BEAM® Robotics Kit #1:

4th Edition!

The Type-I SOLARENGINE©

Reissued Kit with the New Technology 'MillerEngine'!

Want to build something that eats light and turns it into bursts of movement? Using simple circuitry and a little ingenuity, this kit lets you make a BEAM® critter that twitches and moves by itself. Make a speedy solaroller, a SYMET robot, or just something that lives on your windowsill. Construct it well, and it should last for years! (Some soldering skill required)

Contains all you need to build your own BEAM® SOLAR GIZMO!

Produced by

SOLARBOTICS

Documentation Release: October 21, 2000

Table of Contents

We strongly suggest you inventory the parts in your kit to make sure you have all the parts listed. If anything is missing, contact Solarbotics Ltd. For replacement parts information.

Introduction

First off, you should know that BEAM Robotics is a research and education organization dedicated to the promotion and construction of unorthodox robots and gizmos for fun and real world applications. This kit is designed as an entertaining and easy starting point for those who wish to explore the principles of BEAM philosophy.

The components in this kit are the bare necessities for achieving mechanical movement from the universe's most common energy source - **LIGHT**. This means no dependancy on batteries, adaptors, wind up springs, or even *you* for it to continue "living" its merry life. With careful and sturdy construction, you should be able to pick up your BEAM critter in 20 years and say "Look! It's still working!" This kit is the Type-I solarengine, which depends on a voltage-sensative trigger, meaning once it stores enough power, it triggers. The other types of solarengines are time interval based (Type-II), and "charge-curve differentiated" (Type-III).

Once the kit's electronics are assembled, you can move on to find applications for your solarengine, like a solar dragster (solaroller), a bidirectional robot (SYMET), or anything else you'd like to apply battery-less motion to. Advanced applications of this kit include solar rope-climbers, high & long jumpers, aquavores & photovores (light-seeking robots). Other bizarre applications are solar-powered name-tags, flag-wavers, baby satellite dishes, and ornament turners. Go wild and find your own applications to add to this list.

Finishing this kit will mean that you have achieved several significant tasks:

- A basic understanding of transistors, resistors, capacitors, and solar cells
- Recognition of fundamental motor drive systems
- How to solder electronic components onto a printed circuit board (PCB)
- How to get your partner to hold components together while you burn their fingers with a soldering iron.

In other words, you should have fun assembling something that moves by itself while we try to sneak educational things into your head.

The kit should contain the following goodies:

1 - Motor/cassette mechanism
1 - PN2222 transistor (small black thingy with 3 leads)
1 - 1381 voltage detector (another slightly bigger black thingy with 3 leads)
1 - Resistor (tiny cylindrical thingy with colour strips and a lead out of each end)
1 - Diode (another tiny cylindrical thingy with a lead out of each end)
1 - 4700 microfarad capacitor (large battery-like thing with 2 leads)
1 - 0.47 microfarad capacitor (small yellow thing with two leads)
1 - 24mm x 22mm Solar Cell (the squarish glass thing)
1 - Printed Circuit Board
2 - Solarcell & Motor wire (black and red twisted wire)
1 - Instruction book (well, of course, right?)

You will require:

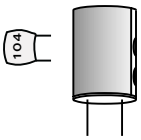
- A soldering iron & *electronics* solder (not plumbing solder)
- A pair of snips, old scissors, or other metal-trimming device
- A pair of safety glasses
- Glue, be it from a hot-glue gun, epoxy, Superglue, or whatever
- A sense of humour. Otherwise, you'll be finding this manual *very strange*.

Parts Overview

This is the part you've probably skipped over unless either you've already got your circuit working and want to know more about why, ***or*** you're waiting for a bus to pick you up and take you to work/school (please don't read this while driving). Whatever your reason, here's the poop:

The circuit is made of five types of electronic components, of which the first three make up a good 80% of what you will find in almost any electronic device. These are:

Resistors - These are devices that "resist" the flow of electric current. Think of them like a narrow neck in a river.

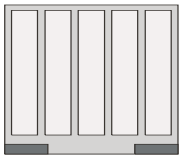


Capacitors - Capacitor acts much like a small rechargeable battery, except that they charge and discharge much more efficiently. Think of these like water tanks on the side of the river that can be filled then emptied back into the river.

Transistors - Transistors are essentially switches that use a tiny amount of current to control the flow of a much larger current. These are like dam floodgates on a river.

Diode - This is like a one-way check valve, allowing current to flow through it in one direction only.

1381 - The 1381 voltage trigger is a small three pin integrated chip (IC) that looks much like a transistor. It was originally designed to detect low voltage levels in the batteries of portable electronic devices, like cellular telephones and portable computers. These take very little power to monitor the voltage, making it much more efficient than older trigger devices like zener diodes or flashing LEDs.



Solar Cell - Solar cells are very thin specialized chips that convert the photons impinging the PN junction into electrical current. Translation: The thingy that turns light into electricity. Usually the bigger, the better.

Motor - The motor you'll be using in this kit is from a *micro-cassette player.* This mechanical assembly was originally designed to be used in an answering machine, but you're going to use it for the motor and other mechanical bits you may want to rip off it. A motor is simply a way to turn electrical energy into mechanical motion we can see and use.

You may notice a few minor inconsistencies in the pictures in the manual. The original manual was written and photographed using the original "Flashing LED" solarengine. This kit is updated to use the much simpler and more efficient "Miller Engine". If you see a picture of something that doesn't look *quite* like what you built, this is most likely the case.

