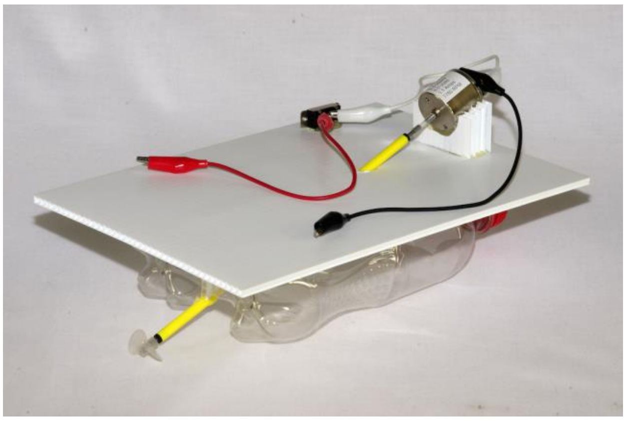
JUNIOR SOLAR BOAT

CONTENTS:

DESCRIPTION

This kit contains most of the components needed to construct a functional solar powered boat for participating in the Model Solar Boat Challenge – Junior Division. This unit includes instructions on how to assemble these components together.

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



SECTION 1. GENERAL AND PLANNING INFORMATION

DESIGN CONSIDERATIONS

1.1 GENERAL

As well as being a fun educational project, students can use the knowledge they have gained and use the boat to participate in the Junior division of the Victorian Model Solar Vehicle Challenge boat competition. For full details of the competition regulations, how to enter, additional resources and help available go to www.modelsolar-vic.net.

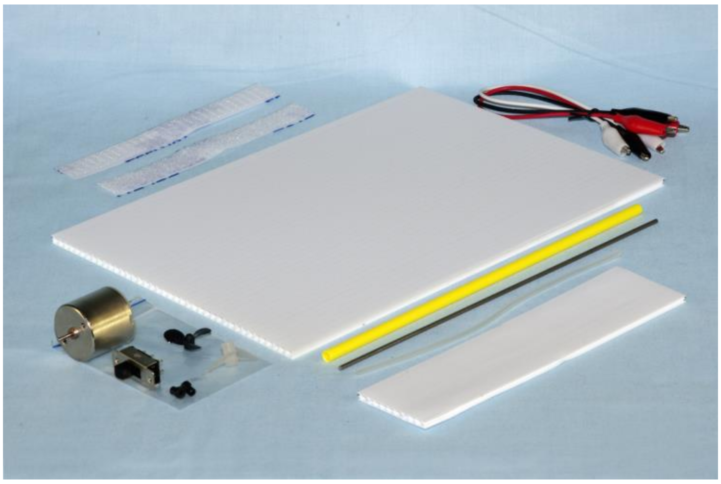
1.2 ITEMS FOR INVESTIGATION

This SOLAR BOAT project provides a number of different aspects 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.
- Evaluate the suitability of various materials for the platform, such as polystyrene, PVC, acrylic, plywood or balsa wood (refer to the Model Solar Boat Challenge rules for guidelines)

SECTION 2: COMPONENTS & MATERIAL REQUIRED

2.1 COMPONENTS SUPPLIED



2.2 ADDITIONAL REQUIREMENTS

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

- Solar panel
- Self-adhesive foam tape – Single-sided
- Self-adhesive foam tape – Double-sided
- Material for the hull – e.g. polystyrene block

2.3 TOOLS REQUIRED

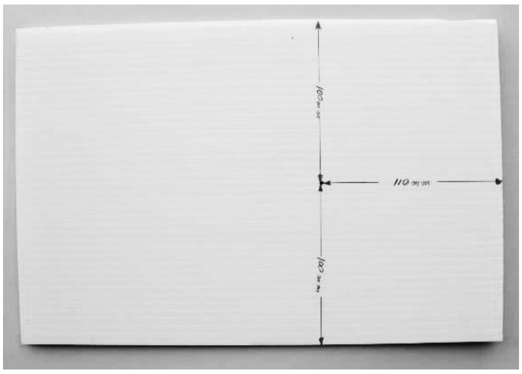
The following tools are required:

- Assorted hand tools
- Soldering equipment and solder
- Scissors
- Pliers
- Knife - “box cutter”
- Ruler and pen

SECTION 3: ASSEMBLY OF THE SOLAR BOAT

3.1 FABRICATION

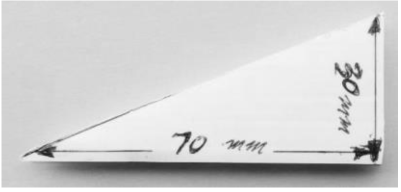
3.1.1. BASE



On the 200mm by 300mm corflute base, mark the position of the propeller shaft hole 110mm from one end and in the centre of the sheet.

