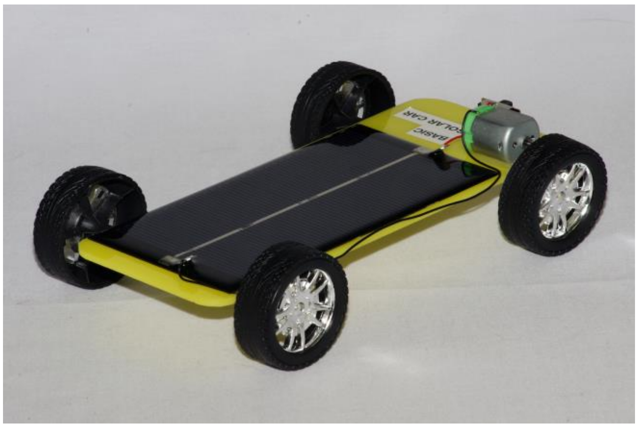
SOLAR CAR – BASIC

CONTENTS:

DESCRIPTION

The SOLAR CAR - BASIC is a simple four-wheeled vehicle, driven by an electric motor, powered by a solar panel. Power to the wheels is transferred from the motor by gears. This car will run on a smooth level surface from 25% sunlight upwards.



The solar panel consists of one large section producing 2.0 Volts and 0.87 Amps of electricity, under a 100% sunlight condition.

The illustration shows the prototype vehicle. The concept has limited scope for variation. Students should design a vehicle to suit their own needs.

SECTION 1: GENERAL AND PLANNING INFORMATION

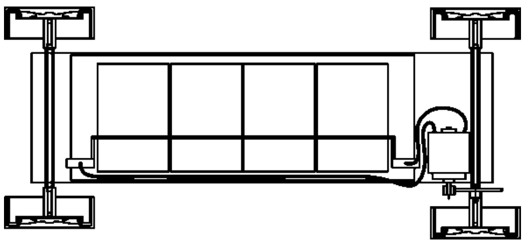
1. DESIGN CONSIDERATIONS

1.1 GENERAL

Before starting construction, the student needs to carefully plan and layout all of the components:

- The plan view of our prototype vehicle is shown below.
- The exploded view indicates the relationship between the various components.
- The design of the SOLAR CAR should be considered as a complete unit, not just as separate parts.
- The student needs to determine the material from which the platform is to be constructed.

When deciding on the platform's size and shape:



- The platform can be made from any size piece of material, even a very narrow one, in which case stability needs to be considered.
- The axle shaft and guide tube length provides an upper limiting factor for the width (i.e. across the wheels).

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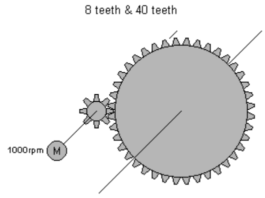
NOTE: Cut-outs may be made for the wheels to allow a wider vehicle to be constructed

Other things to consider:

- The designer needs to determine which gears will be used - a selection of spur and pinion gears are provided, and a number of combinations are possible with the supplied gears and provide a choice of different performances (acceleration and top speed).

- The student should calculate the ratios available and determine which spur gear / pinion gear combination to use.
- How do these various ratios translate into actual speed? Take into account wheel size and motor speed (how fast does it spin under full sunlight? On an overcast day?).



NOTE: Maximum motor speed at maximum efficiency is approximately 7,350 rpm.

- The vehicle shown in our drawings is basic but allows scope for the student to develop and make a more sophisticated vehicle.
- The vehicle can only travel in a fixed direction - either straight ahead or in a fixed circle (which can be achieved by fixing the front axle shaft on an angle).