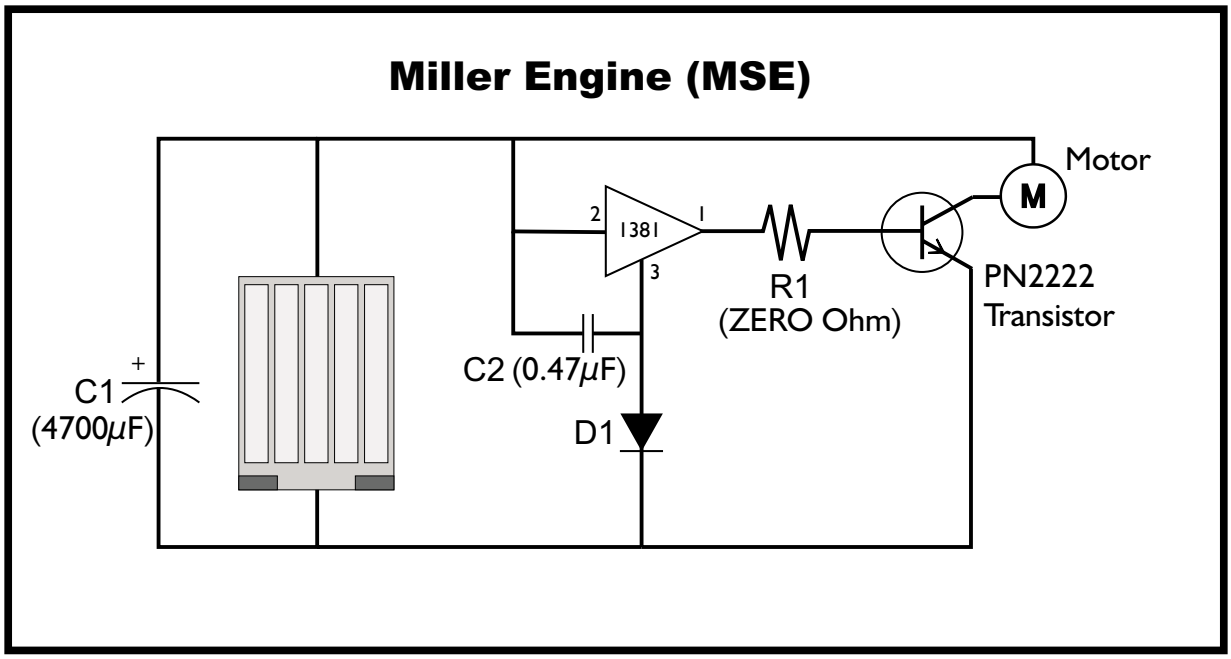
Solarengine Theory

The Miller Solarengine (MSE) is a simple, effective Type-1 (voltage triggered) solarengine with configurable turn-on voltage and discharge time. The turn-on voltage is determined by the type of 1381 selected (in this kit, we use the 1381-C), and the discharge time configured by the size of capacitor C2.

While the solarcell charges the capacitor, its status is monitored by the 1381. When a preset voltage is reached, the 1381 turns on the PN2222 transistor via resistor R1, which pulls power through the motor, making the motor turn. R1 is presently a *zero* ohm resistor - the same thing as a piece of wire. You can change R1 to something else if you are planning on driving components other than a motor, like a LED, or another electronic circuit. Raising R1 will make the circuit stay on longer, but it won't pass as much power.

The 1381 stays on as long as it thinks there is voltage anywhere from the trigger voltage to the trigger voltage - 0.3V. To extend how long it stays on, we use capacitor C2 and a diode. C2 gets charged up through the diode at the same time as the solarengine main storage capacitor C1, but discharges much slower through the 1381 voltage trigger to the transistor. Since the discharge through the resistor is relatively constant, we can adjust how long the 1381 stays on.

Using a C2 of 0.47μF, we get a discharge time of approximately 1/5 of a second while powering the motor out of a micro-cassette mechanism. This lets the circuit activate at about 3.2V, and discharge down to 1.8V. If you want, you can put in a smaller C2 to get more frequent, high-power bursts, or a larger (1.0μF) for longer bursts, but the default 0.47μF capacitor is practically ideal for the components in this kit.



Change this:	Motor Time On:	Time to Recharge:	Result:
Larger C1 Storage Cap	Same	Same	Longer initial charge-up, quick, high-energy bursts. This is because C2 sets how long it stays on for. Make C2 larger to increase how long it stays on for when increasing C1.
Larger Solarcell	Same	Quicker	Quicker initial charge-up and recharge times.
Larger C2 Timer Cap	Longer	Longer	The motors stays on longer, which pulls more power out of the capacitor. This takes longer to recharge, but gives
Smaller C2 Timer Cap	Shorter	Shorter	This will result in quick, high-energy bursts, but won't spin the motor for as long.
Higher 1381 Trigger	Same	Longer	The 1381 sets at what voltage the circuit activates. If it gets too high, it gets harder for the solarcell to charge the
Larger R1 Resistor	Longer	A bit longer	Raising the R1 reduces how much power can go through the motor (Ie: it won't spin as "hard"). It will also keep the circuit on longer because the power flow from C2 slowed down, taking longer to discharge.

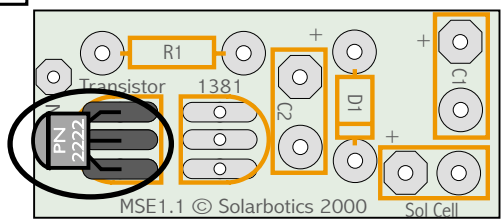
Building It!

This is the fun part - actually building the circuit. Follow the instruction boxes in order, and you will turn these parts into your own functioning solarengine!

Construction Hints:

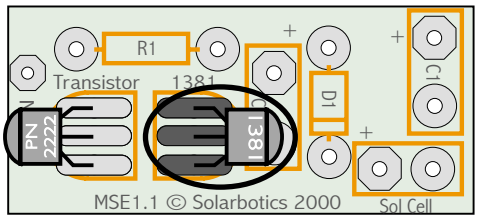
- If you have NEVER soldered before, look at the hint box on the next page! It tells you about soldering do's and don'ts!
- Note that the actual soldering is done on the other side of the board, on the bottom..
- Don't forget to clip the excess wire poking out the bottom when you're done soldering!
- Solder only to the dark pads in each step, and make sure solder does NOT "bridge" to the next pad.

1 PN2222 Transistor



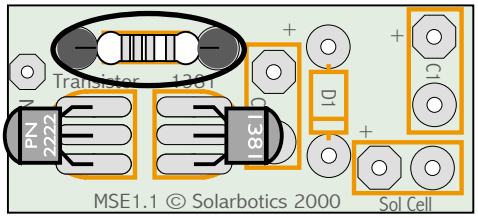
Solder the 2n2222 Transistor in place as shown. Take care to ensure that the transistor numbers are facing upward, and the curve of the device matches the curve on the board..