NOTE: The shaft diameter (6.5mm) is larger than the gap between the reinforcing ribs (5.0mm).

3.1.2. SHAFT SUPPORT

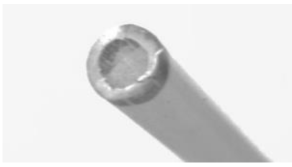


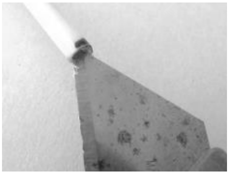
Mark out and cut a right angle triangle in corflute to the dimensions shown.

3.1.3. MAKING AND ASSEMBLING THE STERN TUBE

Prepare the stern tube: mark the length required on the yellow tube - 210mm for this kit. Cut the tube using a suitable craft knife.

HINT: to minimize squashing of tube place it on a cutting board then roll it under the knife blade keeping moderate pressure on the blade. It will need to be rolled several times (back and forward is ok)

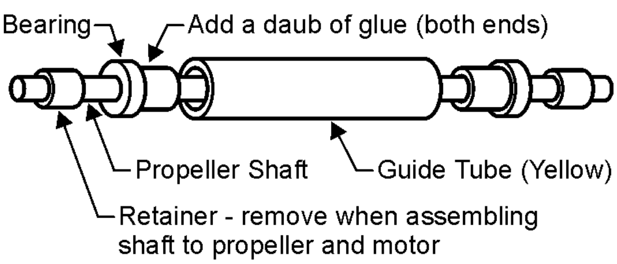




There will be some burrs on the tube end, those on the inside must be removed to allow the shaft to rotate freely.

To remove the burr place the knife blade in the end of the tube and rotate the tube while holding light pressure against the blade.

To make the Stern tube for the Propeller shaft follow the following steps:

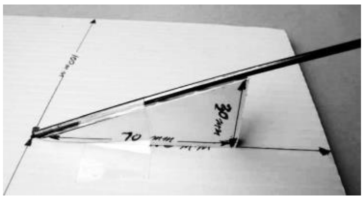


- Slide a 250mm propeller shaft through one propeller shaft bearing, the Guide tube and then the other propeller shaft bearing
- Put some glue on one propeller shaft bearing and push it into the Guide tube
- Repeat with the other bearing

HINT: use 2 short pieces of coupling to hold the bearings in place while the glue dries. Remove the coupling pieces and discard.

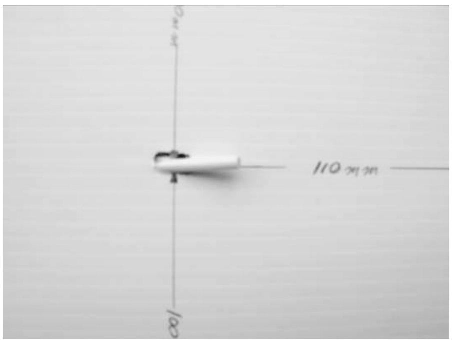
Once the glue has dried, check how easily the steel shaft turns within the tube.

3.1.1. MOUNTING THE STERN TUBE

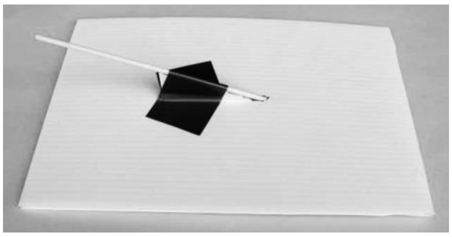


Make the hole for the stern tube and propeller shaft. Using the corflute triangle as a guide, push a piece of the 2.5mm diameter steel rod through the corflute and out the other side as shown below. Ensure the hole is halfway between the reinforcing ribs of the corflute.

