

SOLAR BOAT CHALLENGE



Solar Module
Available from Teaching Resources – stock code EL1 006

Using recently available super capacitors and much improved efficiencies from mono-crystalline solar panels, TEP associate Kieron McGeever explains how to get your students involved in an interesting and topical project that should provide a range of learning opportunities.

Renewable Energy

With the development of low cost and more efficient solar panels it has become more practical to use them in school projects. They can be used to replace batteries in projects that require low output and long duration of use, such as environmental control systems used in green houses, sun lounges and weather monitoring stations. Solar cells have the smallest environmental impacts of all the renewable energy sources. Electricity produced from photovoltaic cells does not result in air or water pollution, deplete natural resources, or endanger animal or human health. In many practical projects solar cells will only be part of an energy storage system which will also require the use of a rechargeable battery or capacitor.



Solar boat challenge race

Solar Boat Challenge

In Australia there are several competitions for schools to encourage children to think about the environment and energy production. One challenge is to design and build a Solar Boat.

“The challenge is intended to promote and develop an interest in Engineering and Technology and the use of renewable and solar power with school children. It is hoped that by doing this our future citizens, scientists and engineers will be more aware of, and participate in, a more environmentally friendly approach to energy usage.”

Further information about the Australian challenge can be found from this site:

<http://www.wilderness.com.au/SolarBoatGallery/index.htm>

There is also a British equivalent of the solar boat challenge and further information on how to race solar boats can be found on this web site:

<http://www.engineeringinspirations.co.uk/solarboatchallenge.html>

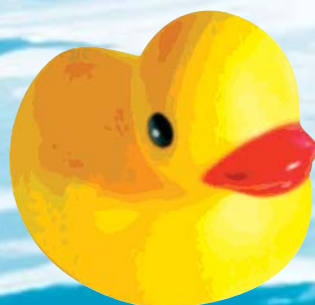
A Solar Powered Boat as a project in Britain presents some interesting technological problems that can be tackled by students in both Key Stage 3 and Key Stage 4. The basic electronics are very simple: you have a circuit which contains a motor and you replace the battery with a solar cell as the energy source and provided you have balanced the motor to the solar cell, moderate light will make it work. The challenging part is then to develop this system so that it will power a boat.

Designing and constructing a solar boat

There are three main elements to the design of a solar boat, they are:

- ☀ The hull design
- ☀ The solar power circuit
- ☀ The drive system

Each element will affect the performance of the boat to a significant degree and this offers the opportunity for a team approach to designing the boat.



Continued overleaf ➔

SOLAR BOAT CHALLENGE

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The Hull

The hull can be constructed in a number of different ways, but the main criteria is that it must have a big enough displacement to carry all the weight of the motor, solar cells and drive system and remain stable i.e. not turn turtle.

☀ Bottle Hull

Fizzy drinks bottles work very well as they are very light and very strong. Two bottles can be fixed together to make a catamaran or they can be cut open and turned into standard boat hull, a two litre bottle makes a good sized boat hull for this method. Fitting the equipment can be done with good quality double sided sticky tape which is very waterproof and makes a strong joint.

☀ Wooden Hull

Readily available softwoods or balsa wood may prove ideal as well as sheet materials. Wooden construction methods are fairly straightforward and so long as the hull is made waterproof by painting. Weight is clearly a factor with wooden boats but could be lightened with a little imagination.



☀ Formed Plastic Hull

Sheet plastics such as high impact polystyrene or rigid foam PVC can be used to make very good lightweight hulls and can be formed to shape using a vacuum forming machine or the plug a yoke system used to make the TEP Pods. Mountings for the other components of the boat can be designed into the hull shape for easier assembly.

The Circuit

The solar powered circuit is possibly the easiest part of the project. This consists of a motor and a solar panel connected in a circuit. The solar panel (which is made up of a number of solar cells) needs to match the motor loading to achieve maximum efficiency. Solar panels can be made up of a number of cells connected in series or parallel to achieve a desired output, just like a battery. Most motors available will require at least two solar cells to be connected in parallel to achieve sufficient voltage and speed from the motor, depending on the rating of your cells.

Solar Panel

The output from a solar cell is directly proportional to the amount of light that falls onto it. Each panel is 60mm square and will need to be mounted (to achieve maximum output) perpendicular to the light source. In the design of the boat the mountings for the cells should take into account the latitude of where the cells are going to be used. In this country an angle of around fifteen degrees to the horizontal will gain maximum energy from the sun at midsummer, but this can be adjusted by experimentation for place and time of year.

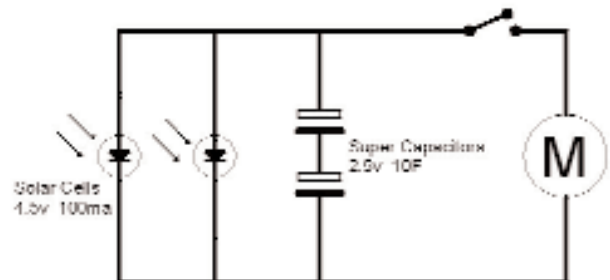
Energy Storage

In this country, as we all know, sunlight can be very variable and the speed of a solar powered boat can be drastically affected by even a small shadow passing over the panels. To overcome this problem to a limited extent, storing excess energy in the circuit to be used when the light level falls is a good refinement to the design.