2 1381 Voltage Trigger



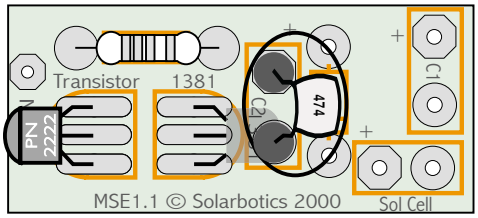
Solder the 1381 voltage trigger in place as shown. Again, make sure the 1381 numbers face up, and the curve on the device matches the curve on the circuit board.

3 Resistor



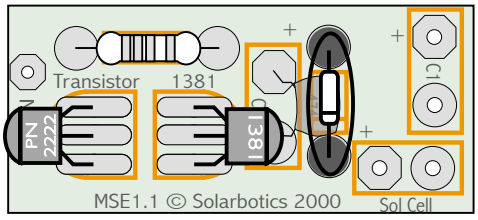
Bend the legs 90° down to the sides of the resistor, and insert it into the holes labeled 'R1'. It doesn't matter which way it goes in.

4 0.47µF Capacitor



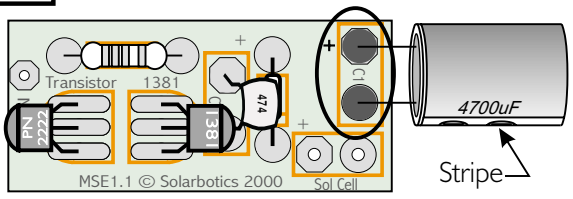
Insert and solder the small capacitor in as shown. Don't worry about polarity - it doesn't matter which way it goes in.
Note: The 1381 is greyed out here for clarity.

5 Diode



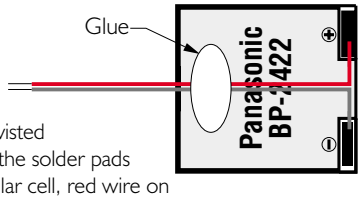
Insert the diode as shown. MAKE SURE that the band on the diode matches where the band is on the circuit board underneath. Note: The capacitor is greyed out for clarity.

6 Power Capacitor



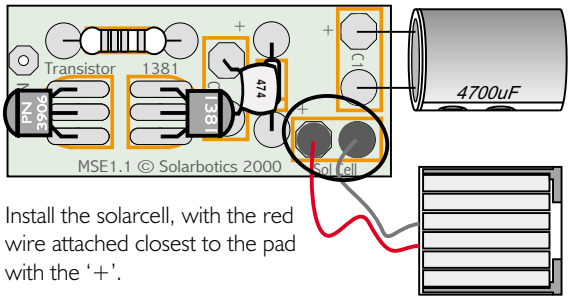
Install the large 4700uF capacitor to the pads labled 'C1'. Polarity is important! Make sure the side *opposite* the capacitor's stripe (-) is soldered to the pad near the '+' sign.

7 Solarcell Preparation



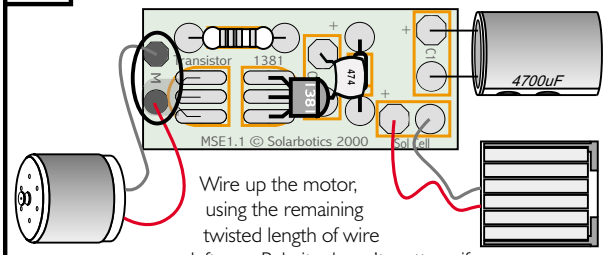
Take one length of twisted wire and solder it to the solder pads on the back of the solar cell, red wire on positive (+), black wire on negative (-). Be quick when soldering to the cell, as the pads may burn off if you're not careful. Glue the wires across the back of the solar cell to protect your soldering job.

8 Adding the Solarcell



Install the solarcell, with the red wire attached closest to the pad with the '+'.

9 Installing the Motor



Wire up the motor, using the remaining twisted length of wire leftover. Polarity doesn't matter - if it spins in the wrong direction, simply reverse the connections! Note that the2n2222 transistor is greyed out for clarity.

10 Performance

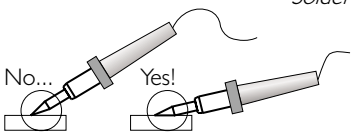
There! You are practically finished! The motor should spin every 5 to 20 seconds under a desklamp or direct sunlight. Now all you have to do is harness the movement of your solarengine!

From a loose collection of parts....

…to this - a fully functional solarengine powering the motor on a microcassette motor!

Hint Box

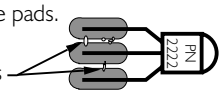
Solder only on HIGHLIGHTED pads in each step box.



Hold soldering iron so that it sits flat to the surface when soldering. It transfers heat much better this way.

Motor going the wrong way? Swap the motor leads!

One of the most common errors is to accidently "bridge" the pads between components. Make sure that there aren't any tiny flecks of solder or wire between the pads.



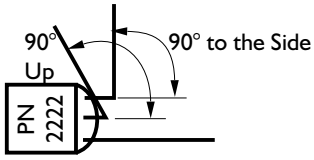
If your PCB has holes in the mounting pads, put the component legs through it to hold it in place while you solder. Just remember to trim off the excess leg underneath. ***BE SURE*** *that solder flows from the pad to the component legs! A good test is to wiggle each component - if a leg looks like its moving, resolder it.*

The Free-Form Miller Solarengine

Freeforming a Solarengine gives you the flexibility of a much smaller package with the exact same performance of a Solarengine built on the printed circuit board.

You will need a PN2222 transistor, a diode, a 1381 trigger, a storage capacitor (1000 to 4700μF), a timing capacitor (0.47μF to 2.2μF), wire, a motor and a solarcell (solarcell must generate 3.2V MINIMUM).

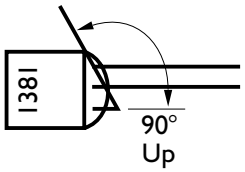
1 PN2222 Transistor



Bend the right side lead (the *collecter)* 90° to the side.

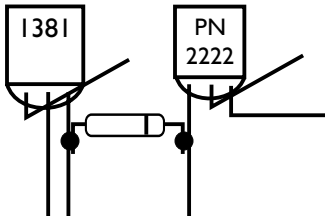
Bend the middle lead (the *base)* 90° up, so it points up at you.

