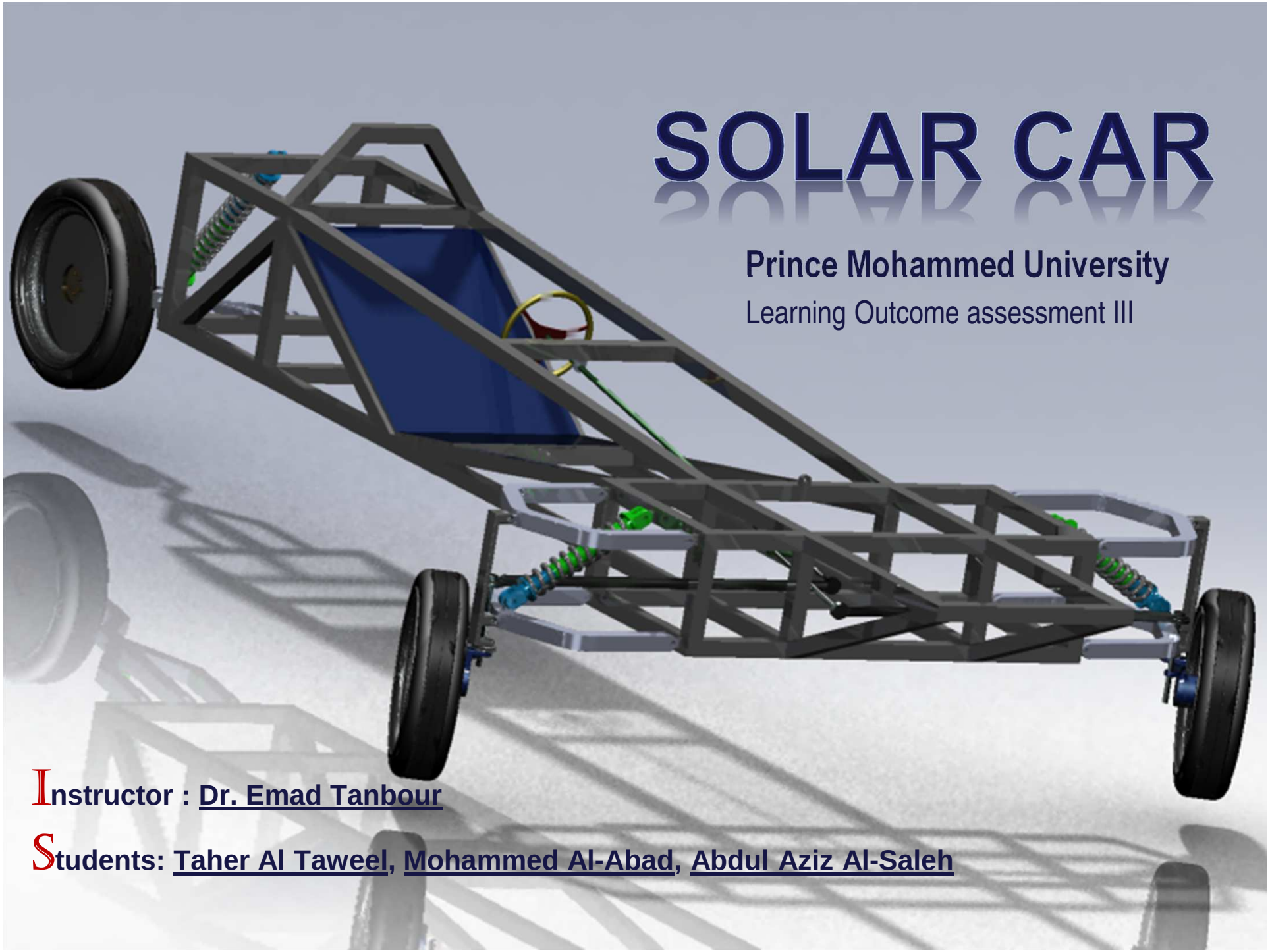
SOLAR CAR

Prince Mohammed University

Learning Outcome assessment III



Instructor : Dr. Emad Tanbour

Students: Taher Al Taweel, Mohammed Al-Abad, Abdul Aziz Al-Saleh

Outlines

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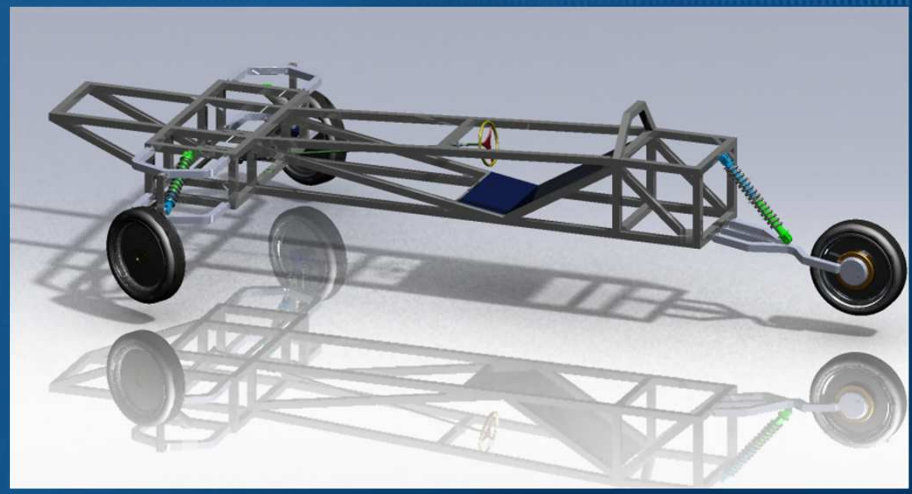
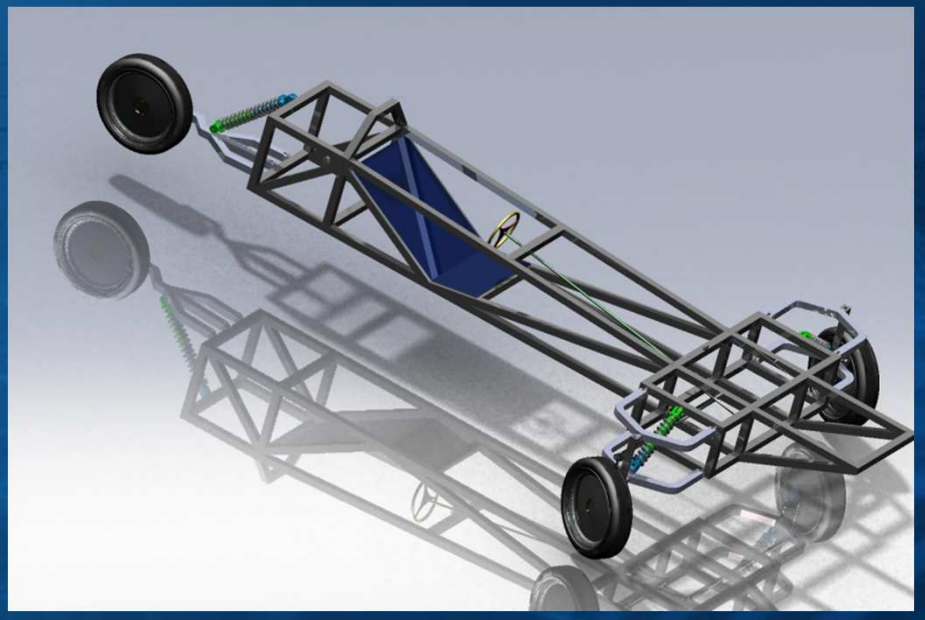
- Literature Review
- Solar Car Project:
  1. Objective
  2. Design Process:
     - A. Frame & Skin Design
     - B. Suspension System
     - C. Steering System
     - D. Solar Panel
     - E. Battery
     - F. Motor
     - G. Brake System
- Q and A





Introduction

How does it work?

Simply by using a solar panel to convert light energy from the sun into electrical power.

The power is transmitted by a wire to the motor, causing the drive shaft to turn.

The drive shaft causes the wheels to spin which let the car to move forward.

literature Review

According to:

Energy Information Administration

Saudi Arabia is the world's largest producer and exporter of total petroleum liquids.

Saudi Arabia is the fastest growing consumer of energy in the Middle East, particularly in the area of **transportation fuels**.

nergy Information Administration www.eia.doe.gov

COUNTRY ANALYSIS BRIEFS

Saudi Arabia

Last Updated: August 2008

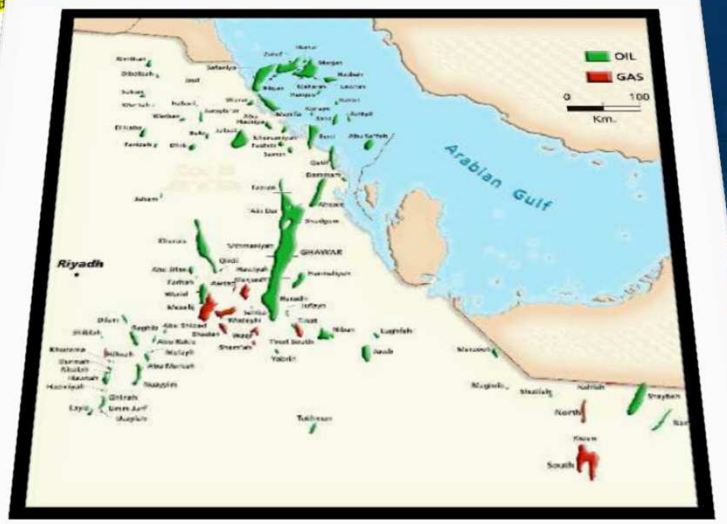
Background

Overview

Saudi Arabia is the world's largest producer and exporter of total petroleum liquids and is currently the world's second largest crude oil producer behind Russia. Saudi Arabia's economy remains heavily dependent on oil and petroleum-related industries, including petrochemicals and petroleum refining. The International Monetary Fund reported that in 2006, the last available data, oil export revenues accounted for around 90 percent of total Saudi export earnings and state revenues and above 40 percent of the country's gross domestic product (GDP).

Saudi Arabia is the largest oil producer f the Organization of the Petroleum Exporting Countries (OPEC). With approximately one-fifth of the world's proven oil eserves and some of e lowest production osts, Saudi Arabia is expected to remain the world's largest et oil exporter in the near and

Saudi Arabia's hydrocarbon sector operations are dominated by the state-owned oil company, Saudi Aramco. Saudi Aramco is the world's largest oil company in terms of proven or "booked" reserves and production of hydrocarbons. In addition, Saudi Arabia's Ministry of Petroleum and Mineral Resources and the Supreme Council for Petroleum and Minerals has oversight of the sector and Saudi Aramco directly. The Supreme Council, which is comprised of members of the royal family, industry leaders and government ministers, is responsible for petroleum and natural gas policy-making, including contract review, as well as Saudi Aramco's strategic planning. The Ministry is responsible for national planning in the area of energy and minerals, including



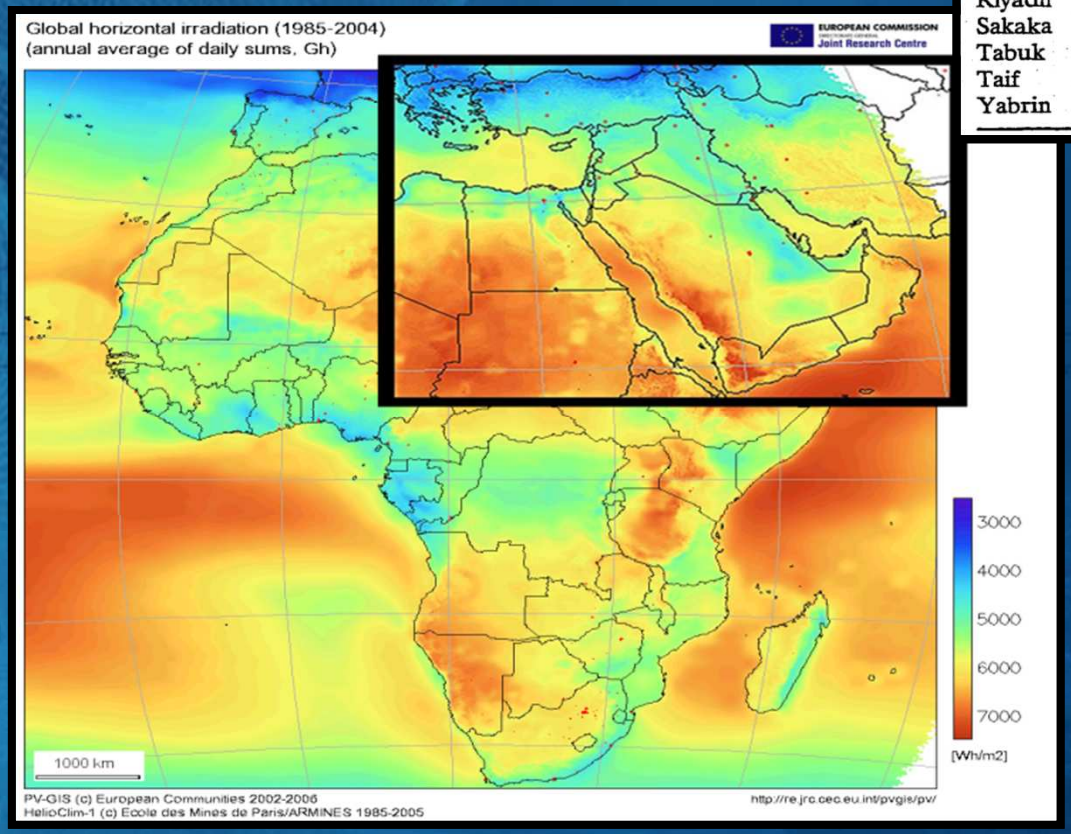
Source: Saudi Aramco

literature Review

According to:

According to King Abdulaziz City for Science and Technology (KACST) :

Station	North latitude	East longitude	Altitude (m)	Global radiation (Wh m^{-2})	Sunshine duration (hours)
Abha	18°13′	42°29′	2200	5824	8.7
Al-Hofuf	25°30′	49°34′	160	5671	8.7
Al-Qatif	26°33′	50°00′	8	4729	8.4
Bisha	20°01′	42°36′	1020	7004	9.2
Derab	24°25′	46°34′	0	6183	8.7
Hail	27°28′	41°38′	1010	5239	9.4
Madina Al-Munawara	24°31′	39°35′	590	6368	9.1
Najran	17°33′	44°14′	1250	6936	9.1
Qurayyat	31°20′	37°21′	2	5562	9.0
Riyadh	24°34′	46°43′	564	5132	9.2
Sakaka	29°58′	40°12′	574	5319	9.0
Tabuk	28°23′	36°35′	773	4479	9.1
Taif	21°14′	40°21′	1530	5429	8.9
Yabrin	23°19′	48°57′	200	5631	9.1

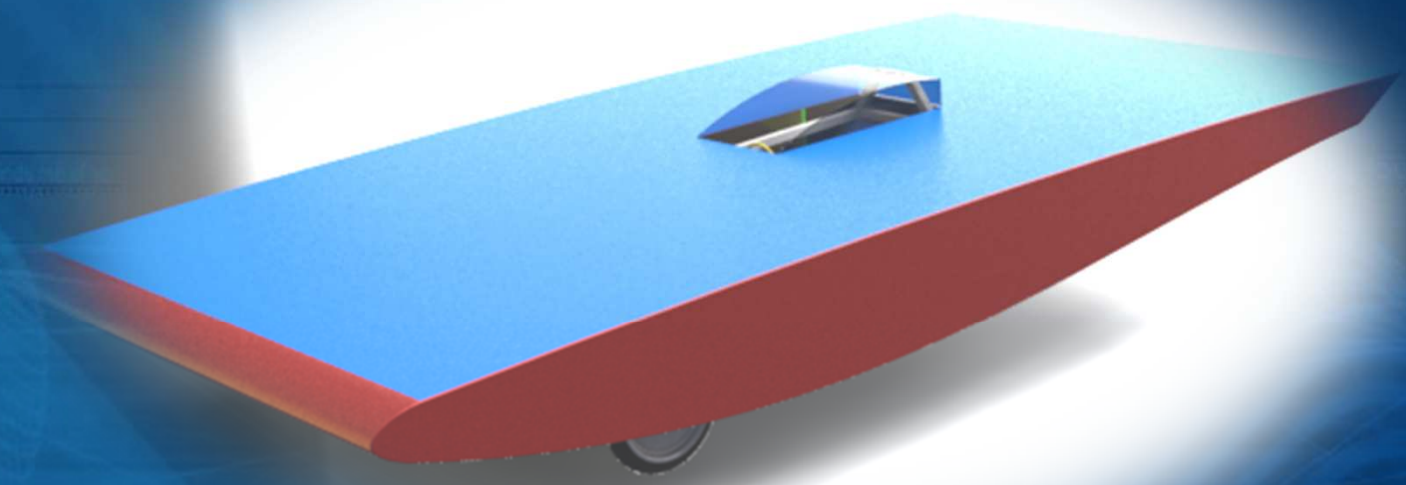


Saudi Arabia is located within the world's solar belt where high solar insulation allows for the efficient operation of solar cell

Solar Car Project

1. **Objective:**

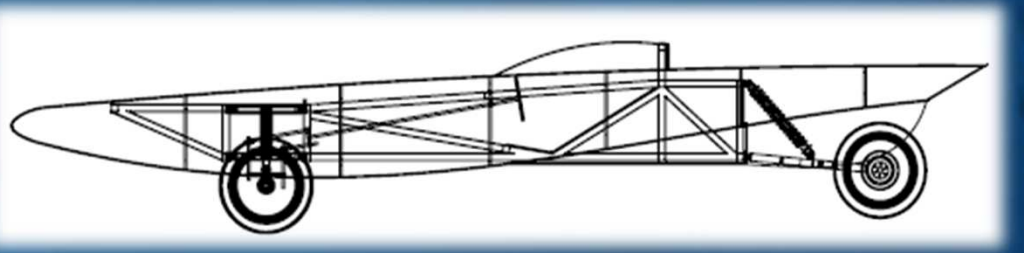
The objective is to design an intermediate speed solar car that can be manufactured and assembled locally in Saudi Arabia, so that it can be utilized to increase the public awareness about renewable energy systems.

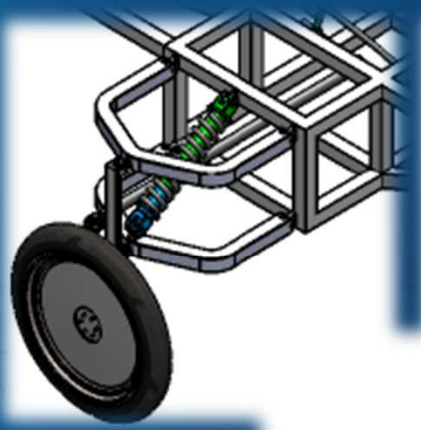


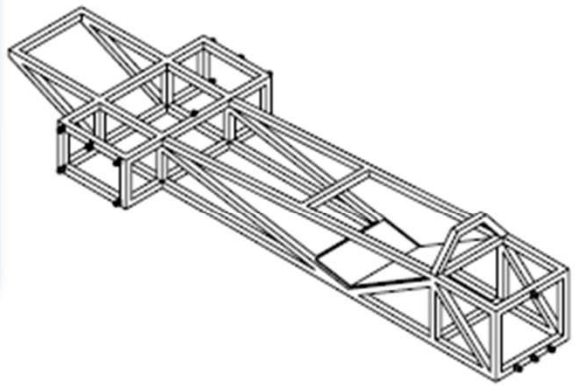
Solar Car Project

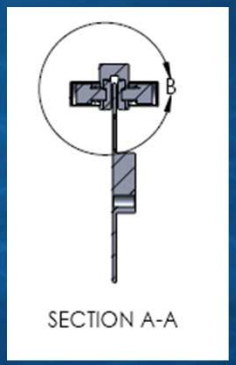
2. Design Process:

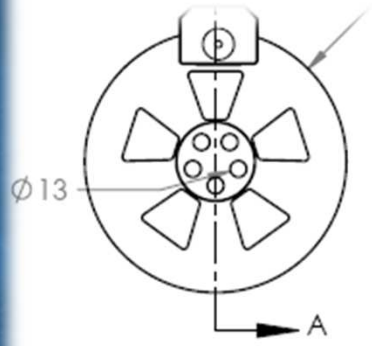
- A. FRAME & SKIN
- B. SUSPENSION SYSTEM
- C. STEERING SYSTEM
- D. SOLAR PANEL
- E. BATTERY SELECTION
- F. MOTOR SELECTION
- G. BRAKE SYSTEM

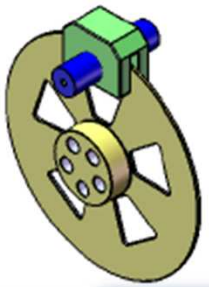








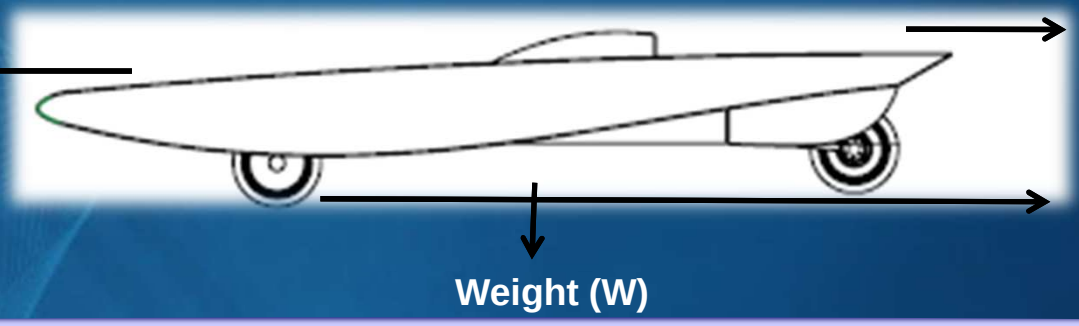




A B C D E F G

Frame & Skin

Introduction:



Because of the limited power the following aspects should be taken into consideration:

1. Reduce the drag force.
2. Reduce the weight.
3. Reduce the frictional force.
4. Reducing the required power.
5. Increasing the area exposed to sun light.

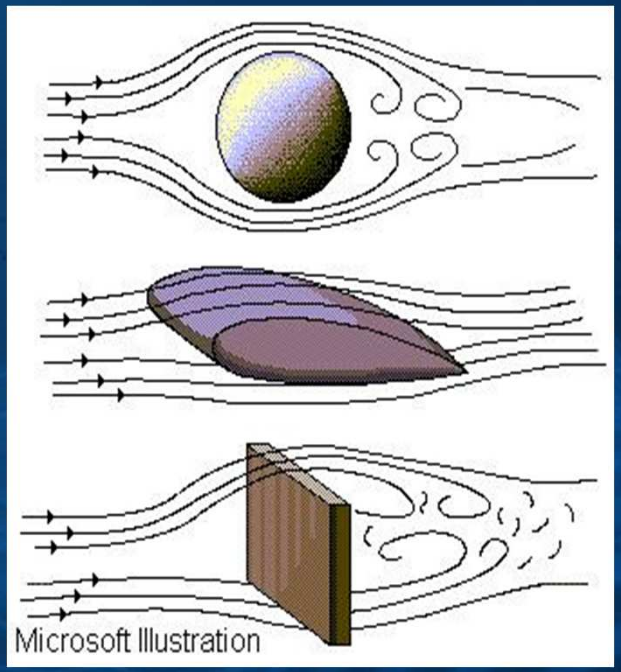
A B C D E F G

Frame & Skin

1. Drag Force

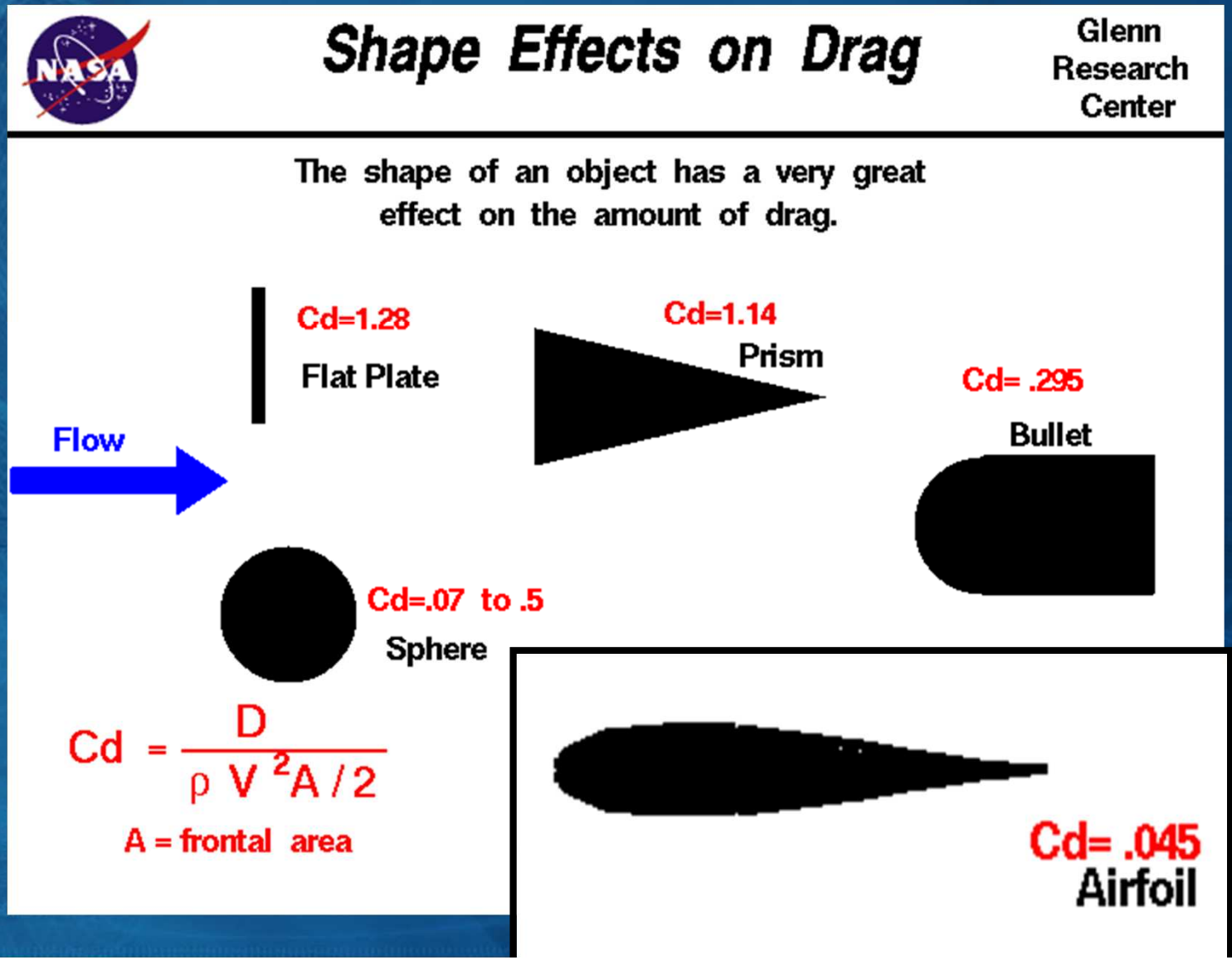
1) $F_d = \frac{1}{2} \times C_d \times A \times \rho \times v^2$

