motor power lost due to efficiency =0.3*4.144

=1.2432 W

Power delivered to shaft= Motor power –Heat loss - Efficiency loss

=4.1439-1.243-2.569= 0.332 W

Loss in Air resistance:

Power loss due to air drag/ resistance, $F_w = \frac{1}{2}(Cw)(A)(\rho)(v^2)$

=0.04 N

Loss in Air friction:

Power loss due to air friction = $F_w\,(v_{half})$

=0.04*1.05

=0.042 W

Rolling Resistance:

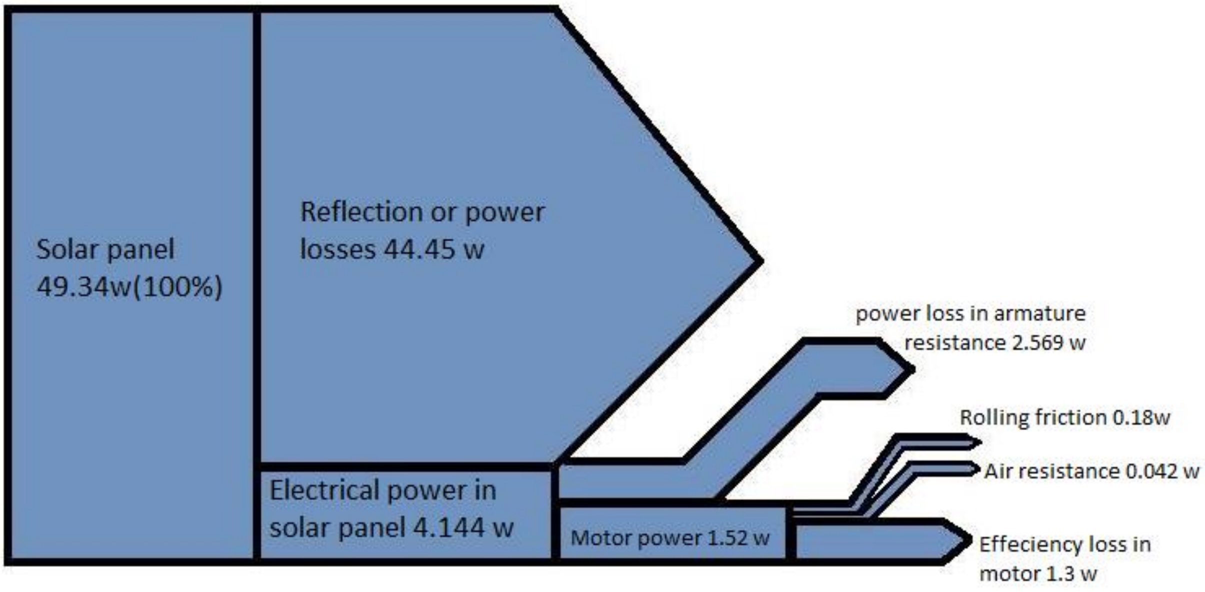
$F_r = \mu(m)(g)$

= 0.012*1.5*9.8

=0.1764 N

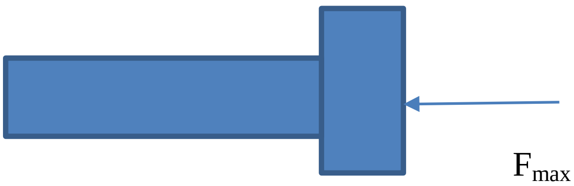
Power loss in **rolling friction** = $F_r \mathbf{V_{half}}$

=0.1764*1.05 =0.185 W



8. Stress on hitting component:

Stresses on hitting component is normal stress. There is no sheer force according to our design.



Normal Stress = F_{max} /Area of cross section

The maximum force acting on our SSV during collision is F_{max}=1.4 kN

Area of cross section of the hitting support = 3 * 1.5 cm^2

= 4.5 *10^{-4} m^2

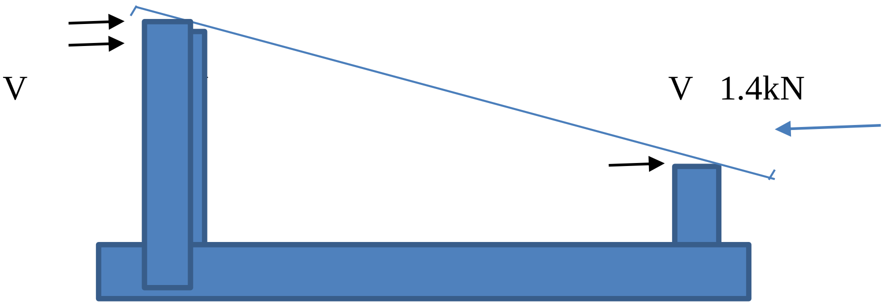
Normal stress = 1.4 * 10^3/ (4.5 * 10^{-4}) Pa

= 3.1MPa

Let we consider there is no normal forces acting on the shaft is equal to average normal stress on the shaft are zero.