2 1381 Voltage Trigger



Bend the left side lead (the *output)* 90° up so it points towards you.

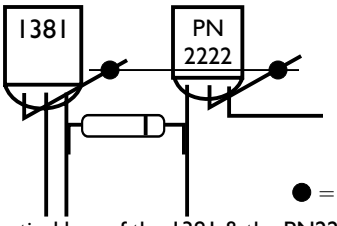
3 1381/PN2222/Diode



● =Solder point

Place the 1381 and PN2222 transistor side-by-side, and join the inner legs with the diode as shown. Note that the black band of the diode is on the RIGHT side.

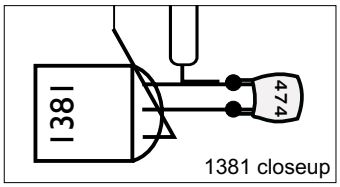
4 Wire



● =Solder point

Bridge the vertical legs of the 1381 & the PN2222 with a wire, then cut off the excess leads. If you can bend & solder the legs together, you won't need a wire at all.

5 Timer Capacitor

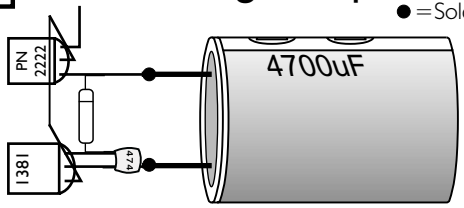


● =Solder point

Mount the desired discharge timer capacitor (in this case, 0.47μF) across the middle and right legs of the 1381. If the capacitor has polarity, connect positive (+) to the middle leg of the 1381.

6 Main Storage Capacitor

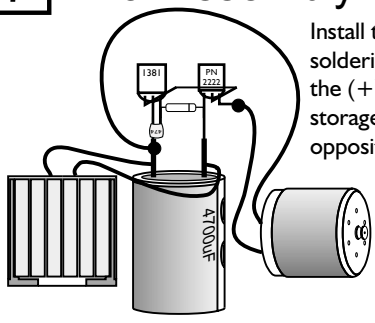
● =Solder point



Solder the main capacitor to the assembly so that the capacitor leg nearest the stripe on the capacitor body (-) is soldered to the left leg of the PN2222 transistor, and the other leg (+) is soldered to the middle leg of the 1381.

7 Final Assembly

● =Solder point



Install the motor by soldering one connection to the (+) side of the main storage capacitor (the lead opposite the striped side). Solder the other connection to the right leg of the PN2222 transistor. There - you're done!

Trouble Shooting

Well, you take yer six-shooter, line up the troublesome BEAM critter on a wooden fencepost and... aw, it's really not that hard to fix this circuit. There isn't much that can go wrong with this particular layout. Run through this checklist and see if you can isolate your problem. If you're still stumped after this, leave it for a day and come back when your sanity returns.

Problem:	Remedy:
• 1381/transistor/diode installed the wrong way around	• Make sure the PN2222 is furthest away from the 4700µF capacitor. The only other spot left is for the 1381!
• Backwards polarity on the Solar Cell / capacitor	• Make sure the positive wire from the Solar Cell goes to the positive pad as shown nearest the '+' sign on the PCB. The capacitor's '+' is the side *opposite* the striped side
• Broken connection on the Solar Cell	• Uh oh. This takes some extra effort to correct. If the solder pad on the Solar Cell has broken completely loose, reattach it with "Automotive Defogger Repair Paint", commonly available at Automotive supply stores. This is an electrically conductive paint that will dry to a conductive film.
• Solder Bridge (solder crosses copper pads on PCB)	• Carefully examine the PCB to see if any solder hasn't accidently "bridged" from one pad to another. Remove any bridges by melting it with the soldering iron and then sharply tapping the PCB against a hard surface.

Another valuable diagnostic tool is a voltmeter. If you have one available, connect it to the capacitor leads. Voltage in the capacitor should climb to between 2.6 and 3.0 volts before it dumps the power to the motor. If the voltage climbs only to between 0.6 and 0.8 volts, check your soldering job again, particularly the motor connections.

Be sure that none of the existing component leads are accidently pressing against any other leads or PCB traces. If you haven't already trimmed the excess component leads, they may be shorting out against each other on the other side of the circuit board - *trim them short!*

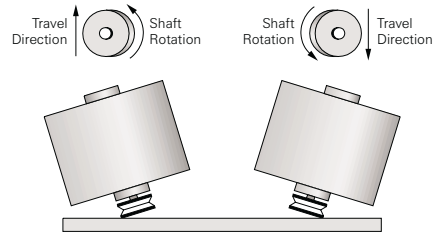
Push come to shove, call us - but ***NOT*** in the middle of the night. The circuit's not designed to operate at night anyway (yeah, yeah - *that's* the reason...).

Let's Get Moving!

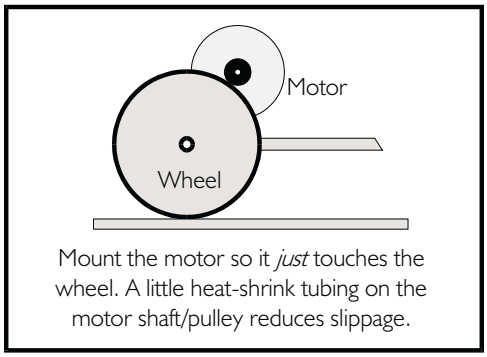
The fact that you're reading this means you have a working solarengine (or you're bored and just filling time until the TV commercials pass to the next program). This section is designed to help you get something moving across your desk/floor/sibling/significant other. All the following locomotion ideas are well tested in existing BEAM machines, with some working better than others in different situations. We suggest that you try the SYMET idea first as it is simple and effective, but do try the others for comparison. And don't hesitate trying to combine them.

"SYMET" Direct Drive

By placing the motor on its face and tilting it just a little, it will move in one direction. Watch a child's toy top roll to a stop, and you'll recognize the mechanism used in the SYMET drive. The term "SYMET" is used because this system lends itself well to the design of "symmetrical" BEAM robots that reverse direction when they bump into something. See if you can come up with a method of making the robot tilt from one side to the other so it changes direction. This system is simple and effective, but also results in robots that don't usually go very straight - ok for photovores, but bad for solarollers.