3.1.2. FIT STERN TUBE TO BASE



Using small (sharp) scissors carefully elongate the 2.5mm diameter hole to take the 6.5mm diameter (yellow) plastic stern tube. On the top of the corflute base elongate the hole in the top face about 5mm towards the 110mm end. On the underneath elongate the bottom face about 5mm in the opposite direction. The stern tube should extend 20mm through the base on the top side.

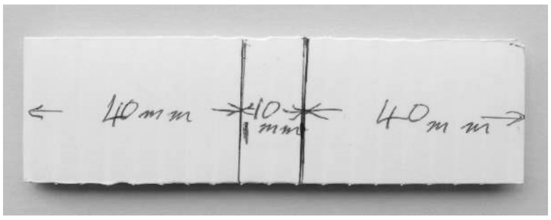


Fit the stern tube through the hole and fix it in place with duct tape at the correct angle with the triangle template used to originally make the hole.

At this stage check that the stern tube is straight by inserting the 2.5mm steel rod (propeller shaft) right through the tube. To check this there are 2 tests that can be used:

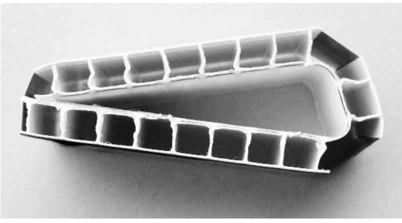
1. Spin the (steel) propeller shaft – it should spin as easily as it did when checked in Section 3.1.3
2. Holding the base so the stern tube is vertical the steel rod should fall out under its own weight. If the rod does not fall freely investigate and adjust till it will fall freely under its own weight. It is essential that the rod is free or there will be significant friction slowing the rotation of the propeller and hence degrading the boat performance.

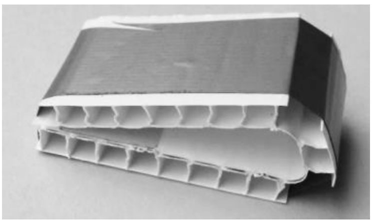
3.1.3. MOTOR MOUNT

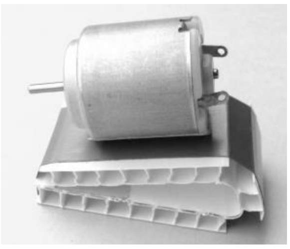


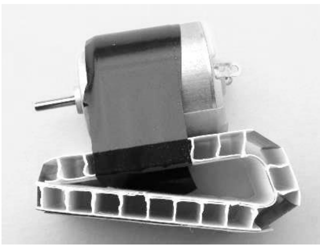
Mark out the motor mount as shown on the corflute.

Make two cuts through the top face only 40mm in from each end. Fold over as shown, hold the ends together with double sided tape and apply tape all around the outside.









Hold motor to mount with double sided tape then secure motor by applying tape around the motor and top portion of the motor mount. Apply double sided tape to bottom surface of motor mount.

3.1.4. PROPELLER AND SHAFT

Mark the length required. Standard length for this boat is 250mm but if you modify the design the length may be different. If so, cut to the required length.

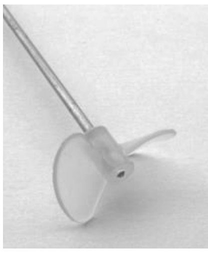
- Repeat with the second shaft

Note: the ends will be deformed (burred). Remove burrs by filing - Burrs must be removed to allow fitting to propeller and plastic tube used to couple motor to propeller shaft.

Deformed end of cut shaft.

Shaft end after filing

3.1.5. FITTING THE PROPELLER TO SHAFT



Place the 2 blade propeller on a block of wood shaft hole upwards. Align shaft with hole and tap shaft end lightly to drive it into the hole in the propeller hub.

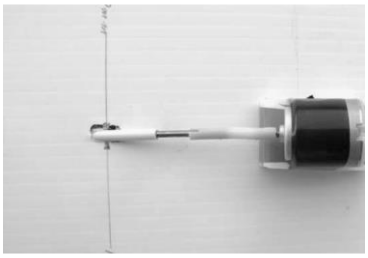
Repeat with the second shaft and the 3 blade propeller.

Propeller fitted to shaft.

The kit contains 2 propeller shafts (250mm long) and 2 different propellers – a 2 blade and a 3 blade propeller. This allows the user to test which performs better under differing sun conditions.