Stresses on solar panel support:

Solar Panel



There are three components supporting our solar panel. The impact force is assumed to be equally acting on three supports. The acting force cause sheer stresses at the joints. Sheer force acting on each support is 0.46kN

Sheer stress = V / Area

Area of support contact to the main board = 4*0.8 cm^2

= $3.2*10^{-4}$ m^2

Sheer stress =$1.4/3.2*10^{-4}$ s

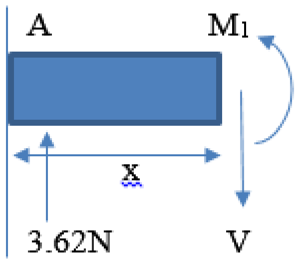
=1.43 MPa

Stresses on Shaft:

W_{wheel}= 3.62N

$F_{bearing}$=3.62 N

Sheer stress between A and B:-



Sheer force V_1= 3.62 N

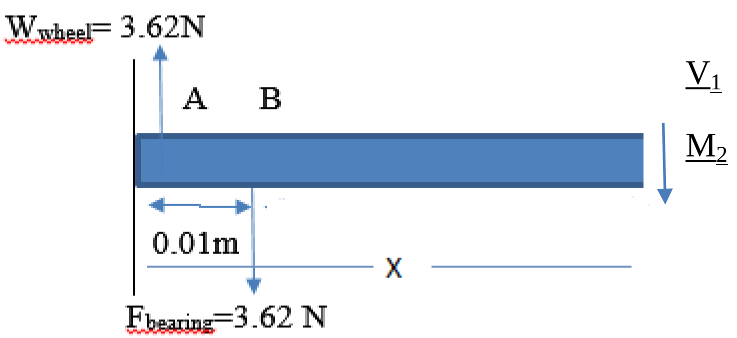
Moment = 3.62 x Nm

Sheer stress = $\frac{3.62}{\frac{\pi d^2}{4}}$

$= \frac{(3.62).(4)}{(\pi).(4^2).(10^{-6})}$ = 0.28Mpa

Sheer stress (σ_1) = 0.28 MPa

Sheer stress between B and C:-



Forces on y-direction:-

V_2=3.62-3.62

V_2=0

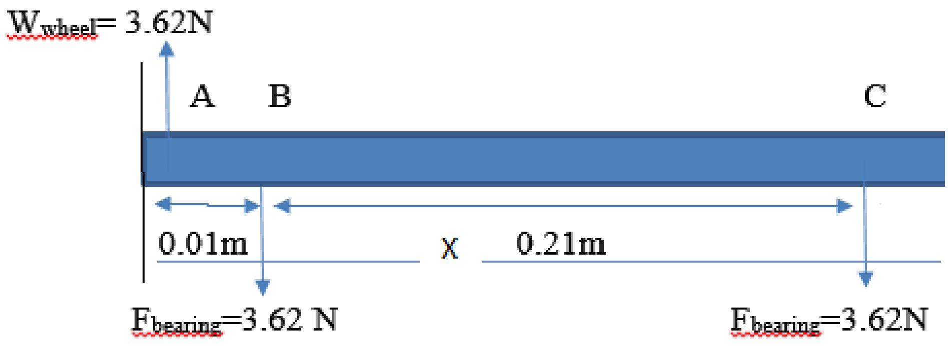
Moment between B and C (Counter-Clock wise direction +):-