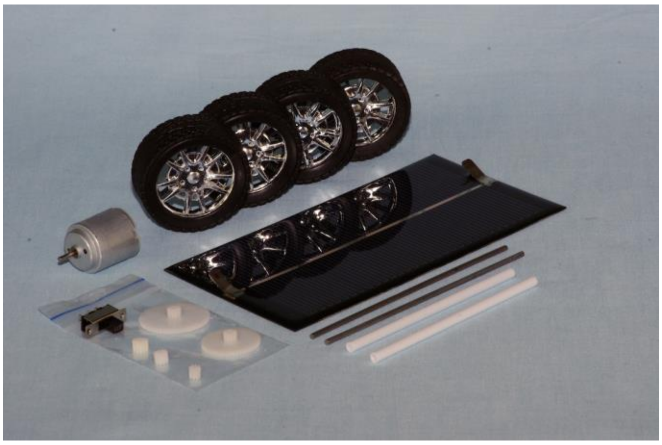
1.2 ITEMS FOR INVESTIGATION

This project provides a number of different aspects of the SOLAR CAR for investigation. Some ideas are listed below.

- To generate electricity the solar panel needs to be placed in direct sunlight. The amount of sunlight available varies all the time, and will not generate the same power every time. To measure the intensity of the sunlight a calibrated #10 Solar panel can be used together with a multi-meter.
- If working in a class, you may wish to assemble a number of these vehicles with different gearing. This will allow you to test the calculations made for the various gearing combinations. This can be tested using a stopwatch over a known length of track (or a variety of distances) to establish when top speed is reached, and what that top speed is. Or you may wish to race them (Section 6 has a suggested track)
- Evaluate the suitability of various materials for the platform, such as PVC, acrylic, plywood or balsa wood.

SECTION 2: COMPONENTS & MATERIAL REQUIRED

2.1 **COMPONENTS SUPPLIED**. The following components are supplied in the kit:



2.2 ADDITIONAL REQUIREMENTS

The following material is to be supplied by the student / designer:

- Electric hook-up wire – Multi-strand
- Hot glue or double-sided foam tape
- Material for the platform (PVC or acrylic sheet, plywood, etc.) We used 3.0mm thick PVC sheet (approximately 90mm x 250mm) for this project.
- NOTE: Plastic materials can be purchased from plastics suppliers (in the Yellow Pages under the heading "Plastics Fabricators" or search the Internet.)
- If you choose to modify the design, or carry out testing as described later, our component range has an assortment of items that may be useful. These include: on-off-on toggle or slide switches, and steering components.

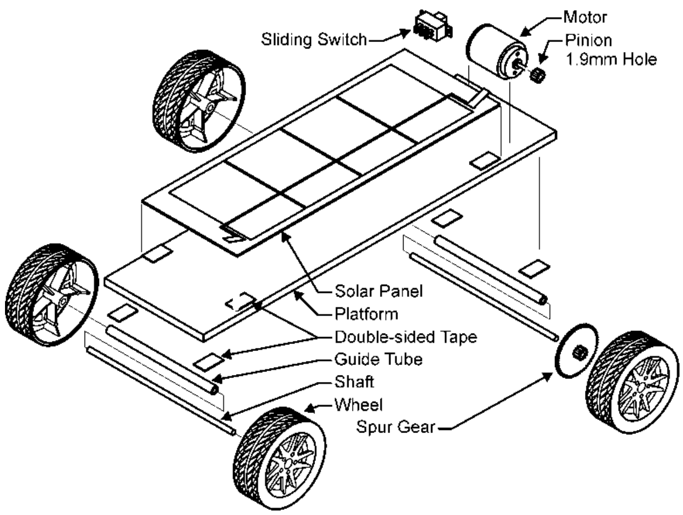
2.3 TOOLS REQUIRED

The following tools are required:

- Assorted hand tools
- Soldering equipment and solder

SECTION 3: ASSEMBLY

3.1 FABRICATION



Cut the platform material to the required size and shape.

Cut the steel shafts to the required length - de burr the ends with a file.

HINT Place a nail or piece of wire into the wheel hole to measure its depth.

HINT: The length of the steel rod needed is worked out by taking the length of the plastic tube plus 2 times the depth of the wheel hole (i.e. for both wheels) plus 2 mm for clearance (so the wheel will not jam up against the plastic tubing).

HINT: When working out the rear axle length, remember to allow for the large (spur) gear as well.