Direction of travel depends on which edge of the pulley touches the surface.



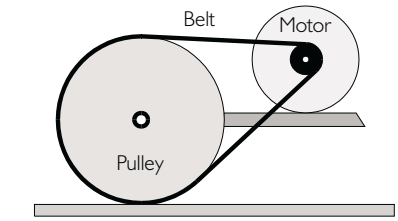
Mount the motor so it *just* touches the wheel. A little heat-shrink tubing on the motor shaft/pulley reduces slippage.

Friction Drive

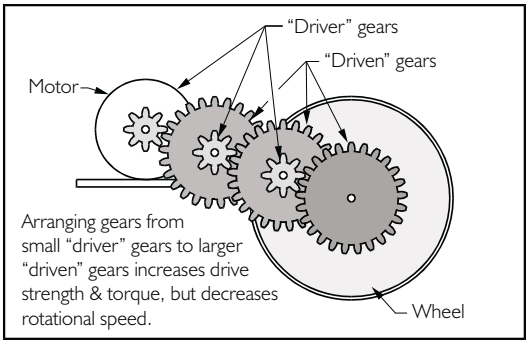
By removing the pulley and placing the shaft of the motor right up against a wheel, you can motivate your BEAMbot with a friction system. This arrangement results in straighter-travelling BEAM critters, but reversing direction becomes a problem. Slippage between the shaft and the wheel becomes a concern, which can be fixed by increasing the force between the motor & wheel, or increasing the friction between the two with some heat-shrink electrical insulation on the motor shaft.

Pulley Drive

This is basically what your average "Walkman" or portable stereo is already doing, so you should have the parts readily available. You may be able to cut the pulley drive right out of the system, motor included. If not, build your own based on the same pieces, making sure to use the black belt from the cassette mechanism. Elastic bands stretch too much, and why not use the belt that's *designed* for this purpose? Be careful not to make the belt too tight - you'll simply be wasting power.



Make double-use of the belt by making it act as a tire as it goes around the pulley.



Arranging gears from small "driver" gears to larger "driven" gears increases drive strength & torque, but decreases rotational speed.

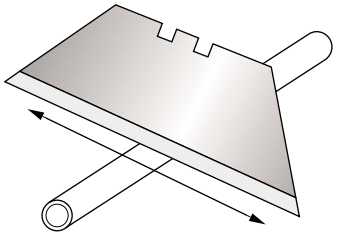
Gear Drive

Most electromechanical toys and devices have a geardrive somewhere in them. However, it's often tough to find gears that match your motors and wheels exactly. Rip a few things apart and you may get lucky. If possible, try salvaging the whole geartrain instead of just prying the gears loose -it'll work better than trying to realign them yourself. Good places to start looking are in auto-reverse tape players and clock mechanisms.

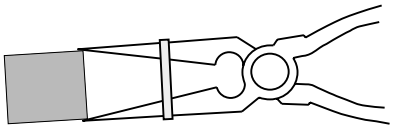
Hint Box

Here are some techniques we've found that are valuable when starting off in BEAM robotics. Instead of taking you many hours of experimentation, we've put them all on this single page!

Keep super-glues away from anything you plan to solder - it results in some nasty fumes when heated!



Brass tubing (commonly available at hobby shops) can be cut without crimping by rolling it with a razor blade. Dull blades work too.

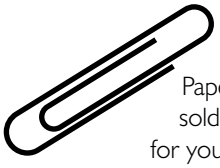


Put an elastic band around the jaws of your needle-nose pliers to hold parts while soldering. It saves you burning your fingers!

Looking for a cheap & handy clamp to hold pieces together while you solder them? Look for a wood clothespin, and whittle it to the right shape needed to hold your parts.

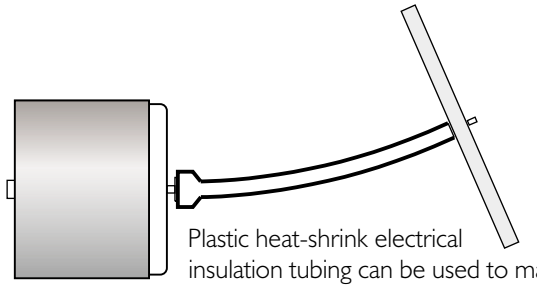
Copper-clad welding rod (MIG wire) makes good frame material. (Look in the Yellow pages under "Welding Supplies")

Bronze bushings carefully punched out from cassette deck mechanisms can be used as low friction axle bushings.



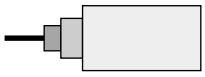
Paper clips can be a cheap source of solderable wire for making frames for your solarengine. Keep an eye out for the copper/brass type.

Mount your motors on flexible wire frames. This allows you to tweak the motor installation to optimize performance.

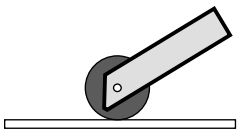


Plastic heat-shrink electrical insulation tubing can be used to make flexible drive shafts. Think of propellor shafts...

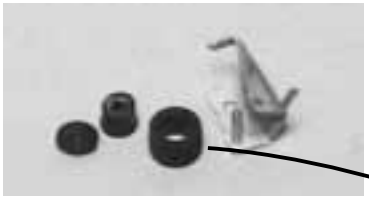
Any shaft can be made bigger to fit gears/wheels/pulleys by using successive layers of plastic heat-shrink electrical insulation tubing



Another Hint Box..

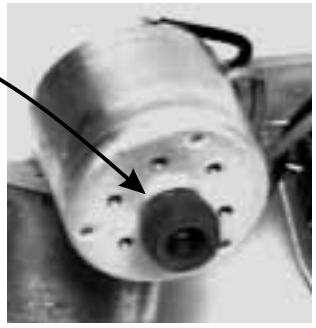


Rubber pinchrollers from cassette deck mechanisms make GREAT wheels for Solarollers!

