INTRO SOLAR CAR

CONTENTS:

DESCRIPTION

The INTRO SOLAR CAR is a four-wheeled vehicle, driven by Scorpio Technology's High Performance electric motor. The power source is two purpose-designed solar panels. Power to the wheels is transferred from the motor by gears. This car will run on a smooth level surface from 25% sunlight upwards.

Each Solar panel produces 2.0 Volts and 0.9Amps, and they can be connected in series or parallel.

By building and experimenting with this car students will gain a significant insight into renewable energy.

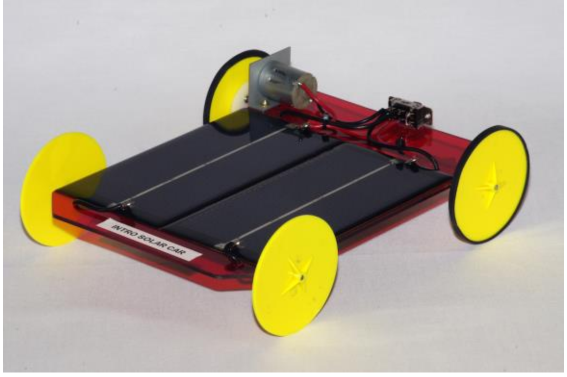


Figure 1

SECTION 1: GENERAL AND PLANNING INFORMATION

1. DESIGN CONSIDERATIONS

1.1 GENERAL

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

The drawings provided are a starting point for the student.

Before starting construction, the student needs to carefully plan and layout all of the components. The plan view of our prototype vehicle is shown in Figure 2.

The exploded view (Figure 3) indicates the relationship between the various components. The design of the INTRO SOLAR CAR should be considered as a complete unit, not just as separate parts.

The design should be carried out with the testing envisaged, and the end usage in mind.

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 length provides an upper limiting factor for the width (i.e. across the wheels – the body can be wider)

Other things to consider:

- The guide tube is cut into 4 pieces, which are used as bearings for the axle shafts.
- The vehicle as shown in our drawings is basic, but it also 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 predetermined circle. This (circular travel) can be achieved by putting the front axle shaft on an angle.
- There is a choice of spur and pinion gears provided. This allows you to calculate the ratios available and how to maximise the torque and speed available from the Solar Panels and Motor.
- Determine which spur gear / pinion gear ratio to use.