Where: C_d: is the drag coefficient
A : is the projected frontal area
v : is the speed of the car
ρ : is the density of air = 1.2 kg/m³



Frame & Skin

1. Drag Force

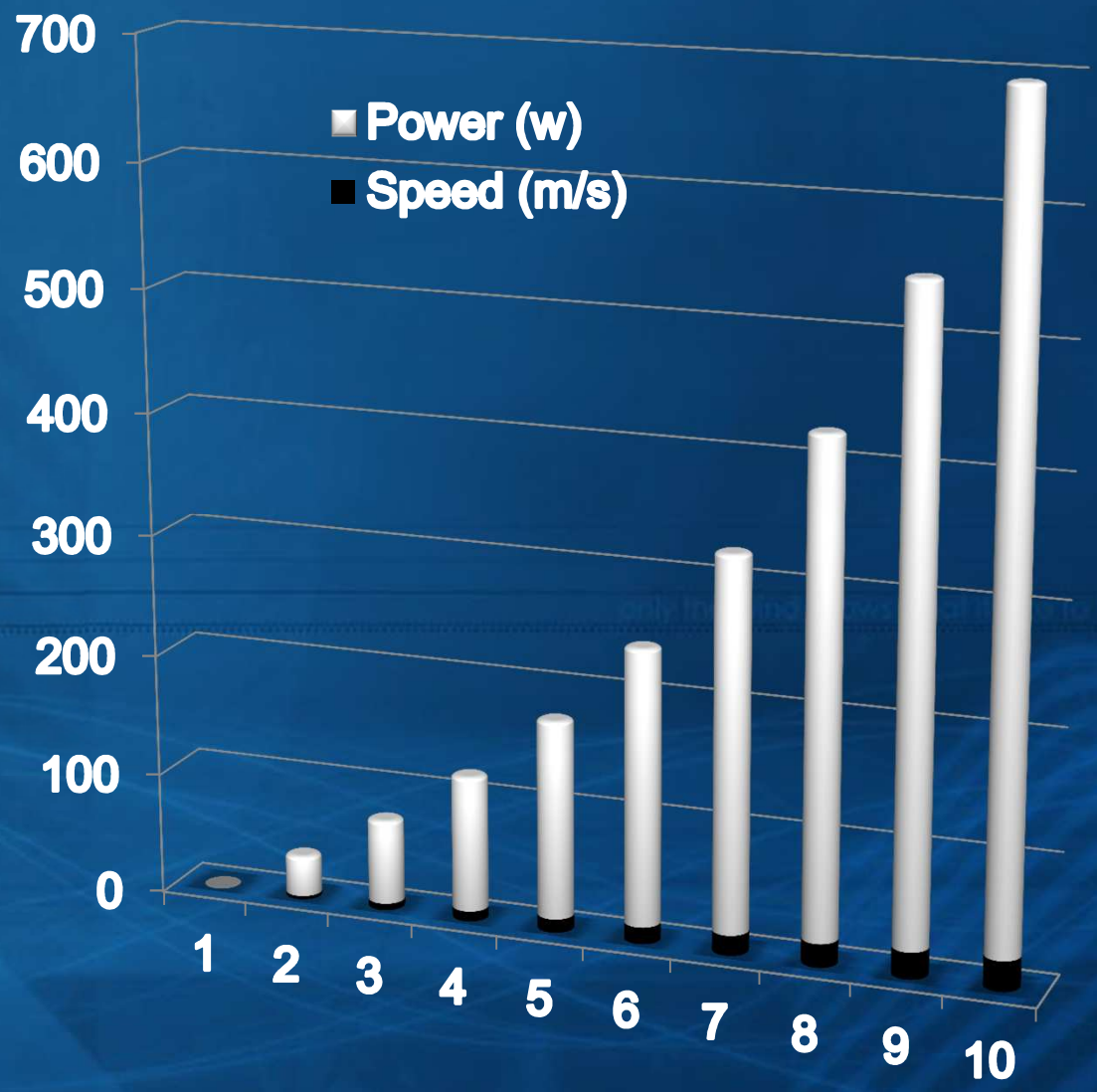


A B C D E F G

Frame & Skin

1. Drag Force

	Speed (km/h)	Speed (m/s)	Power (w)
1	0	0	0
2	10	2.77777	33.2144
3	20	5.5555	69.5152
4	30	8.33333	111.988
5	40	11.111	163.7218
6	50	13.8888	227.8004
7	60	16.6667	307.3111
8	70	19.4444	405.3492
9	80	22.22222	524.974
10	90	25	669.3



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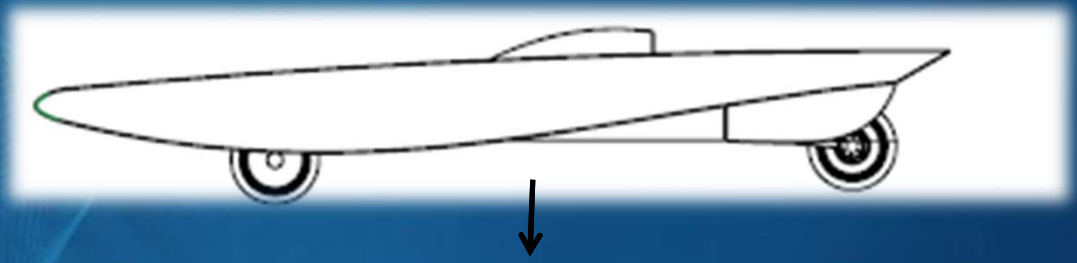
Frame & Skin

2. Weight of the Car:



More weight means more power required to move the car, So to reduce the car weight:

1. Light weight materials should be used.
2. Three wheels configuration.
3. Space frame design.

A B C D E F G

Frame & Skin

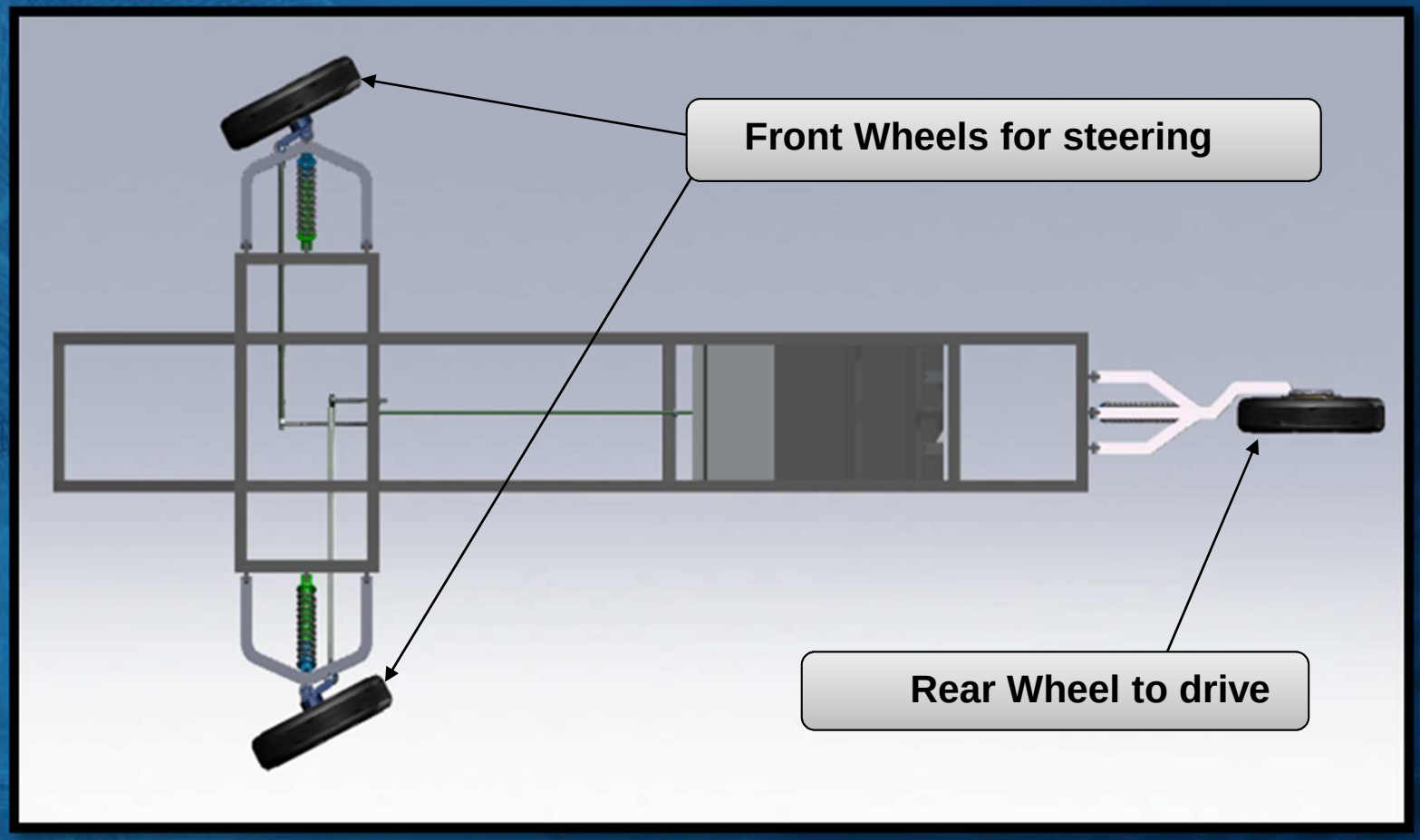
1. Light weight materials: Aluminum (**6061-T6)** is the best choice due to:

   A. Its light weight and high strength-to-weight ratio.
   B. commonly used and commercially available metal.
   C. Easy machining.
   D. Weld ability.

Physical and Mechanical Properties	**Ultimate Tensile Strength, psi**	**45,000**
	Yield Strength, psi	**40,000**
Chemistry	**Aluminum (Al)**	**95.8 - 98.6%**
	Chromium (Cr)	**0.04 - 0.35%**
	Copper (Cu)	**0.15 - 0.40%**
	Iron (Fe)	**0.70%**
	Magnesium (Mg)	**0.8 - 1.2%**
	Manganese (Mn)	**0.15% max**
	Silicon (Si)	**0.4 - 0.8%**
Zinc (Zn)	**0.25%**	

Frame & Skin

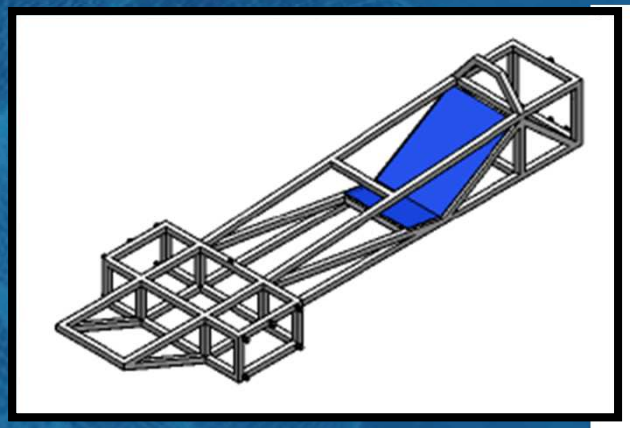
2. Three wheels configuration: this will eliminate a wheel which removes one quarter of the car's weight and reduces rolling resistance.