- Press the selected spur gear onto the rear shaft, with enough of the shaft protruding through the gear, to push the wheel onto.
- Insert the shafts into the guide tubes. Press the wheels onto both shafts.
- Press the selected pinion gear onto the motor's shaft

HINT: Place the gear on the bench, insert the motor shaft into the pinion gear's hole and gently tap the end of the shaft (where it exits the motor) with a small hammer. Stop when the pinion gear is level with the end of the shaft - do not push the gear too far, or it will rub on the motor casing.

WARNING: Don't just push the motor down by hand as this can push the motor armature out of its bearings and jam the motor.

3.2 ASSEMBLING THE SOLAR CAR

NOTE: the best methods for attaching items to the chassis are either hot glue or single and double sided tape.

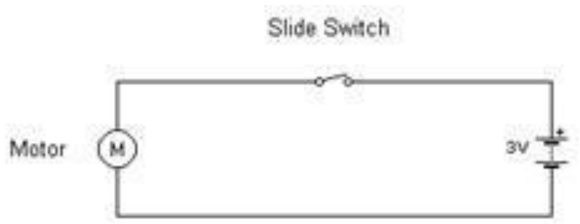
WARNING: If using hot glue, be very careful as it can burn you, if you get it on yourself.

- Attach the solar panel to the platform using double-sided foam tape.
- Attach the pre-assembled front axle (guide tube, shaft and wheels) to the platform with hot glue.
- Attach the pre-assembled rear axle to the platform.
  NOTE: Make sure that the rear shaft guide tube is at right angles to the car's platform and both guide tubes are parallel to each other – unless you have chosen for the car to travel in a circular path.
- Use hot glue or double-sided foam tape to attach the motor to the platform. The pinion gear should engage the larger diameter gear of the rear wheel's spur gear, and the motor and wheels should turn freely.
- Attach the switch to the platform.

SECTION 4: WIRING

HINT: When soldering wires, strip a short piece of insulation from the end of the wire, twist the strands and "tin" them using a hot soldering iron to apply solder to the ends.

- Solder wires to the switches end terminals. These are then soldered to the solar panel's terminals – one to each.
- Solder two additional wires to the switch's middle terminals.
- Connect the two wires, from the switch's middle terminals to the motor terminals, but do not solder them yet.
- Push the sliding switch to the "on" position:
  - If the vehicle moves forward, solder the wires to the terminals.
  - If it goes in reverse, swap the wires and then solder them.



WIRING DIAGRAM

SECTION 5: TESTING

5.1 SUNLIGHT VERSUS ARTIFICIAL LIGHT

For testing your car a good substitute for sunlight is a powerful halogen lamp. Mains powered halogen flood lamps are readily available from lighting shops or hardware suppliers.

A 500 watt lamp directly facing the panel and about 300mm away, will produce a light level equivalent to about 50% Sun.

CAUTION: The lamp puts out more heat than the sun, so to avoid panel damage only illuminate the panel for about 40 seconds – then allow the panel to cool down.

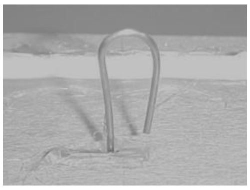
A safer option is a low voltage 100 watt handheld halogen spotlight. This type of lamp is available from automotive accessory stores and is usually 12 volt rated. You will need a suitable battery or power supply. This lamp is suitable to demonstrate power generation (with the vehicle held in the air) but is not sufficient to run a vehicle.

NOTE: In the classroom, the light may appear very bright to our eyes, but the car does not run as the light level is far too low for the solar panel to produce useful quantities of power. Fluorescent lights are a poor substitute for sunlight, as the frequency of light they produce is very different from the sun. Incandescent lamps are much better, however remember that full sunlight is around 1000 Watts per square metre. In a typical room at home you might have 500 Watts of light in a room of 15 square metres, this is only about 3% of the energy provided by full Sunlight, so it is no wonder solar panels do not work well inside.

SECTION 6: SUGGESTED RACING RULES

If racing SOLAR CARS you will need to make 2 wire hooks to guide the vehicle along the guide line.