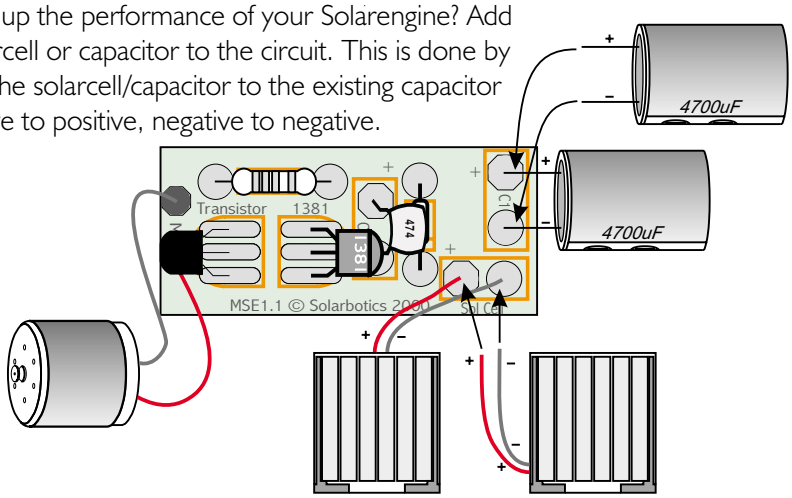


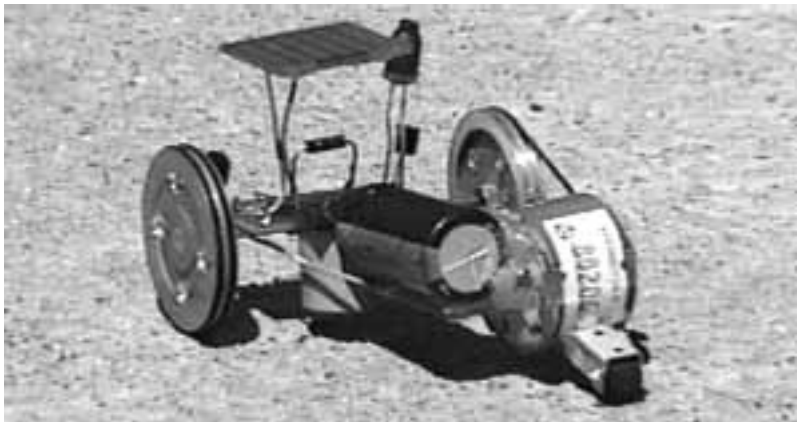
Once you have a pinch roller removed, it's fairly easy to tear it completely apart. Why?....

...Because you can stretch the rubber tire over the pulley on the motor to make a *very* effective wheel for a SYMET-style drive!



Want to jazz up the performance of your Solarengine? Add another solarcell or capacitor to the circuit. This is done by soldering in the solarcell/capacitor to the existing capacitor wires, positive to positive, negative to negative.



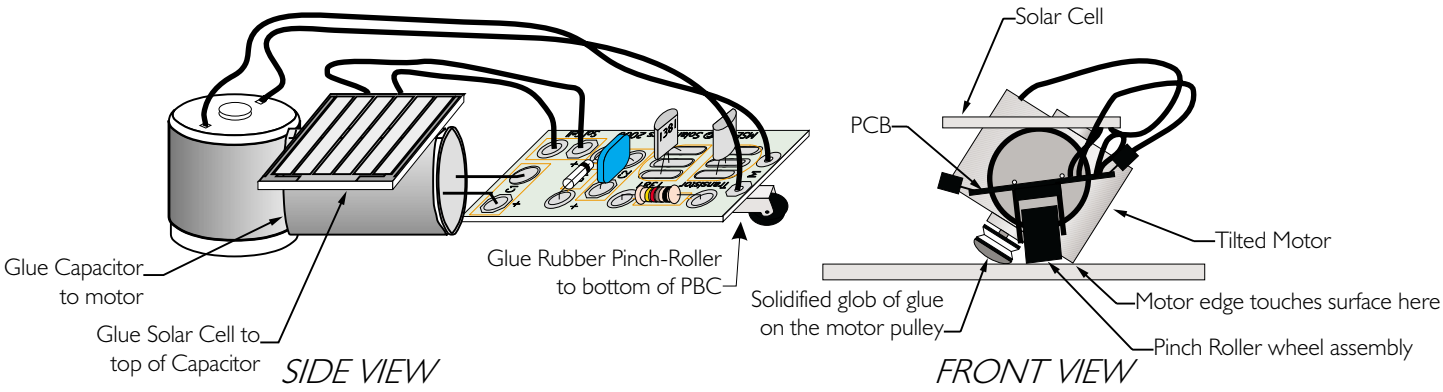


This Solaroller was built by Logan Edwards, a 12 year old student at one of our BEAM Workshops. With the addition of an extra capacitor underneath the PCB, his Solaroller goes in 4" spurts. He's used the flywheels from two of the metal cassette mechanisms and a pinch roller to make a belt & pulley powered tricycle.

Ideas for your Solarengine
The Solaroller!

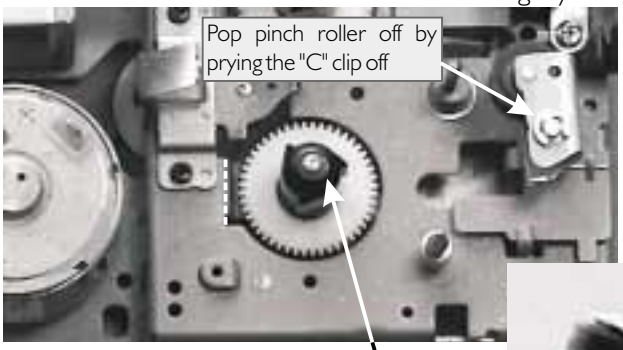
Now that you have your Solarengine functional, what are you going to do with it now? If you need a little "push" in the right direction, feel free to borrow from the following ideas.

This particular Solaroller is built with the "Symet" style drive described earlier. By tweaking the alignment of the pinchroller wheel, this design should kick along in a fairly straight line.