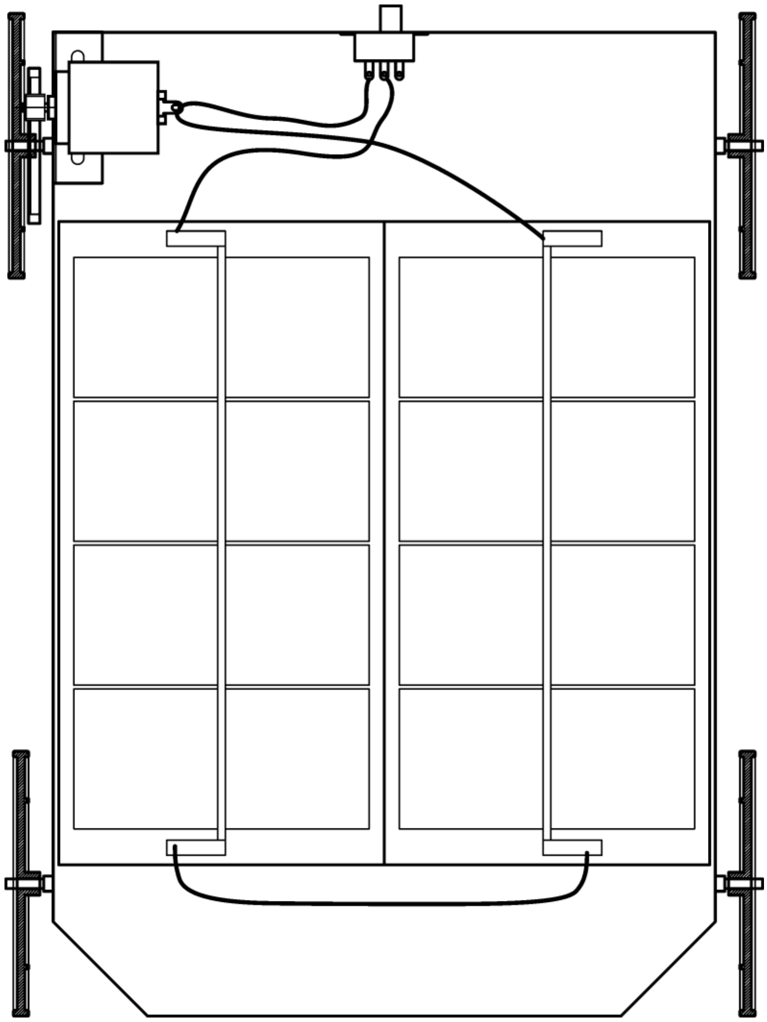


Figure 2

- How does this ratio 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 1: The maximum motor speed, at maximum efficiency, is approximately 11,350 rpm.

NOTE 2: To investigate gearing further, we have more information in the Theory section at the end. Alternatively, a program such as “Crocodile Clips” is a useful program for simulating the operation of gears, and investigating their operation.

1.2 ITEMS FOR INVESTIGATION

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

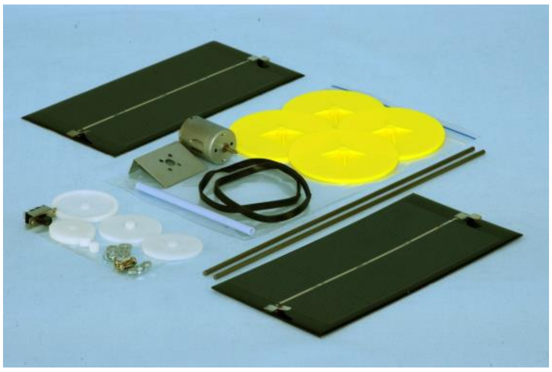
- The 2 panels can be connected in series or parallel – an on-off-on switch is provided to allow switching between these options. Consider how switching between series and parallel affects the performance. Does it affect the gear ratio selection (only one pinion and one spur gear can be used)?
- The 2 panels are useful for experimentation, as it means that you could experiment with the output of the panel in 3 different configurations:
    - Only one panel to see how much power is output, what speed is attained.
    - Both panels connected in series.
    - Both panels connected in parallel.

- Establish conditions for using the solar panels in series or parallel. Set up a test schedule for these experiments.
- If working in a class, you may wish to assemble a number of these vehicles using the different gear combinations available. This will allow you to test the theory / calculations made for the various gearing combinations. These 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 it is).
- How are these speeds affected by having the sections connected in series? In parallel?
- Evaluate the suitability of various materials, such as PVC, acrylic and plywood or balsa wood.
- Investigate adding steering. This could be either manual (set the steering in a chosen direction before each use) adjustable by mounting the axle in the same manner steering is achieved on a billycart or controlled (how would you control it? Remote control? Or by a wired controller?). For some ideas on steering, you could look at our FORKLIFT, RADIO CONTROLLED VEHICLE and FOLLOW WHITE LINE VEHICLE.
- You may wish to incorporate forward / reverse operation by using a two position (on-off) switch as well.

SECTION 2: COMPONENTS & MATERIAL REQUIRED

2.1 COMPONENTS SUPPLIED

The following components are supplied in the kit:



2.2 ADDITIONAL REQUIREMENTS

The following items are to be supplied by the student / designer: Material for the platform (plastic and plywood are both suitable), fine electrical wire, double-sided tape, hot-glue gun.

NOTE: We used 3.0mm thick Plywood (approximately 175mm x 260mm) for this project. 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.

SECTION 3: MAKING THE VEHICLE

3.1 ASSEMBLING THE AXLES TO THE PLATFORM

- Cut the platform material to the required size and shape.
- Work out where on the base you will be fixing the axles.
- Draw a line where each axle will be placed. They should be parallel if your car is to travel in a straight line.
- On the line you have marked measure the length of the guide tubing, from the edge of the base inwards. This is where the tube will be fixed.

NOTE: The plastic tubing should protrude past the edge of the base by about 5mm.

- Cut the plastic guide tubing into 4 equal lengths.
- Put 2 pieces of tubing on the steel shaft and position them so they line up on either side of the base.
- Apply hot glue to the sections marked for fixing the tube.