M_2+3.62(x-0.01)-3.62(x) =0

Therefore M_2 = 0.0362 N-m

Sheer stress = $\frac{0}{\frac{\pi d^2}{4}}$ = 0 N

Sheer stress between C and



Forces on y-direction:-

V_3 +3.62 +3.62 = 3.62

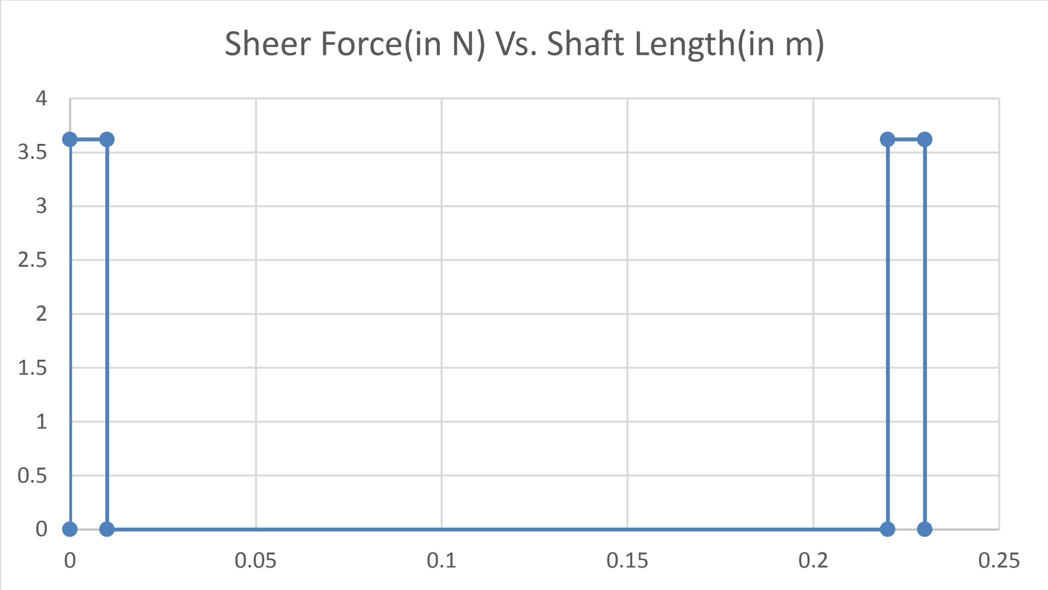
V_3= -3.62 N

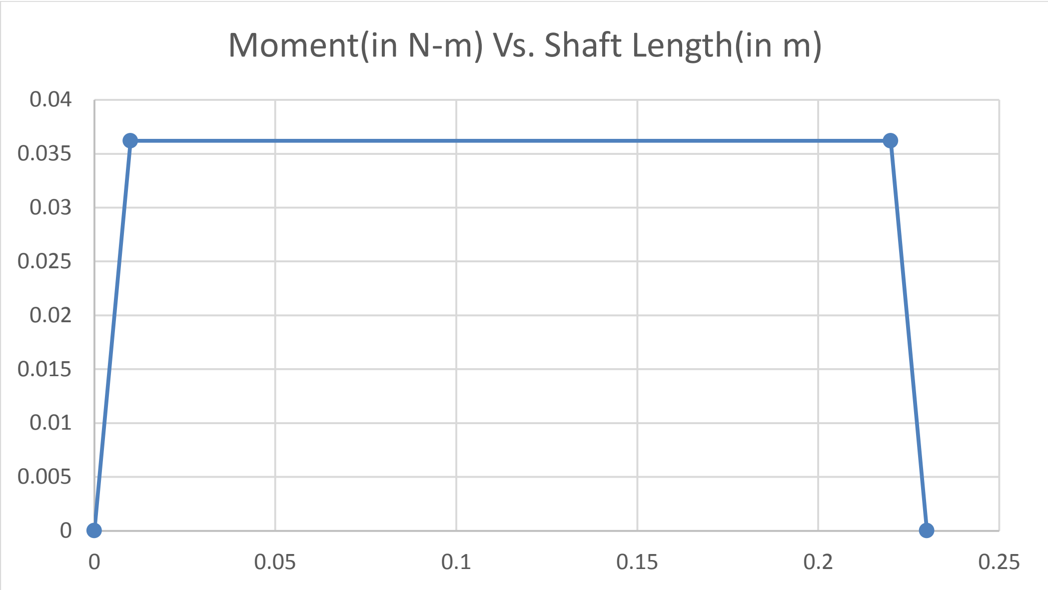
Moment at D (Counter-Clock wise direction +):-

M_3 - 3.62(x) + 3.62(x-0.01) - 3.62(x-0.21) =0

M_3 = 3.62x-0.796

Sheer stress = $\frac{3.62}{\frac{\pi d^2}{4}}$ = 0.28Mpa





There is no normal stress on shaft. The maximum sheer stress on the shaft is 0.28 MPa

Therefore, the maximum force that shaft can sustain is

F_{max}= max. Sheer stress * Area of cross section

$F_{max} = 0.28*10^{6} *12.56*10^{-6}$

= 3.51 N

Therefore the shaft of our ssv can sustain 3.51 N

The maximum stress compared to other components is on hitting component.

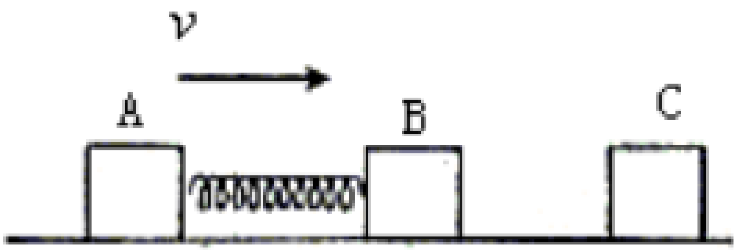
8.collision test example:

$$m_a = m_b = 2kg, m_c = 4kg$$

$$u_a = u_b = 6m/s$$

Therefore total (initial) energy $=\frac{1}{2}(2)6^2 + \frac{1}{2}(2)6^2$

$6^2 + 6^2$=72J.



(A) After collision final velocity of B and C are

$v_b = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1$ =2m/s

$v_c = \left(\frac{(1+e)+m_1}{m_1 + m_2}\right) u_2$ =2m/s [since c=0 both move forward]

I.e. just after collision B and C have same speed.

(B) At maximum compression A, B and C have same speed

Therefore acceleration of C.G and C.M

$$2(6) + 2(6) = (2 + 2 + 4)v^1$$

$$24 = 8v^1$$

$$v^1 = 3mts/sec$$

(C) Potential energy (PE_{max}) in spring is

$$\frac{1}{2}(2+2+4)(3)^2 + \frac{1}{2}kx^2 = 72$$

Upon simplification, 32 + (PE_{max}) = 72

PE_{max} = 40J.

(D) The maximum compression all have speed and then spring pushes the blocks backward.