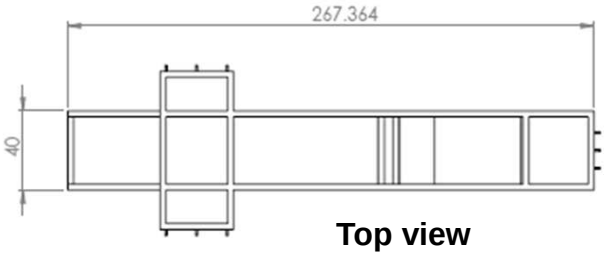


A B C D E F G

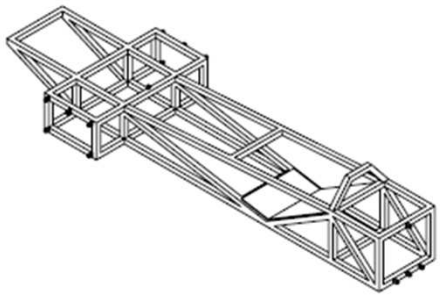
Frame & Skin

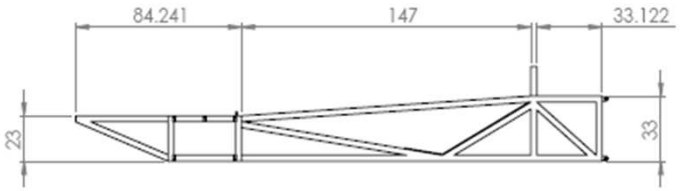
3. Space frame design: A square cross sectional tubes will be used because it is considerably easier to cut and weld at an angle.



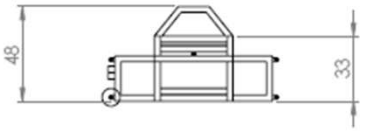


Top view

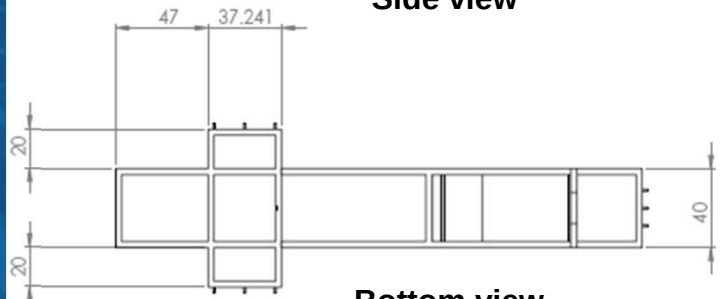




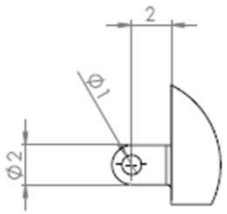
Side view



Front view



Bottom view

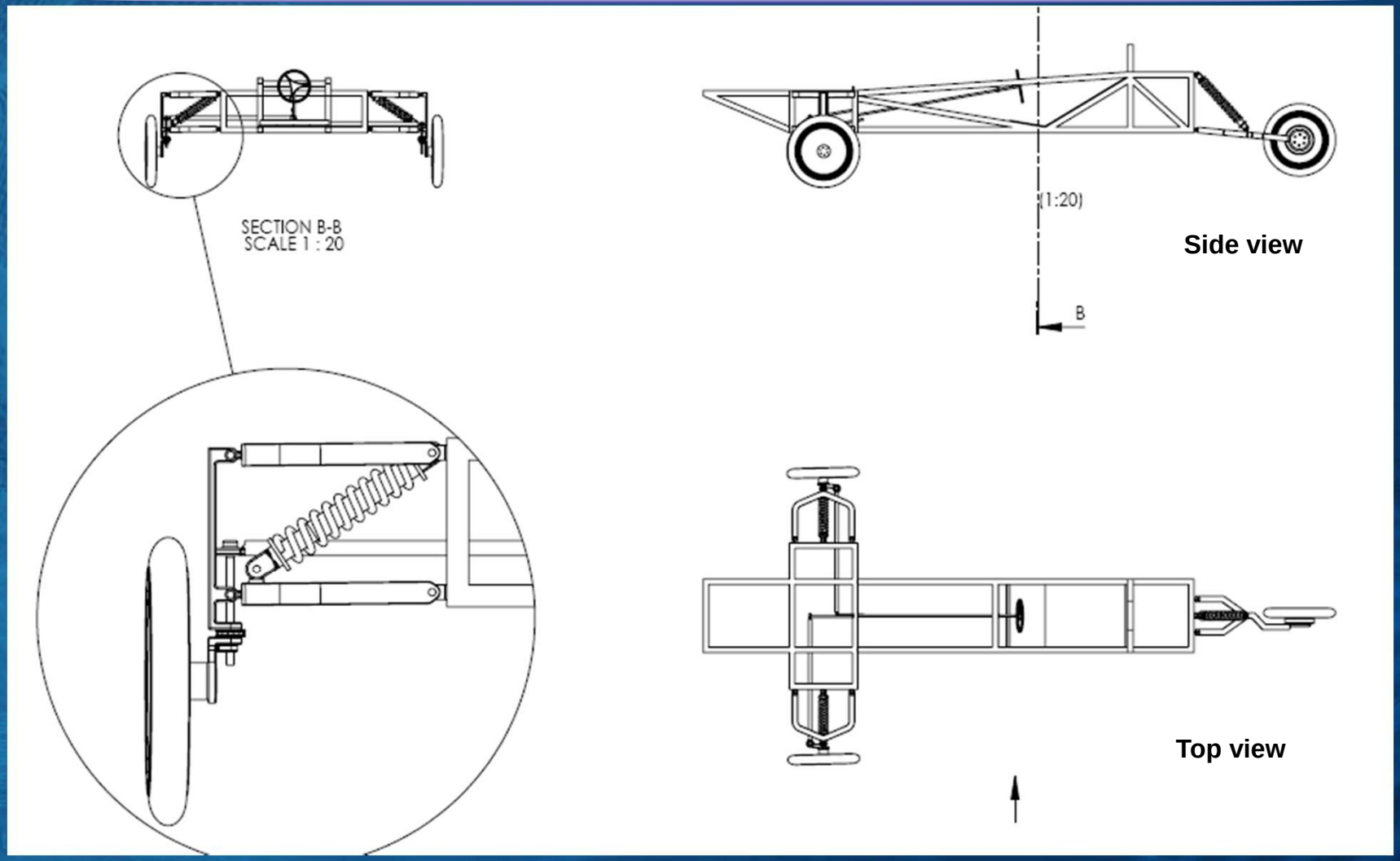


DETAIL E
SCALE 1 : 2

A B C D E F G

Frame & Skin

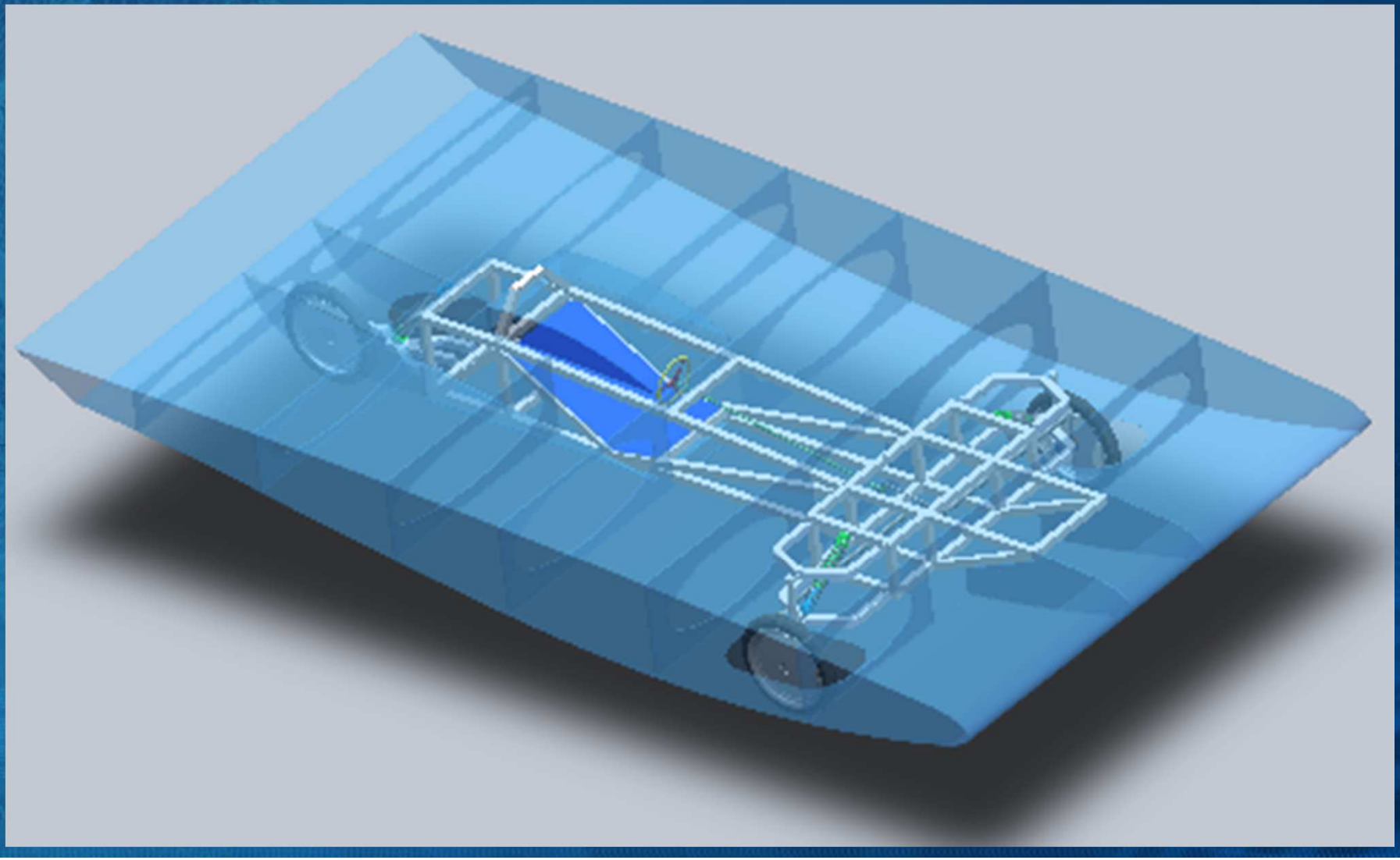
3. Space frame design: The wheels, motor, batteries and all other mechanical and electronics can be mounted on it and can be driven as a car.



A B C D E F G

Frame & Skin

3. Space frame design: The body of the car will be attached to the frame.



A B C D E F G

Frame & Skin

2. Weight of the Car:

The total weight of the car can be calculated and used to find the frictional force and the table shows the total weight of the solar car

Name	weight (kg)
Driver	70
Wheels	3.6
Breaking system	4
Steering	4
Motor	7
Solar panel	29
Battery	25
Suspension	9
Body	50
Frame	50
Others	20
Total Weight	212.6

Frame & Skin

3. Frictional Force:

Frictional Force (Fr)

2) Fr = Crr x W

Where: Crr : is the coefficient of rolling
W : is the total weight of the car

A B C D E F G

Frame & Skin

3. Frictional Force:

Wheel specifications:

Size: 2.15×16 in Tubeless type

Outer Diameter: 433.2 mm

Wheel Weight: 1,250g

Designed Wheel Load: 100kg

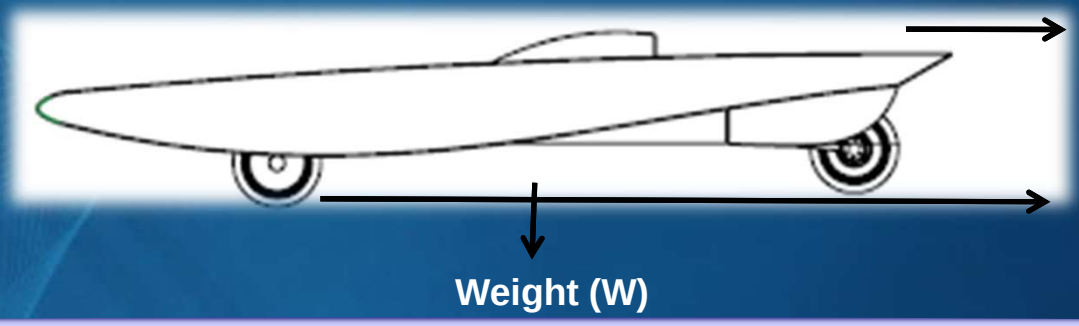
Compatible Tires: MICHELIN radial (Solar Car Type)

Tire Type	Rolling Resistance Coefficient (Crr)
Michelin Solar Car Radial	0.004
High Efficiency Production Tires (ie: used on GM EV1)	0.008
Typical SUV Tires (ie: Ford Explorer)	0.015

The Michelin Solar Car Radial is world-renowned for its low rolling resistance.