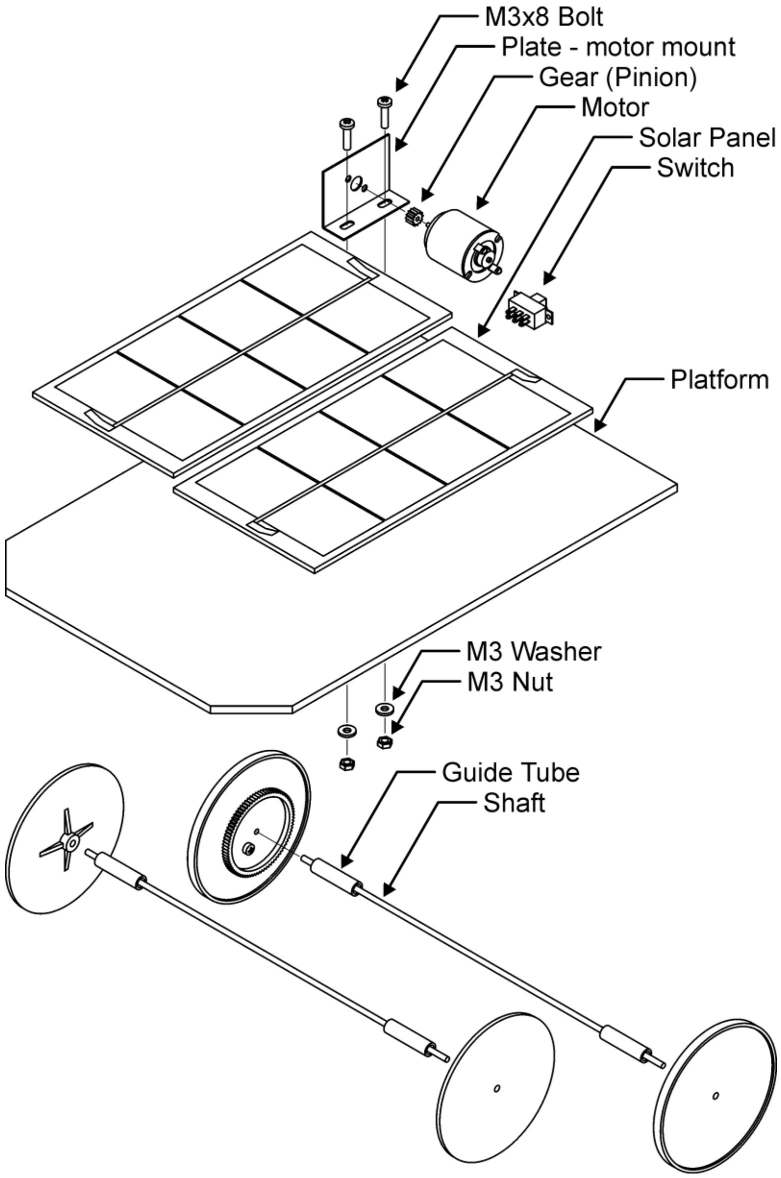


Figure 3

- Carefully hold the ends of the steel rod and use it to press the plastic tubes down on to the hot glue.
- Leave the steel rod inside the plastic tubes until the glue has cooled and then remove the rod.
- Repeat this process for the second axle.

NOTE: Ensure that the shaft guide tubes are 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.

- Cut the steel shafts to the required lengths and de- burr the ends.

NOTE: Both axles are different lengths (due to the gears etc.) – that should be taken into account before cutting the rear axle.

3.1 THE REAR AXLE GEAR

- Fit the selected spur (large) gear to the shaft 10mm from the end of the shaft.
- Fit the gear spacer onto the shaft until it sits up against the large gear.
- Drill a 3mm hole through the gear spacer and the selected gear.
- Assemble the spur gear, the spacer and the wheel using the M3x12mm bolt, washer and nut.

NOTE: Fit the Wheel's flat side against the gear spacer.

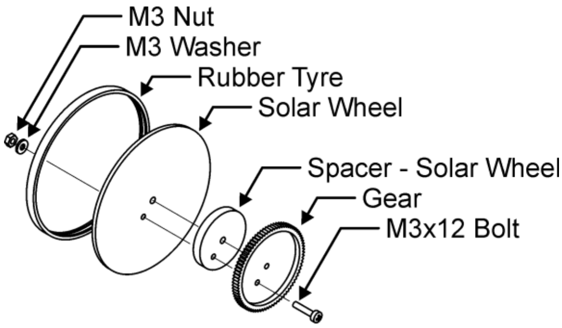


Figure 4

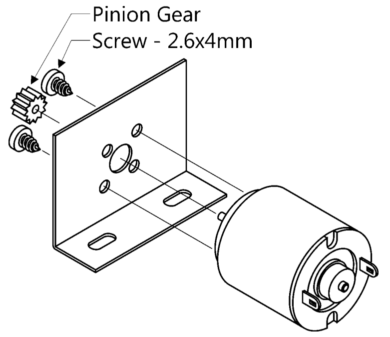
3.2 ASSEMBLING THE MOTOR AND MOUNTING PLATE