6.1 HOOKS FOR THE GUIDE LINE

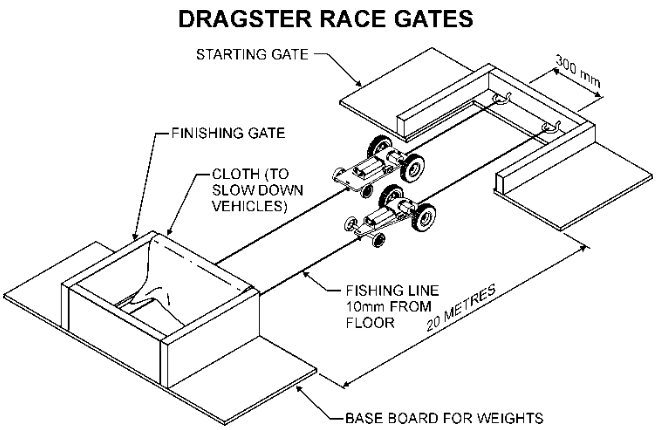


- Drill two holes at the front, and two holes at the back of the vehicle (before mounting the solar panel.
- Bend some wire into the shape shown. Push it up through the two holes. Bend the short section over to hold the wire in place. Use some glue to hold the wire firmly in place.

NOTE: The bottom of the hooks should be about 5 mm above the ground (the line is 10mm above the surface). The hook should be long enough to prevent the guide line from coming out of the hook when racing.

6.2 RACE RULES

- The race is over a 20 metre distance.
- Each SOLAR CAR is guided along a (fishing) line 10mm above the racing surface.
- The guide line must be tight
- The vehicle is only to be turned on when the starting signal is given.
- No pushing of the vehicle at the start is allowed.
- Vehicles that do not start or stop during the race are disqualified.
- A vehicle leaving the guide line is disqualified.
- A separate stopwatch will be used for each SOLAR CAR competing



SUGGESTED RACE TRACK CONSTRUCTION

SECTION 7: THEORY

7.1 HOW THE SOLAR PANEL WORKS

Silicon solar cells (photovoltaic cells) generate electricity when exposed to sunlight, but a halogen lamp can also be used. These cells can be likened to a generator using sunlight as fuel. The electricity generated from the photovoltaic cells can be used immediately or stored in a rechargeable battery.

7.2 THE SOLAR CELL

Solar cells are silicon based and typically in the order of 0.3mm thick. They are a glass like material, which is very brittle. Consequently they must be mounted in a way that offers protection.

A single solar cell, when exposed to sunlight generates electricity at a voltage of just over 0.5 volts and a current which varies with the area of the cell and the light intensity. The power generated by the cell at 25 Degrees Centigrade when exposed to light having the same frequency spectrum as the Sun with an energy density of 1000 watts per square metre is its rated power.

Typically high quality cells have a conversion efficiency of around 20%, that is, they produce electrical energy equal to 20% of the light power falling on them.

The front side of the cell exposed to the sunlight is negative (-ve) and the underside is positive (+ve).

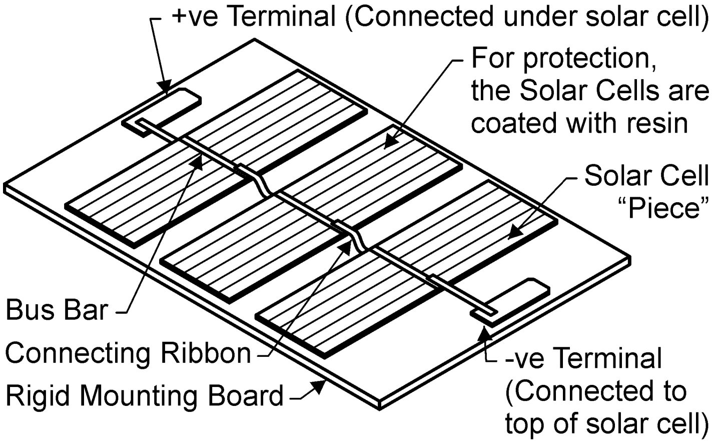
As the cell temperature increases the power produced falls, predominantly due to dropping voltage. As a rule of thumb power falls by about 0.45% per Degree Centigrade increase in cell temperature.