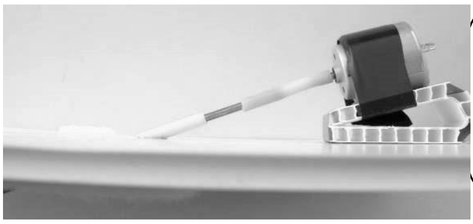
- If experimentation is carried out with different stern tube angles the different propellers can also perform differently.

3.2 MOUNTING THE MOTOR TO THE BASE

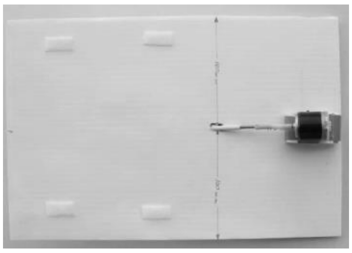


Align motor with propeller shaft and stick motor mount to base with the double sided foam tape on the motor mount.

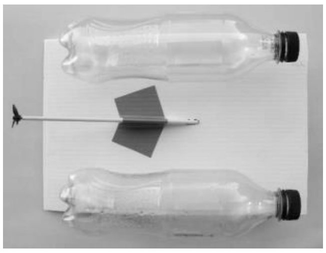
Note: alignment is critical. Misalignment will increase losses and have a detrimental effect on performance.



It is recommended to initially secure the hulls with Velcro so the hull position can be moved fore and aft to adjust the trim of the boat and raise or lower the propeller in the water to obtain the desired position.



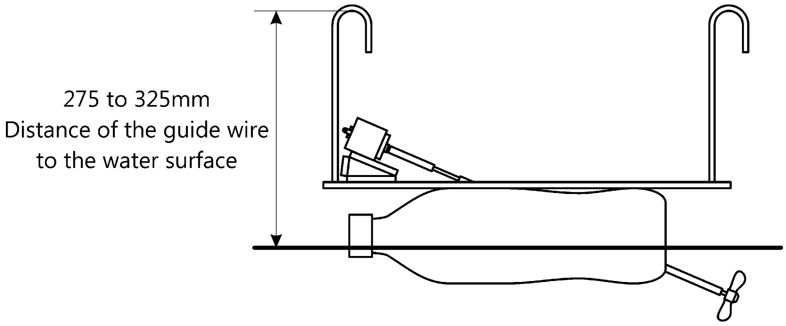
Top view



Under side view showing the bottle hulls in place.

3.3 GUIDE WIRES

For boats to steer a straight line, they should be fitted with rods with open loops through which the guide line will run. This line is located as near as possible to 300mm +/– 25 mm above the water. Other designs than the one shown may be used.



SECTION 4. WIRING UP THE SOLAR BOAT

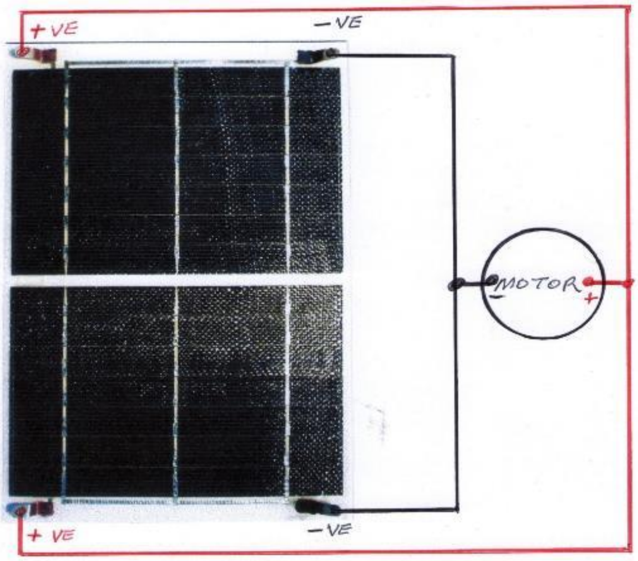
No Solar panel is supplied with this kit – the choice of solar panel is up to the user.

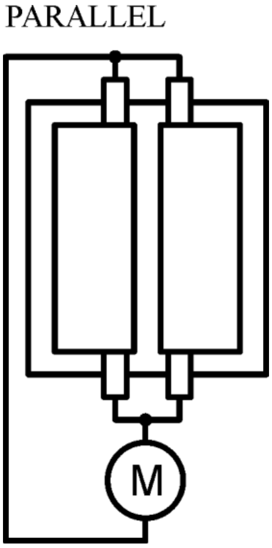
Note: for illustration purposes the panel shown is the Scorpio Technology #26 panel.