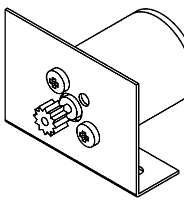
Fix the motor to the motor mounting bracket using the 2.6x4mm self-tapping screws.

Fit the pinion gear to the motor shaft as described below.

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

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.





3.3 ASSEMBLING THE VEHICLE

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

WARNING: Take care if using hot glue to avoid burns.

- Attach the solar panels to the platform, in the position chosen, using double-sided foam tape.
- Slide the front steel shaft through the two shaft guide tubes and then fit a wheel to the other end of the shaft.
- Test the fit of the wheels and axles. The wheels should spin freely. There should be less than half a millimetre side play of the axle.
- Fit the rear shaft (with the gear assembly) into the shaft guide tubes. Fit the last wheel onto the end of the shaft and test that the wheels spin freely.
- Place the motor mounting plate onto the base and slide it into position so that the pinion gear on the motor meshes with the large gear.
- Mark the centre positions of the mounting holes of the motor mounting plate onto the base of the vehicle.
- Drill 3mm holes and insert the M3x8mm bolts through the motor mounting plate and base. Fit the washer and screw the nuts onto the bolts – finger tight.
- Slide the motor mounting plate along until the pinion gear meshes with the large gear and tighten the nuts.

- Attach the switch to the platform.
- Stretch the tyres over the rear wheels. As the wheels are very narrow, it can be fiddly to get the tyres to seat properly

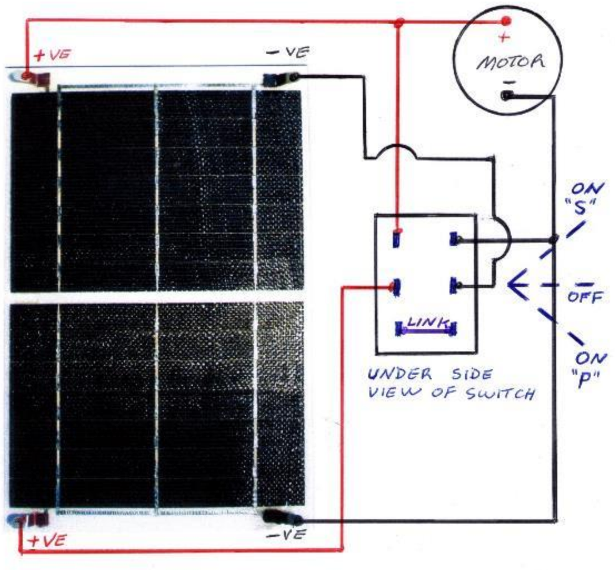
SECTION 4: WIRING THE VEHICLE

4.1 GENERAL

You may wish to carry out a range of experiments, using the various combinations of the solar panel (one section, series or parallel). This can be done by using the 3-position switch: Series-Off-Parallel.

NOTE: The diagrams illustrating how to wire the panels in series or parallel and included for reference purposes only.

4.2 SWITCHED SERIES OR PARALLEL



The 2 solar panels can be wired in series or parallel selected using the switch supplied.

Typical output in full Sun:

Series:

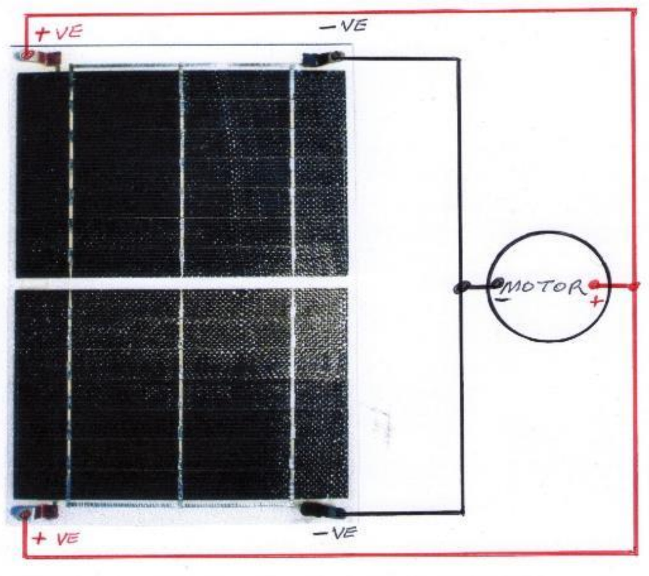
4.0 Volts 0.9 Amps

Parallel:

2 Volts 1.8 Amps

4.3 WIRING IN PARALLEL

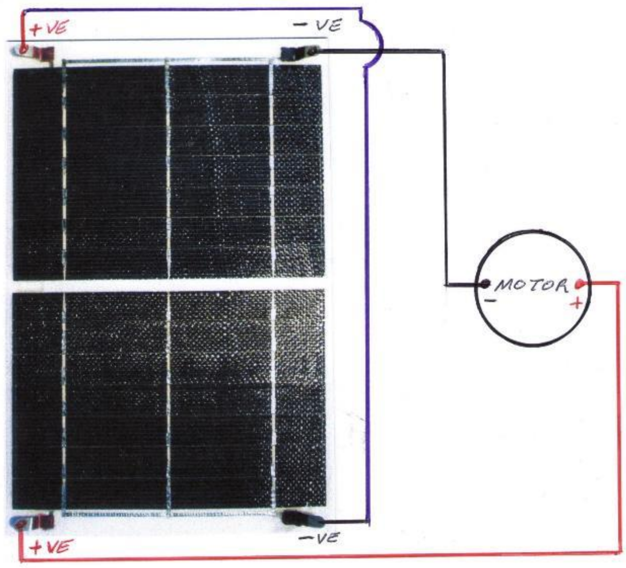
How to wire the panel in parallel is shown below.



Typical output in full Sun: 2 Volts 1.80 Amps

4.4 WIRING IN SERIES

How to wire the panel in series is shown below.



Typical output in full Sun: 4.0 Volts 0.9 Amps

4.5 SOLDERING

NOTE: When soldering wires, strip a short piece of insulation from the end of the wire, twist the strands and use a hot soldering iron (approx. 350°C) to apply solder.

WARNING: Take care when soldering to prevent burns.

- Solder all the wires except for the motor.

Test the operation of your INTRO SOLAR CAR (either in sunlight or as below).

- If the car goes backwards, swap the wires connected to the motor, and solder them in place.
- If the car goes forward as expected, solder the motor's wires in place.

SECTION 5: TESTING THE VEHICLE

To test the INTRO SOLAR CAR, expose the solar panel to direct sunlight. The motor should run in sun levels above 20%.

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.

NOTE: 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.

5.2 EXTENSION WORK

An option to further improve the performance of this vehicle would be to use the SOLAR PANEL POWER CONTROLLER (Low Voltage).

SECTION 6: THEORY

6.1 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.

6.2 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).

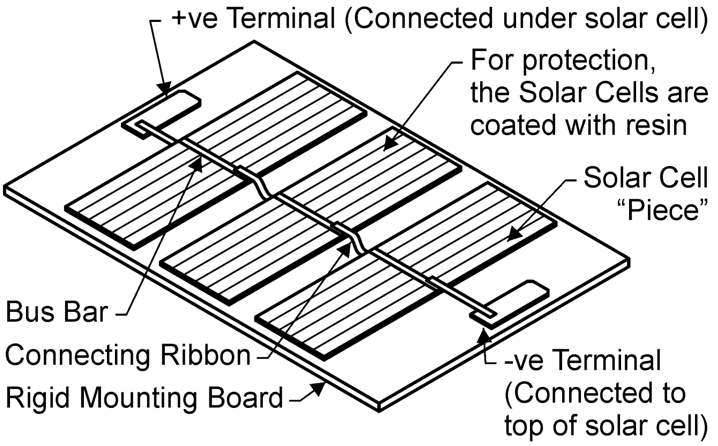
As the cell temperature increases the power produced falls, predominantly due to dropping voltage. As a rule of thumb power falls by about 0.45% per Degree Centigrade increase in cell temperature.

6.3 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

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/

6.4 SPEED AND ACCELERATION

6.4.1. 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!!!!

6.4.2. 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 ($1.6 m/s^2$)**

6.4.3. 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.