7.3 THE SOLAR PANEL

The solar cells are manufactured in different sizes. Standard sizes include 100 x 100mm, 125 x 125mm and 156 x 156mm. For hobby purposes, they are far too large, with too many amperes.

Depending on the Amps (current) required, the cells are cut to the required sizes and connected in series, to give the required voltage. Thus, for example, if three (3) cells 100 x 100 mm are connected in series you will have 1.5 Volts and about 2.8 amps.

Consider our Solar Panel No. 11, as supplied in our Solar Car Kit (version 2). The panel consists of two arrays, each being 1.5Volts, 0.3 amps. When using it in full sunlight, one array is enough to drive the car. However, if the sky is overcast the car will not run, as the amps generated are too low.



Construction of a "hobby" solar panel - 1.5 volts

ILLUSTRATION ONLY

A TYPICAL HOBBY SOLAR PANEL

Now if the two arrays are connected in parallel, the amps will be doubled, your car will run.

In full sunlight, if you connect the two arrays in series, the voltage generated will be doubled allowing the car to run twice as fast

Excellent in depth technical information on solar cells and panels can be found at http:www.pveducation.org/

7.4 SPEED AND ACCELERATION

7.4.1. AVERAGE SPEED

Did you know that you can calculate your vehicles average speed during its race?

You need to know the distance over which your vehicle will race. Time the duration it takes from start to finish with a stopwatch. You can use the following method to calculate how many Kilometres per hour (km/h) your vehicle averages. For example if your vehicle is racing over 20 metres and it takes 5 seconds to cover the distance:

- Divide 1000 metres (the length of one kilometer) by the length of your racetrack (in this example 20 metres). **1000/20 = 50**
- Multiply the time taken by your vehicle to complete the race (in this example 5 seconds), by the result from the previous calculation. **5 x 50 = 250 seconds**

This is the time it would take to travel one Kilometre

- Work out how many seconds there are in an hour. **60 x 60 =3600 seconds**
- To calculate the average speed in Kilometres per hour, divide the seconds in an hour (3600 seconds) by the time it takes to travel one kilometer (in this example 250 seconds). **3600/250 = 14.4 Kilometres per hour**
- This is the average speed obtained over the race. Remember your vehicle is not moving at all at the start. This means it must be going much faster (than the average speed) by the end of the race. How fast is your vehicle going at the end of the race? Hard to tell? No, not really thanks to something called physics!!!!

7.4.2. ACCELERATION

First you must find the acceleration of your vehicle. Acceleration is a measure of how fast your vehicle's speed is increasing. Acceleration is measured in metres per second squared (m/s^2). Another term that will also be used in the calculation is velocity. Velocity is a measurement of speed. Velocity is measured in metres per second (m/s).

- To find this, a formula is used and it assumes that the acceleration is constant (ie. the acceleration is the same throughout the race).

Distance travelled = the starting speed of the vehicle + ½ x acceleration x time taken ^{2}

To find the acceleration for our example:

20 metres = 0 + ½ x acceleration x 5^2

20 = ½ x acceleration x 25

20/25 = ½ acceleration

0.8 = ½ acceleration

0.8 x 2 = acceleration

Therefore **Acceleration = 1.6 metres per second squared ($1.6 m/s^2$)**

7.4.3. END VELOCITY

To find the velocity of the vehicle at the end of the race another formula is used.

Velocity = the starting speed of the vehicle + acceleration x time taken

Velocity = 0 + 1.6 x 5

Velocity = 8 metres per second (8 m/s)

To calculate the final speed, multiply the velocity by the number of seconds in an hour. **8 x 3600 = 28,800 metres or 28.8 Km per hour.**

Can you spot the relationship between the average speed and the maximum speed of a vehicle that starts from a stationary position? What is it, how can this be explained?

NOTE: The time and race distance used in this example are made up values, to show how these calculations work. Your vehicle may achieve better speeds than given in the example.