- Secure the solar panel to the base (if you plan to remove it at any point, the panel should be attached so that it can be removed without damaging the panel – the #26 panel.is fragile, due to its lightweight construction).
- Attach clip leads to panel and motor.

4.1 Wiring In Parallel

How to wire the panel in parallel is shown below.

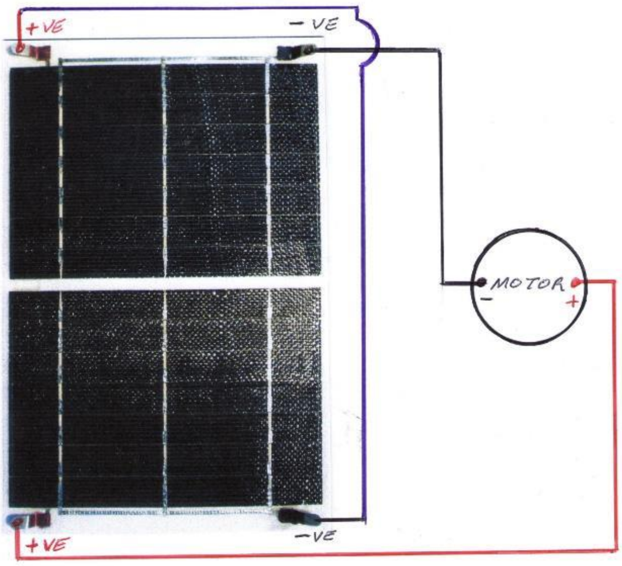


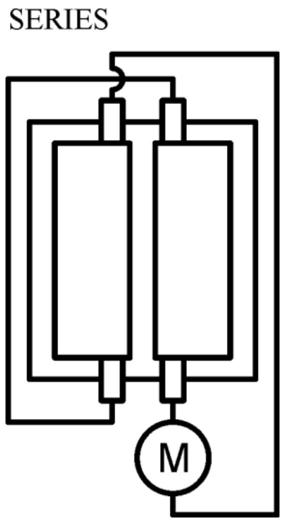


Typical output in full Sun: 3.5 Volts 1.60 Amps

4.2 Wiring In Series

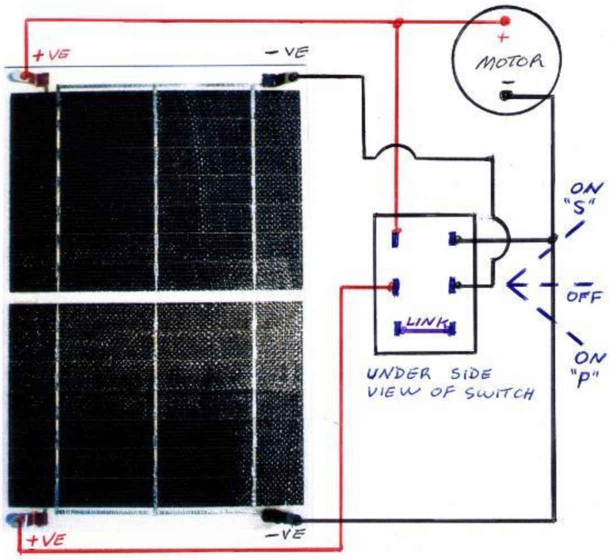
How to wire the panel in series is shown below.





Typical output in full Sun: 7.0 Volts 0.80 Amps

4.3 Switched Series or Parallel



If you wish the Scorpio panel may be wired in series or parallel selected with a switch.

If a double throw double pole centre off switch is used it both meets the regulations requirements for an on off switch, as well as providing series or parallel connection of the two panel sections.