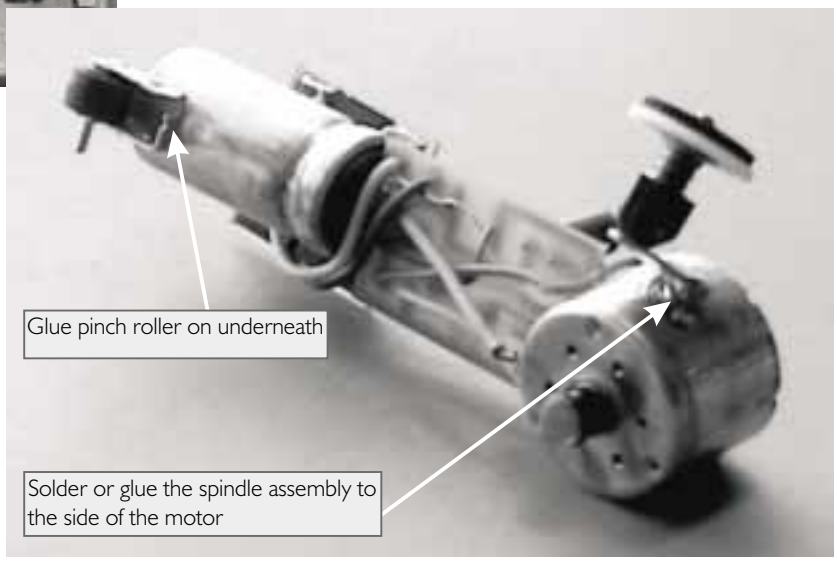


Another Variation...

Another variation of the Solaroller is shown on the cover of this instruction manual. This requires more patience to build, but it performs much better with the addition of the third wheel, which is actually the left spindle clipped out of the metal cassette mechanism. The circuit is also assembled in a slightly different manner. Instead of mounting the capacitor out to the side of the PCB, it is moved to one end and the long capacitor leads are bent to make the connection. The solarcell and motor wires are soldered in underneath for neater appearance. Examine the photographs for further details. This particular Solaroller does the meter in 3m36s under a 100 watt incandescent bulb 16cm (6") above the surface - that's about a 24 hour 1/4 mile time!



1. Pry small black split-ring off (SAVE IT!)
2. Pull spindle off
3. Cut spindle axle off at dashed line
4. Put spindle back on backwards & put the split ring back on



More Ideas for your Solarengine
The Symet, Roundabout & Solar Flag Waver!

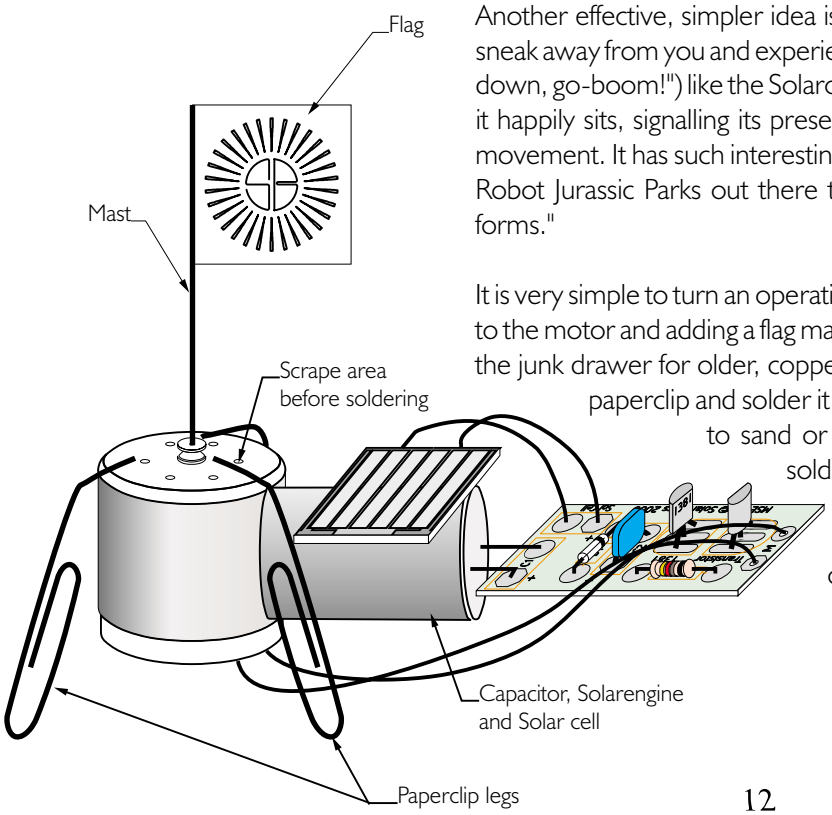
If you want to construct something other than a Solaroller, you may want to try one of these devices - the "Symet", the "Round-about", or the "Solar Flag Waver".

The "Symet" is a simple robot that interacts with its environment by the use of tactile (touch) sensors. When one sensor hits an obstacle, it causes the Symet to tip over to the other side and scoot away in the opposite direction.


Roundabout

The Symet "Roundabout" is an easy implementation of the Solarengine with the addition of two paperclips. By soldering the paperclips to the bottom of the motor (as shown in the picture), the Roundabout will spin around in circles. This makes it more mobile than a Solar Flag Waver, but still keeps itself in a central location.


Symet underside



Another effective, simpler idea is the *Solar Flag Waver* (SFW). This BEAM critter won't sneak away from you and experience "Sudden De-acceleration Trauma" (that means "fall-down, go-boom!") like the Solaroller can. It is also neat to have on your windowsill where it happily sits, signalling its presence to the rest of the world with its occasional blip of movement. It has such interesting presence that there aren't many photovore worlds or Robot Jurassic Parks out there that don't have a selection of these "Robot Plant Life-forms."

It is very simple to turn an operational Solarengine into a SFW by simply adding some legs to the motor and adding a flag mast to the output shaft of the motor. Here's where raiding the junk drawer for older, copper/brass paperclips works well. Unbend one end of the paperclip and solder it to the top of the motor, like in the diagram. Just be sure to sand or file off a spot on the motor so it's shiny - this make soldering to the motor much, much easier. Glue the capacitor/PCB/solar cell to the side of the SFW, mount a mast in place with glue or solder, and tape a business card or small sign to it and you're done!