Frame & Skin

4. The Required Power:



3) $P = (F_{resistance})(v)$

Where: P : is the required power to overcome all resistance forces

V: is the speed of the solar car

F resistance: is the total resistance force which is equal to:

$$\sum F_{resistance} = F_d + F_r$$

Frame & Skin

4. The Required Power:

$$P = \{(Fd + Fr)\ (v)\ \}$$

Where: $Fd = \frac{1}{2}\ (Cd)\ (A)\ (r)\ (v^2)$

$Fr = (Crr)(W)$

$$P = \{((\tfrac{1}{2})\ (Cd)\ (A)\ (\rho)\ (v^2)\ ) + ((Crr)\ (W))\ (v)\}$$

$$P = (\tfrac{1}{2})\ (Cd)\ (A)\ (\rho)\ (v^3) + (Crr)\ (W)\ (v)$$

By susituting the value:

$$P = (\tfrac{1}{2})\ (0.05)\ (0.8)\ (1.2)\ (v^3) + (0.004)\ (2943)\ (v)$$

$$P = 0.0225\ v^3 + 11.7\ v$$

By assuming the car speed is v = 80 km/h

$$P = (0.0225)\ (80)^3 + (11.7)\ (80)$$

The required power to overcome the resistance forces is equal:

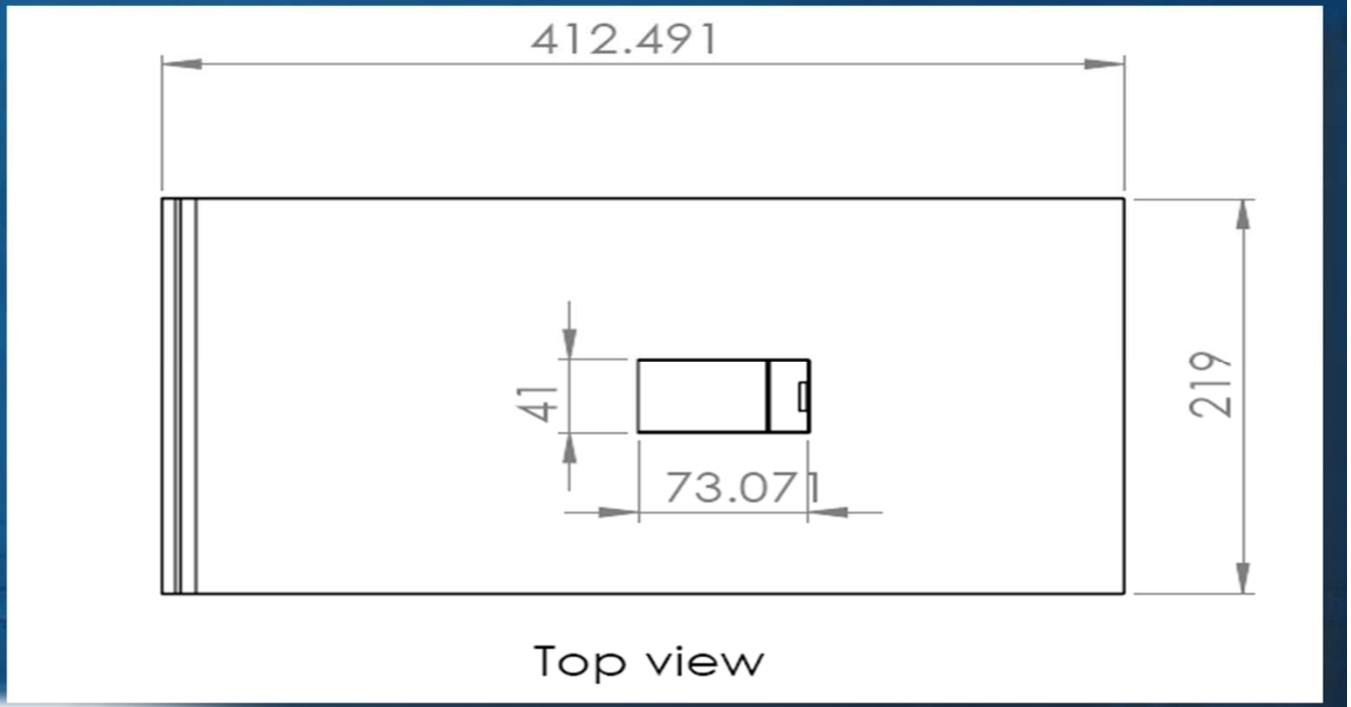
$$P = 524.9\ W$$

A B C D E F G

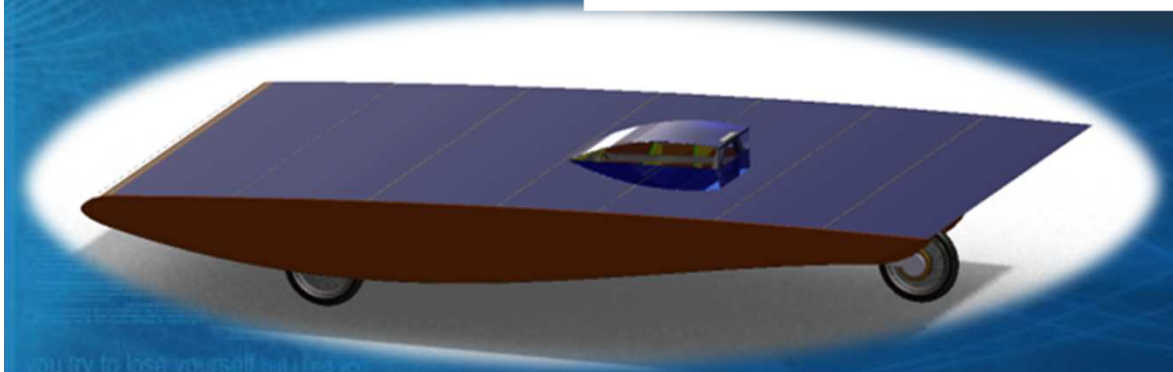
Frame & Skin

5. Increasing the Area Exposed to the Sun Light:

Total area exposed to the sun light is equal to:
8.3 m²



Top view

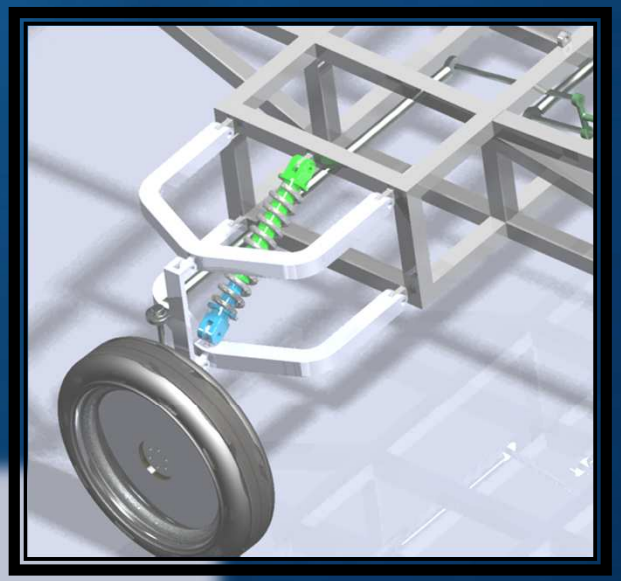


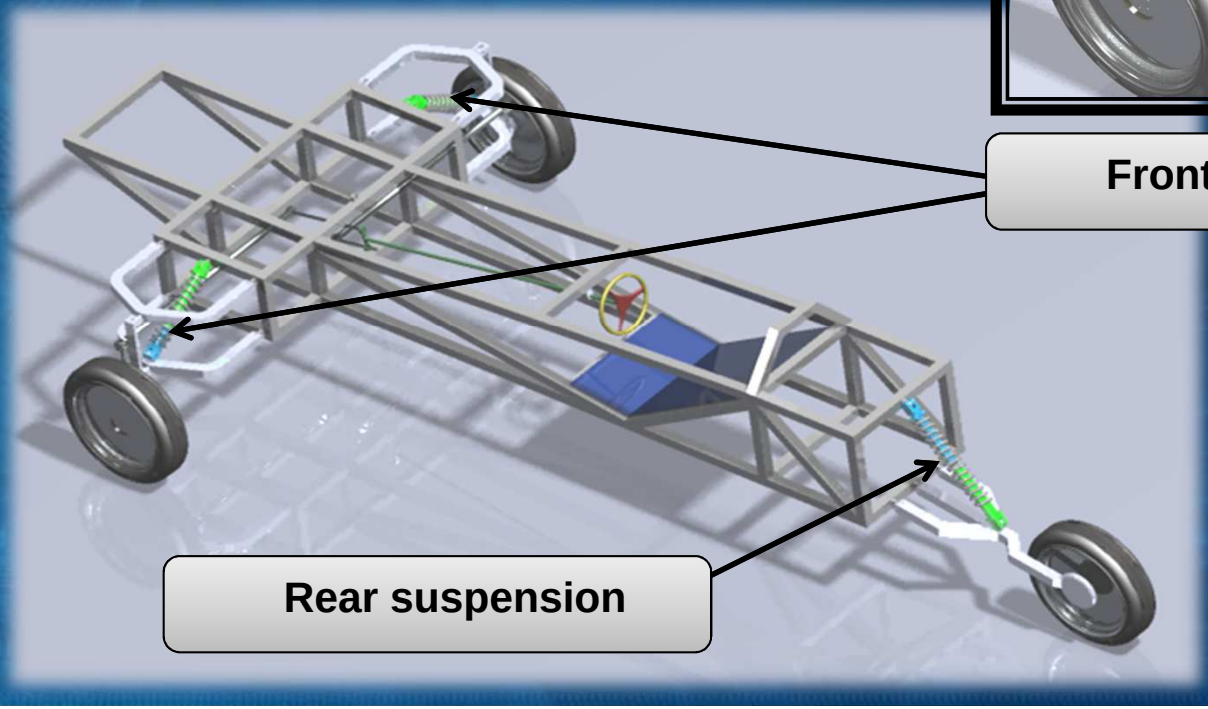
A B C D E F G

Suspension

It is the most complicated mechanical systems because:

1. It must allow the wheels to spin freely while transferring force from the wheels to the frame.
2. Absorbing shocks from bumps in the road.
3. Providing for mounting braking and steering components.





Front suspension

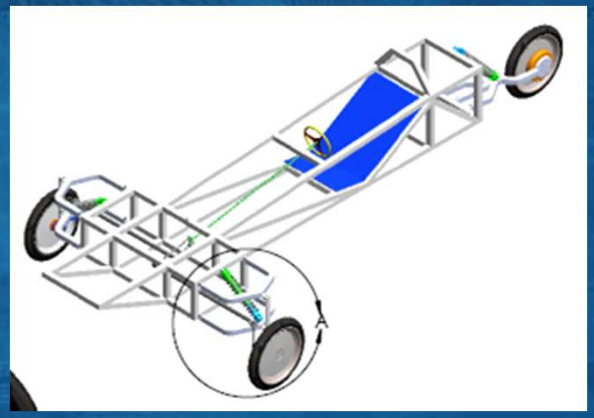
Rear suspension

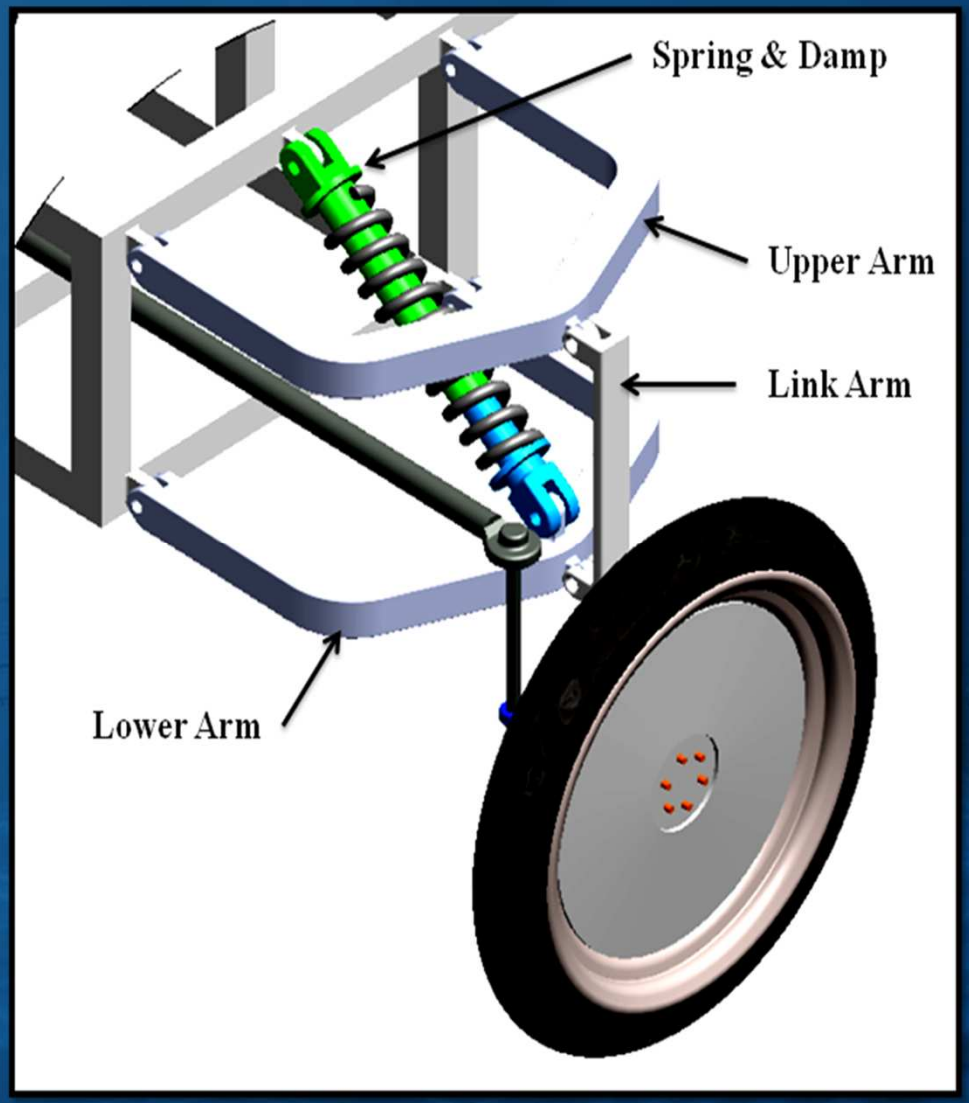
A B C D E F G

Suspension

It is consist of:

1. Upper arm.
2. Lower arm.
3. Coil spring.
4. Dump (Shock absorber).
5. Link arm.

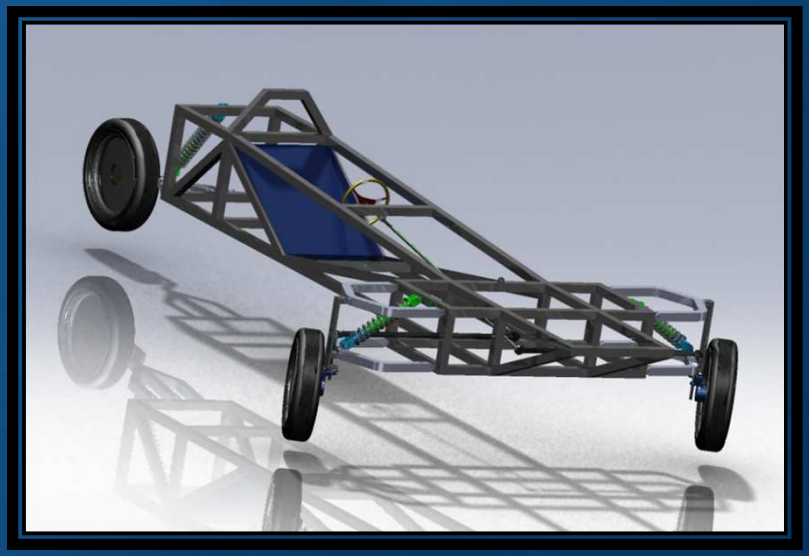


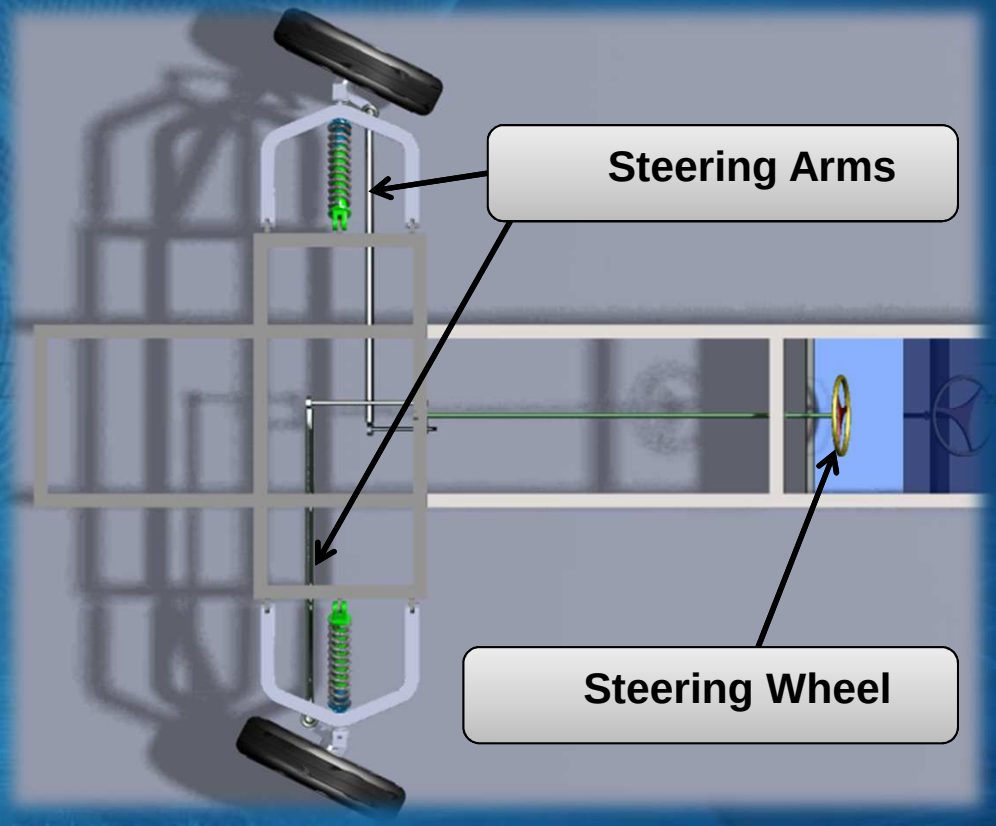


A B C D E F G

Steering

The two front wheels are connected by steering arms to the rod so that it can turned by a steering wheel.





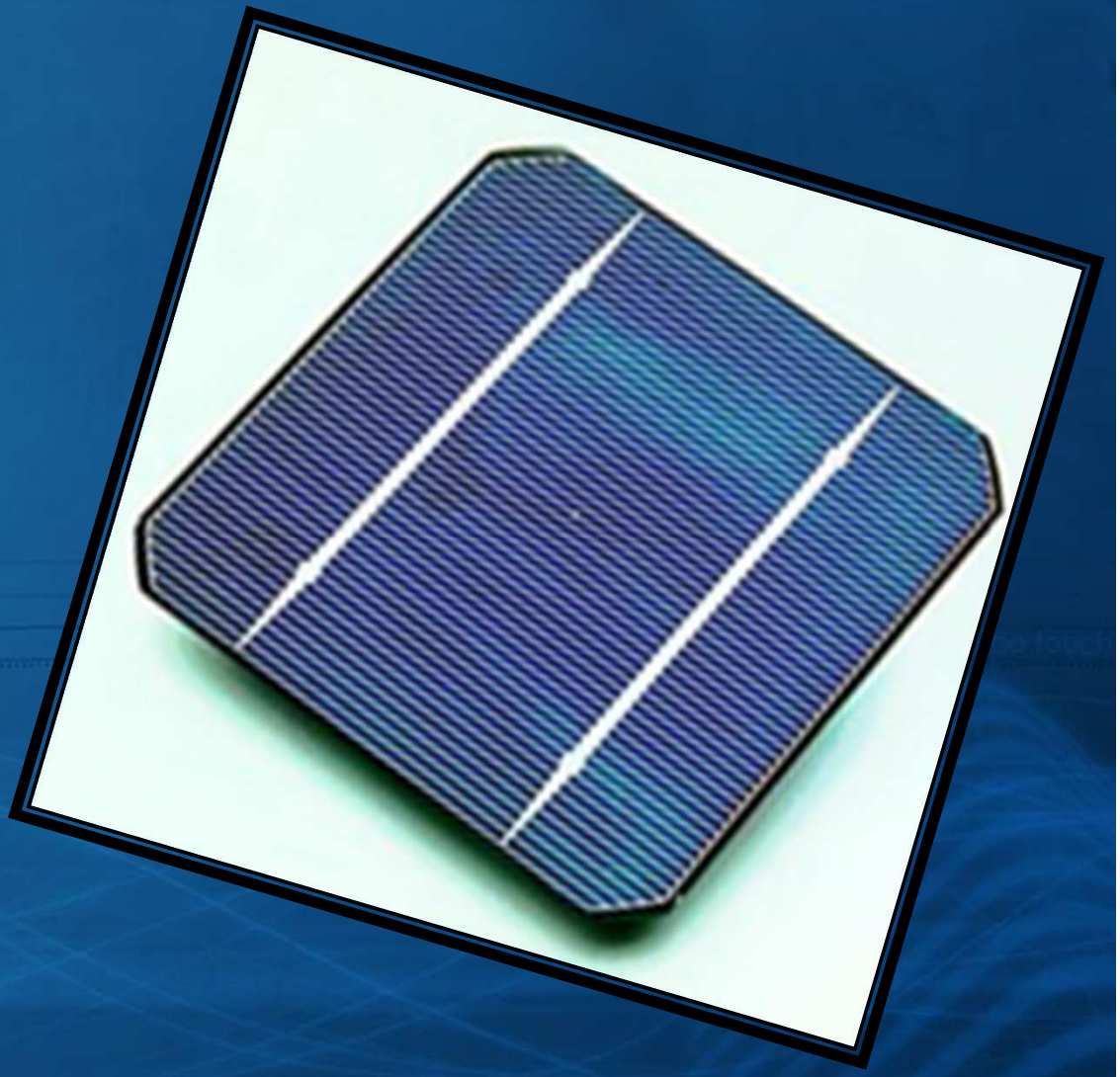
Click here to see the animation

A B C D E F G

Solar Panel

Introduction:

- What is solar panel ?
- How does it work?
- The types of solar panel
- How much it will produce?



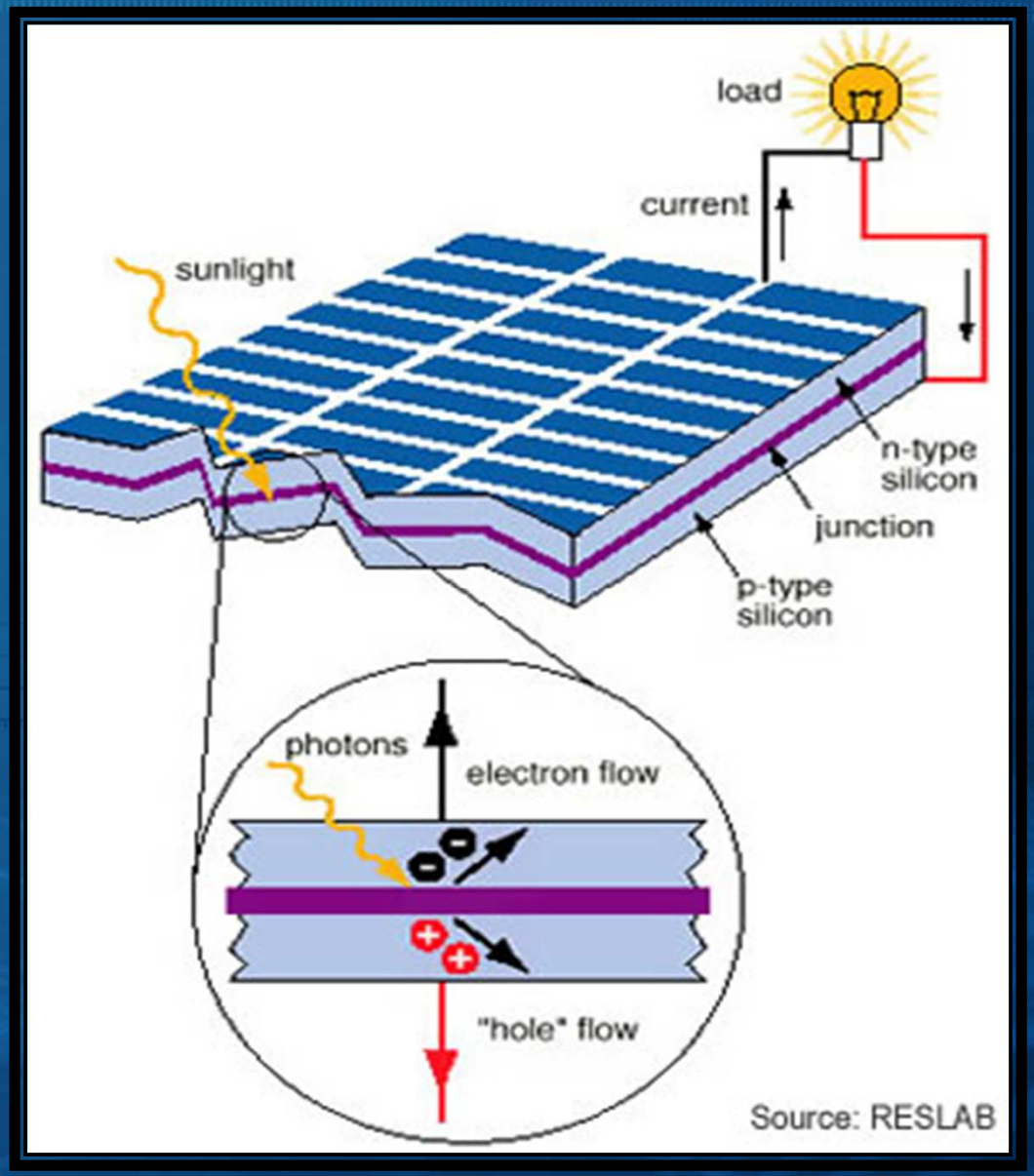
A B C D E F G

Solar Panel

- **What is solar panel ?**

It is consist of:

1. semiconductor
   p-type layer
   n-type layer
2. Junction
3. Contact s

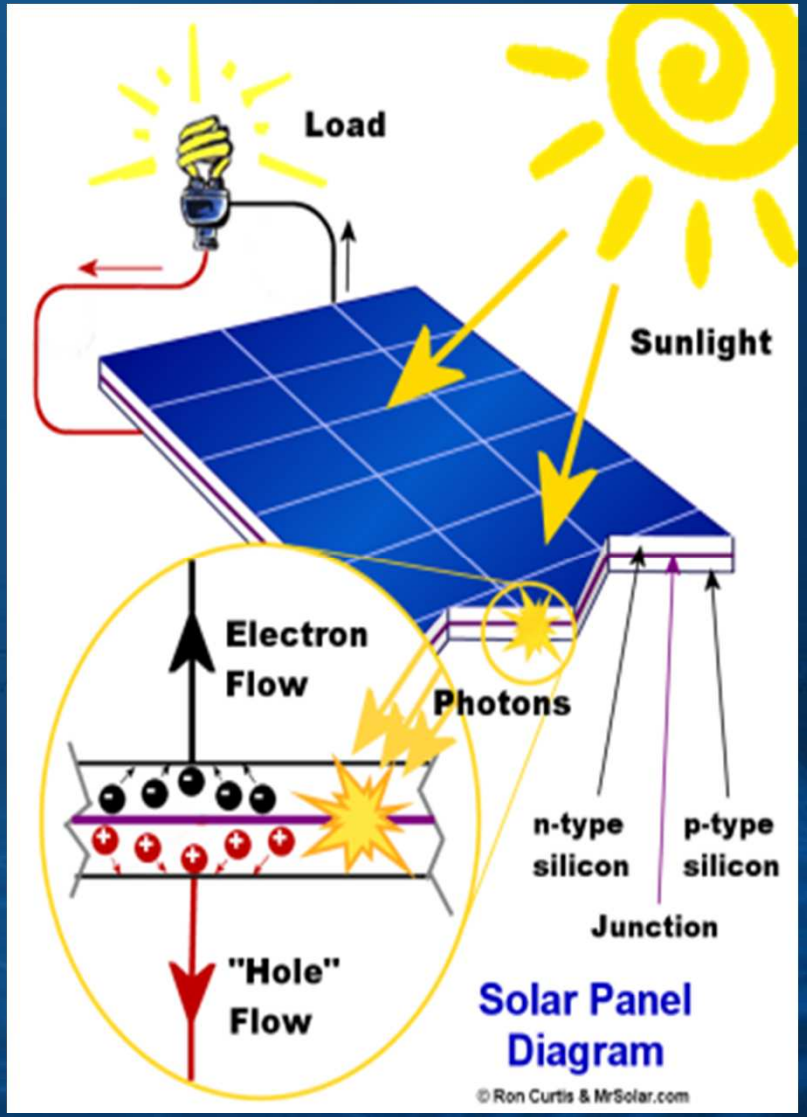


A B C D E F G

Solar Panel

How do solar cells work?

1. When sunlight shines on the cell, photons (light particles) bombard the upper surface.
2. The photons (yellow blobs) carry their energy down through the cell.
3. The photons give up their energy to electrons (in the lower, p-type layer.
4. The electrons use this energy to jump across the barrier into the upper, n-type layer and escape out into the circuit.
5. Flowing around the circuit, the electrons make the lamp light up.



A B C D E F G

Solar Panel

- **The types of solar cells**

1. Ribbon silicon

expensive , flexible and light but it has most less efficiency around 4% to 8 %

2. poly crystalline

Cheap but has less efficient around 8% to % 10

3. Mono-crystalline

it is more efficient compare with two previous 15% to 17%

A B C D E F G

Solar Panel

- **How much it will produce?**

P max **= (P in) (N / 100)**

P max **= (1000) (15 / 100) = 150 w**

Where: P max: is the maximum power.

N: is the maximum photovoltaic cells efficiency which is equal to 15%

Pin: is the energy arriving to the earth on is approximately equal to 1000 W/ m^2

The total maximum power output = A (P max)

(8.3) (150) = 1245 W

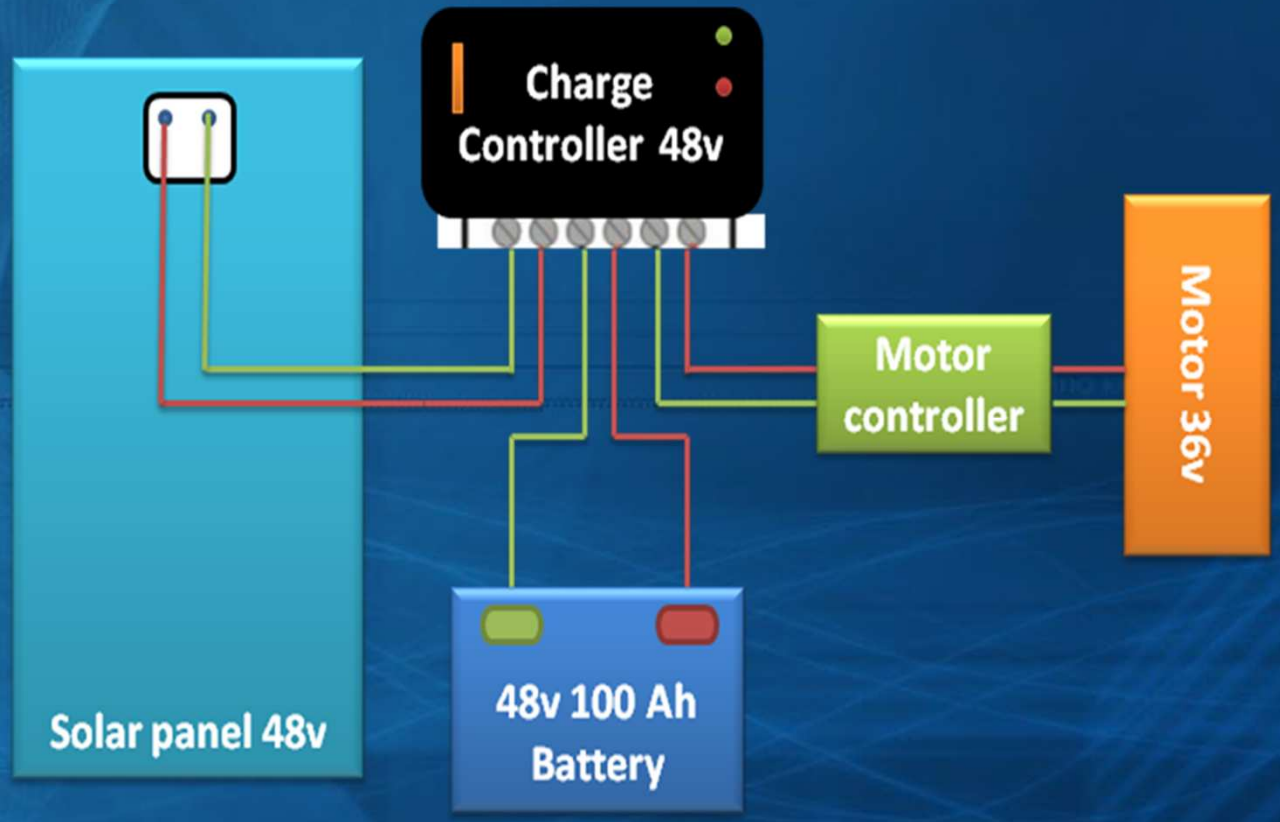
A B C D E F G

Solar Panel

Power Losses :

Assuming the power losses is 15 %

Total power losses = (15/100) (1245 w) = 186.75 w



A B C D E F G

Battery

The most commonly used is deep-cycle batteries and there are two types :

1. Nickel-cadmium batteries

more expensive and can be discharged more completely without harm

2. lead-acid batteries

cheap, available in market and it can discharge more of their stored energy

A B C D E F G

Battery

Battery specification:

Capacity of battery	Voltage of battery	Dimension	Weight
100 AH	48 volt	length =304 mm width =168 mm height = 210 mm	29 kg

The storage capacity of the battery:

Power = (current) (voltage)

The total storage capacity = 100 AH (48 volt) = 4800 watt

A B C D E F G

Battery

Solar Charge Controller:

The charge controller conditions the electricity coming from the solar array to maximize the power and deliver it either to the batteries for storage or to the motor controller for propulsion.

When the solar panel is charging the batteries, the charge controller helps to protect the batteries from being damaged by overcharging.

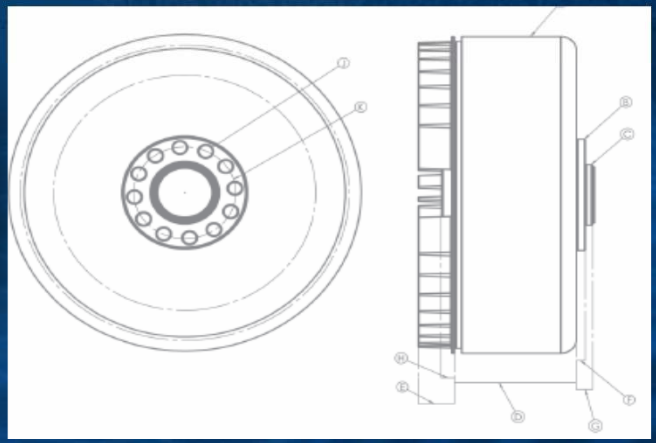
Solar Controller with LCD -48V

Motor

Introduction:

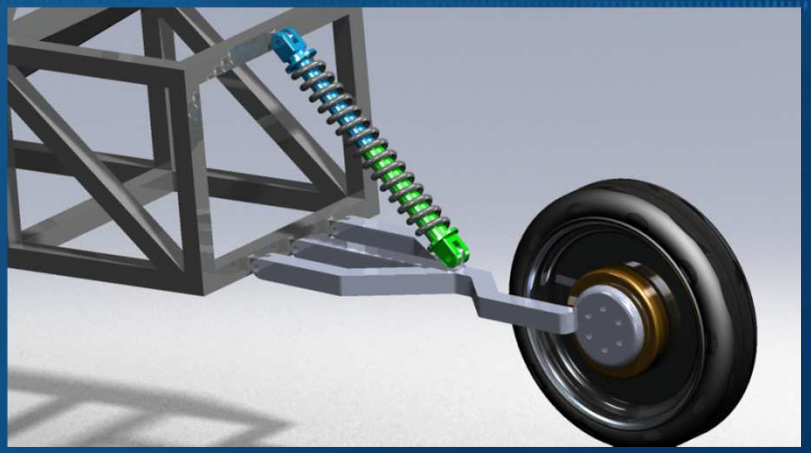
- Generate the torque required to move the vehicle.
- One motor
- Why?
  - Eliminate the power losses due to friction.