This can be done in two ways. One way is to use a rechargeable battery charged from the solar panel, but this is large and heavy and take too long to charge up. The alternative is to use a super capacitor which is small, light in weight and charges up very quickly. A typical super capacitor will have a rating of 2.4 volts and a storage capacity of 10 Farads whilst being smaller than a thimble. This size of capacitor will store enough energy to keep the motor running for several minutes from one charge.



Capacitors, like batteries and solar cells, can be added together to give either higher voltages (connect in series) or greater capacitance /power storage (connect in parallel). The capacitor battery should be made up to match the rating of the solar panel and be wired in parallel with the solar panel and the motor (see circuit diagram below).



5v Solar Powered Motor Circuit

With the solar circuit wired up in this configuration and the capacitors fully discharged, nothing will appear to happen at first when the circuit is switched on. This is because the capacitors will take all the current from the solar panels whilst they are charging up. As the capacitors become fully charged the current flow into them will start to fall off and the motor will start to turn reaching maximum speed when the capacitors are fully charged.

If the light level falls, power from the solar panel will drop and the capacitors will automatically start to discharge and compensate for the fall in current maintaining the motor speed. The capacitors will then recharge when the light level increases again and they will keep on doing this and smooth out the fluctuations in output from the solar panel. This refinement of the circuit is a trade off of consistency of speed against maximum speed, because in reality the capacitors are never going to reach full charge and therefore the motor is never going to reach maximum speed for any given light level, but the fall off in speed will be drastically reduced for any fall off in light level and a higher average speed will be maintained.



The Drive System

There are many variations possible for the drive system of a boat ranging from oars to paddle wheels to aeroplane propellers [air screws] to boat propellers [water screws] and most of them have been tried over the years. The most efficient two methods are the air screw and the water screw.

Air Screws

If you are trying to gain maximum output from your system any old propeller that fits your motor will not do. Propellers are designed to give maximum output at a given rpm, and the larger the diameter of a propeller the more power is needed from the motor to achieve that rpm. Experimentation will show that a motor turning a small propeller quickly will move more air than a larger propeller that only turns slower.

Paddle Wheels

Paddle wheels are the second easiest method of propulsion on a boat as they require no waterproof holes below the water line in the hull. They do require a gear box though as the speed of rotation is critical to their efficient operation. Too fast will simply cause cavitation and little thrust. The task is to get the maximum rpm that gives the maximum speed to the boat. Therefore the gear ratio and the design of the paddles themselves are critical to its success.

Oars!

A simple rowing motion can be achieved with a gear box and an eccentric cam and again it is the speed of rotation that is critical to gaining maximum output from the system.

Water Screw

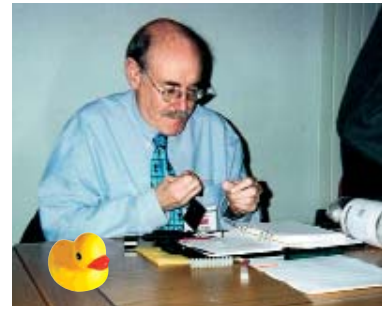
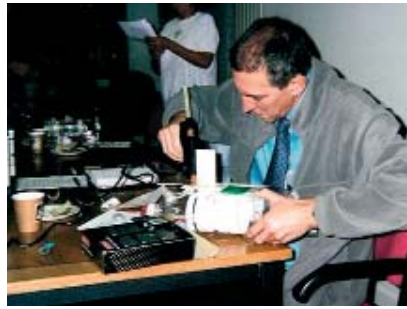
This is possibly the most efficient way of driving the boat and the most difficult to 'build in' as it requires waterproof holes in the hull below the waterline.

The simple solution is to fit a stern tube, made from plastic or copper, angled to come out through the back of the boat below the waterline and finish inside the boat above the waterline. A watertight seal around the tube where it goes through the hull is required. A propeller shaft can then be passed through the tube and attached to the motor with a universal coupling. To get maximum efficiency from the system the motor shaft, propeller shaft and stern tube should all be perfectly inline, even slight miss-alignment will create friction and slow the motor down. The design of the propeller is also critical and the same criteria apply to water screws as air screws. It is a matter of choosing the right size and pitch of propeller to suit the motor. It may also be necessary to fit a gear box to reduce the rpm of the motor and increase its torque by 2:1 or 4:1 to gain more output from a larger propeller.

Solar Powered Project

Solar power provides an interesting new angle to powered projects and a solar boat is an interesting introduction into the use of solar energy. Non of the technology is particularly difficult, but the efficient use of that technology makes it a very interesting project especially if it leads up to a race (see web sites links). The project would especially suit a team approach with up to four students working on a design with each member working on a different aspect of the design, planning and carrying out experiments to find the best way of doing it.

It is a project that is best suited to the summer term for the light levels and for testing outside. Lack of a suitable pool is overcome with a simple test tank made from four lengths of timber screwed into a rectangular shape with builder's polythene or pond liner draped into it. It only needs to be a few centimetres deep and 400 to 600mm wide and as long as required.



This challenge can easily be used to demonstrate industrial practice and processes. There is considerable scope for cross curricular work; it is certainly motivational and will provide hours of fun for your students. I hope you and they get as much enjoyment out of it as I have.

For further information you can contact Kieron at : mac.cercot@ntlworld.com

Pages 40-41 of the Teaching Resource catalogue are packed with useful small permanent magnet motor specifications detailing loads, speeds, sizes.

Useful parts from Teaching Resources include:

- Solar Module – stock code EL1 006
- Super Capacitor – stock code EC4 050