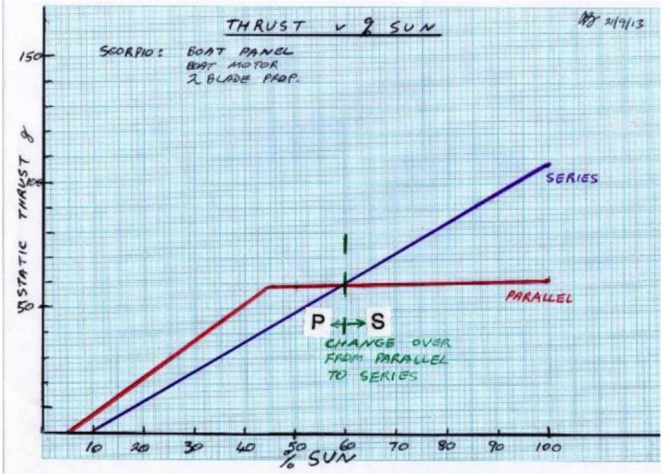
How to wire the switch is shown at left.

Typical output in full Sun:	Series	7.0 Volts	0.80 Amps
	Parallel	3.5 Volts	1.60 Amps

4.4 Test Results

Static thrust tests with a Scorpio boat panel, boat motor and 2 bladed propeller gave the following results. Examination of the graphs show indicate the changeover point from parallel to series should be at around 60% Sun.

Below 60% Sun parallel is indicated and above 60% Sun series is indicated. As Sun levels usually do not change significantly in the short term a reasonable approach to avoid the complex wiring (for primary students) to achieve a switched series / parallel set up would be to use alligator clip leads to configure the panel.



SECTION 5· TESTING THE SOLAR BOAT

To test the Solar Boat, expose the solar panel to direct Sunlight, motor should run in Sun levels above 20%.

If the motor is rotating in the wrong direction swap the clip leads at the motor to the opposite terminals.

SUNLIGHT versus ARTIFICIAL LIGHT

For testing your boat 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 boat 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· FURTHER WORK

6.1 EXPERIMENTING

The following are some ideas that you should test out:

- Change propellers from the 2 blade to the 3 blade to suit Sun level and panel wiring configuration
- Wire the Panels in series or parallel
- Angle panels towards the Sun

6.2 ADDITIONAL UPGRADE TO IMPROVE COMPETITIVENESS

- Improve hull hydrodynamics
- Change shaft angle (reduce)

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.

7.1.1. The Solar Cell

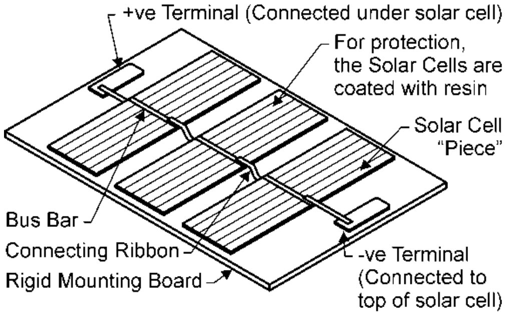
Solar cells are silicon based and typically in the order of 0.3mm thick. They are a glass like material, which is very brittle. Consequently they must be mounted in a way that offers protection.

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 C increase in cell temperature.



Construction of a "hobby" solar panel - 1.5 volts

ILLUSTRATION ONLY

7.1.2. 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 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.

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

7.2 SPEED AND ACCELERATION.

Did you know that you can calculate your boat's speed?

You need to know the distance over which your boat will travel. 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 boat averages. For example, if your boat is travelling over 20 metres and it takes 5 seconds to cover the distance:

1. Divide 1000 metres (the length of one kilometre) by the length of your course (in this example 20 metres). **1000/20 = 50**
2. Multiply the time taken by your boat to complete the race (in this example 5 seconds), by the result from the previous calculation. **5 x 50 = 250 seconds**
3. This is the time it would take to travel one Kilometre
4. Work out how many seconds there are in an hour. **60 x 60 =3600 seconds**
5. To calculate the average speed in Kilometres per hour, simply divide the seconds in an hour (3600 seconds) by the time it takes to travel one kilometre (in this example 250 seconds). **3600/250 = 14.4 Kilometres per hour**

This is the average speed obtained over the distance. Remember your boat is not moving at all at the start. This means it must be going much faster (than the average speed) by the end of travel. How fast is your boat going at the end of travel?

First you must find the acceleration of your boat. Acceleration is a measure of how fast your boat'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).

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

Distance traveled = boat's starting speed + ½ x acceleration x time taken²

To find the acceleration for our example:

20 metres = 0 + ½ x acceleration x 5²

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 (1.6m/s²)**

7. To find the velocity of the boat at the end of travel 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)

8. To calculate 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 boat that starts from a stationary position? What is it, how can this be explained?

Note: Time and 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.