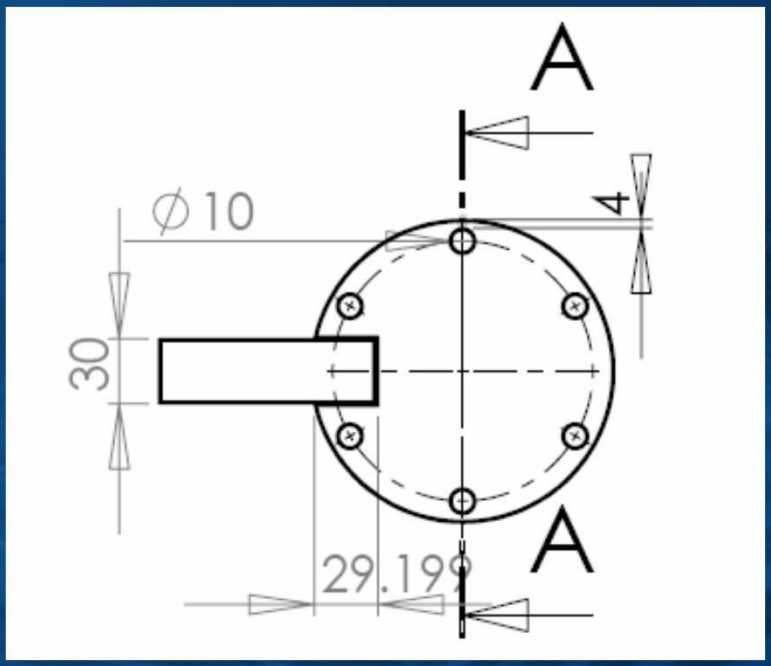
MOTOR TYPE	DIMENSIONS													
	A	B	C	D	E	F	G	H	J	K	L	M	N	Wt
EW15/30	149	66	n/a	70	20	9	9	4	m6 x6	32	m5 x5	52	60	4



Motor

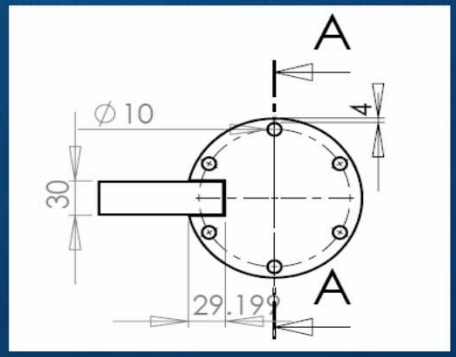
- Aluminum Disk
  - Carry the motor wheel
  - High safety factor
    - load from the car weight .
    - Fatigue stress.



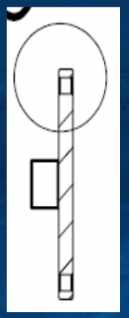


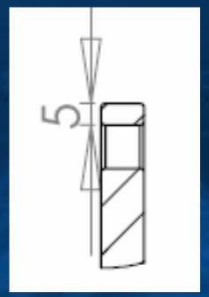
Motor

Stresses Analysis:



- Shear stress
  - Stress = F (force)/ A (cross section area)
    - Finding F
      - » Total load on the rear wheel = 350 * (2/ 3) * 9.8 = 2286 N
      - » F= 2286 / 6, F = 380 N
    - Finding A
      - » A = 0.01(disk thickness) * 0.005 (minimum distance between the 1cm hole and the aluminum disk edge)
      - » = 0.00005 m



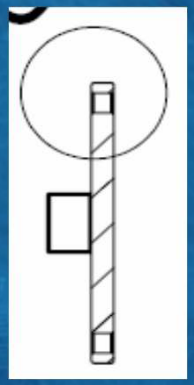


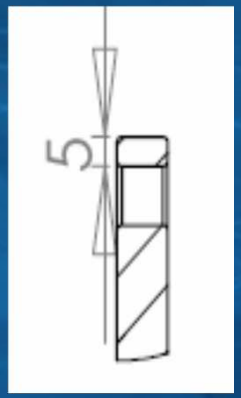
Motor

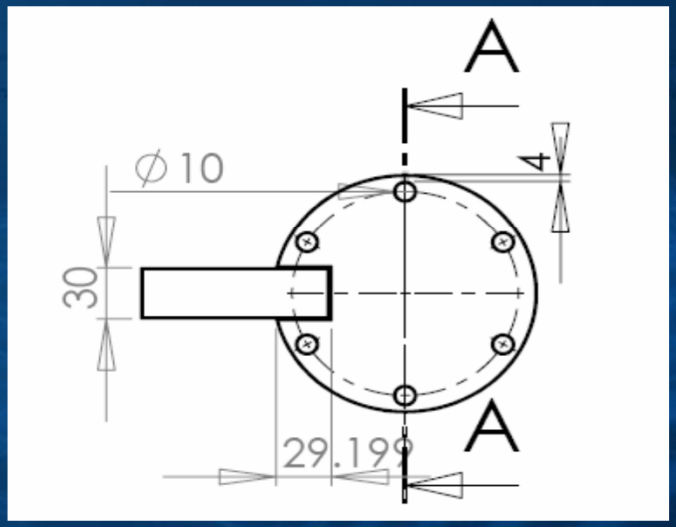
Stresses Analysis:

- Shear stress
  - Stress = F (force)/ A (cross section area)
    - A= 0.00005 m , F = 380 N
  - = 380 / 0.00005 m = 76 * 10 e4 Pa
  - Safety factor = 276 * 10 e6 / 76 * 10 e4

    Safety factor = 36



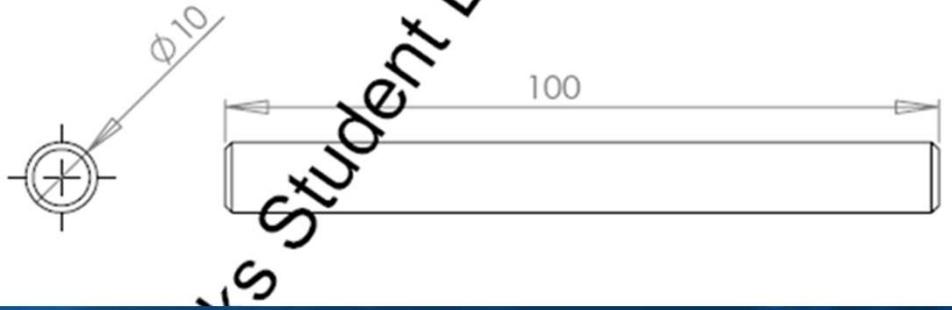




Motor

Stresses Analysis:

- Wheel motor bolts
  - The wheel motor has been designed to be attached on the car frame by six bolts.
    - Stress analysis
      - Stress = F / A
        - » A = 0.05^2(bolts radius)* pi = 7.9X 10^{-3} m^2
  - Stress = 380 / 7.9X10^{-3} m^2
  - = 48383 Pa
  - Safety factor = 620 X 10^6/ 48383 = 12814.



Motor

Wheel motor performance:

The motor supplies the car with maximum torque of 36 N.m

1500 watts ➔ 1500 RPM

TEST DETAIL MOTOR RATINGS	UNIT	EW15	
		30	60
Peak Stall Torque (30 sec)	Nm	36	48
Continuous Stall Torque	Nm	9	12
Rated Power	Watts	1350	1800
Rated Speed	RPM	1500	1500

Motor

Car acceleration:

To find the acceleration of the care we apply Newton's second law.

F (force**)= m (**mass**)* a (**acceleration**)**

a = F / m

F = T (torque)/ r (radius)

F = 36 / 0.2205 = 163.3 N.

a = 163.3 / 350 = 0.47 m/s

50 Km/h after half minutes.

Motor

Maximum speed:

The car need 1350 watt to rotate 1500 rpm. As per car dimension and solar cell type that has been selected it will give 950 watt.

1350 watt ➔ 1500 rpm

950 watt ➔ X rpm

1350 / 950 = 1500 / X

X = 1055 rpm

(1055 (speed in RPM)* 2 * pi) = 110 rad / s

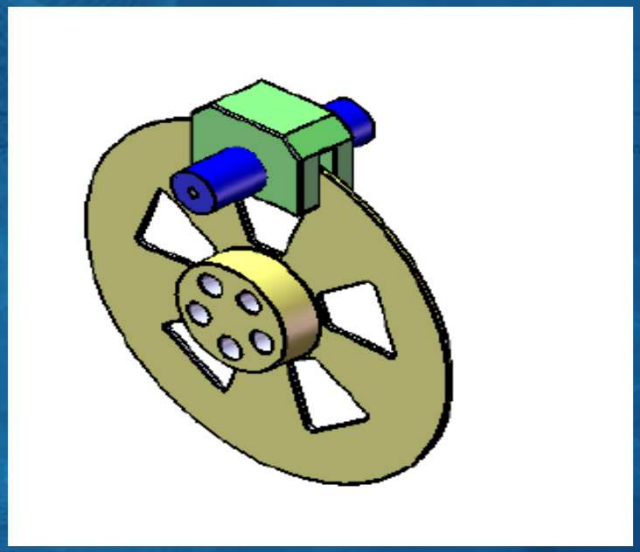
110 (angular speed)* 0.2205 (wheel radius) = 24 m/s = 86 Km/h

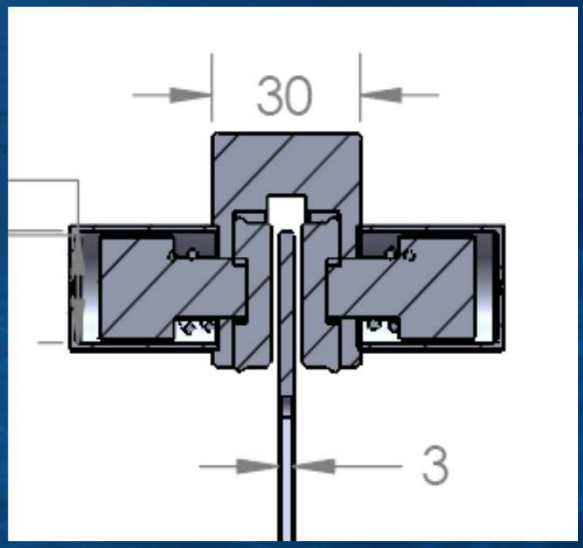
A B C D E F G

Brake System

Introduction:

- The brake system is designed to be assembled in the front wheels.
- Hydraulic system
- Difference in area cross section of pistons.





Brake System

Brake caliber support:

Maximum velocity will be considered as the car velocity to test the support at maximum force.

Assumption the brake disk will stop after 5 second.

P (momentum)= V (velocity) * m

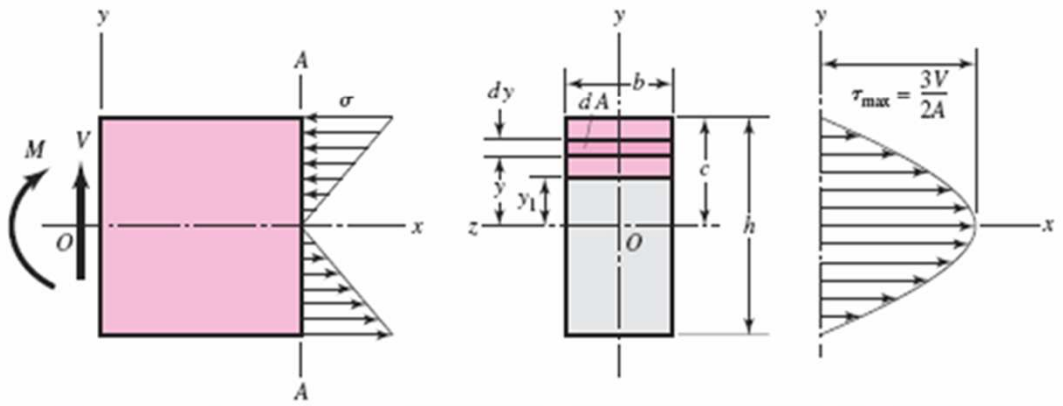
P = 350 * 24 (max velocity) = 8400 Kg. (m/s)

F = 8400 / 5 = 1680 N

Brake System

Stresses Analysis:

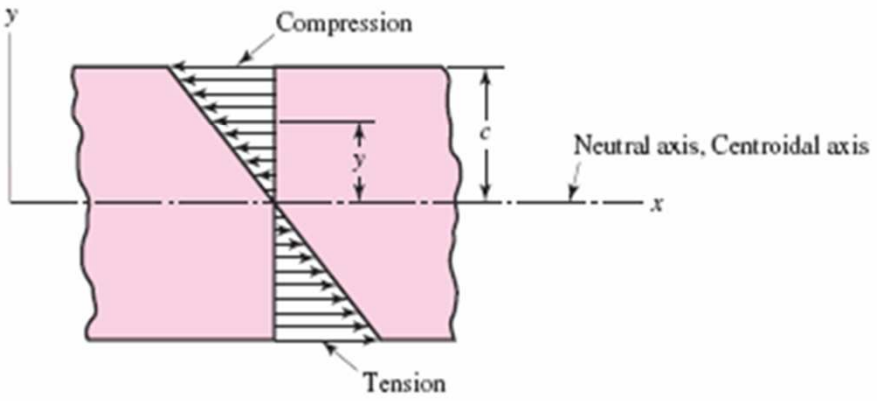
- Brake will designed in minimum safety factor of 20
- Yield strength of Aluminum = 276 $X10^6$ Pa
- Max stress = 276 $X10^6$ / 20 = 138 $X10^5$ Pa
- Max shear stress = 3V / 2A
- 138 X_{10^5} = 3(1680) / 2A
- A = 1.8 $X_{10^{-4}}$ m2



Brake System

Stresses Analysis:

- Normal stress
- Max normal stress = Mc / I
  - M (bending moment)
  - c (max distance from natural axis)
  - I (second moment of area)



A B C D E F G

Brake System

To be discussed:

Torque applied by the brake.

- Brake bad friction.

How the brake caliper will be support.

- Area
- Second moment of area

Suspension spring

- Spring constant
- Displacement

Dumper mechanism

Baring selection

Questions and Answers