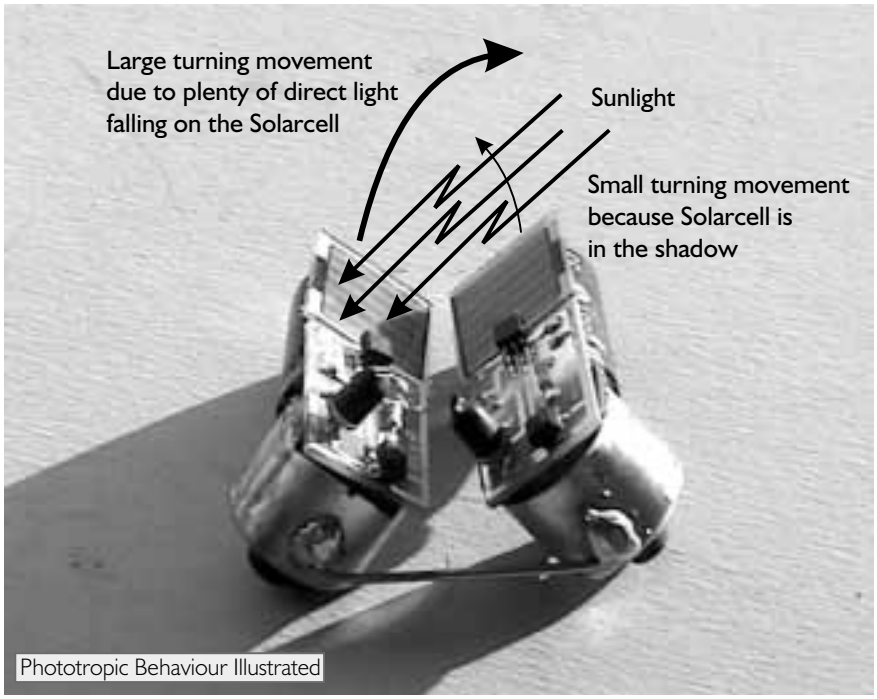
Advanced Ideas for your Solarengine
The Photovore Light-Seeking Robot!

The Solarengine by itself allows you to build quite a variety of interesting devices, but not many that can actively seek out sources of light. Devices that can do this are called **Photovores**, from the Greek & Latin meaning "Light-Eater". The BEAM Photovore is a simple, true, robot that is constructed from two separate Solarengines (in a Solaroller configuration) mounted side-by-side in a "V"-shaped arrangement with a connecting crossbar. Joining two Solarengines together makes a Photovore with the ability to seek out sources of light - an essential behaviour for a solar-powered robot!

When there is an uneven light falling on the Photovore, one of the solarcells will receive more light than the other. This naturally means that one of the solarengines will be more active than the other. By placing the more active Solarengine in a position where it will turn the whole robot *towards* the light, we get a *Phototropic,* or *light-seeking,* behaviour. You could arrange the Solarengines so they make the robot scared of light (a Photophobe), but how much fun is it constantly picking your robot out from underneath the couch where the killer dust-bunnies live?

This particular Photovore is constructed entirely from the contents of *two* Type-1 Solarengine Kits and a piece of copper rod (the crossbar). The pinchrollers from the metal cassette mechanisms were cut apart so the rubber tire could be removed and placed on the output shaft pulley of the motor instead, which gives the Photovore much better traction.

You may eventually want to give your robot the ability to avoid obstacles it may bump into. You can do this by placing touch switches that short out the Solarengine opposite to the obstacle, which will make the Photovore pivot around the dead wheel until it comes free of the obstacle. There are many ways of introducing other behaviours to a Photovore, but this type's built-in ability of finding and maintaining contact with light sources makes it an easy way to constructing your own true BEAM robot.



Phototropic Behaviour Illustrated


Connection Crossbar


Photovore Layout

Build your Device for Competition
The Official Solaroller Race Rules

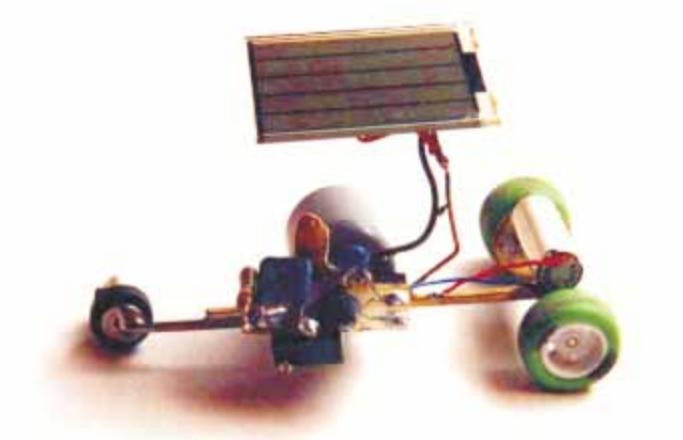


Fig 1: Solaroller "Scooter" (Dave Hrynkiw, 1995)

Object:

Given a maximum solar cell size of 806.5 mm^2 (1.25 square inches), make a self-starting 150mm (6") robot dragster to race one meter (3.3 feet) in full sunlight (or 1,000 watts Halogen lighting). Competitors will race each other down parallel 150mm (6") wide lanes. Fastest to finish, or furthest travelled in 3 minutes wins.

Competitor Design Parameters: Solaroller

1 - At the start of the race, the competing Solarollers potential energy must be zero (0) volts. To insure this, Solarollers must have a pair of shorting wires extending from them far enough to reach a metal shorting bar at the rear of the 150mm (6") starting square. When these wires contact the shorting bar, it must clamp all on-board power storage to zero. Solarollers cannot use any other energy source to motivate them than what they are able to draw from their solar cell. No pre-tensioned springs, elastics, combustion or compressed energy sources are allowed, though any of these may be employed in the design so long as it can be proved that they are at a complete state of rest at the beginning of the run.

2 - Competitors cannot initially exceed the bounds of a 150mm (6") cube. Competitors may split apart or change their physical geometry beyond the dimensions of this cube during a run, but a win will only count when the LAST part of a shape-changing Solaroller has crossed the finish line. Competitors are not allowed to drop, throw or leave behind any part of their chassis. Competitors must finish with everything they started with.

3 - Competitors cannot have parts removed or added to them between races with the exception of replacing broken components necessary to the operation of the vehicle. The replacement parts must be identical to the part being replaced, and fact of this be shown to the judge.

4 - The maximum allowable solar cell surface area cannot exceed 806.5 mm^2 (1.25 square inches). A 24x33mm, 2.7 volt Panasonic Sunceram BP2433 solarcell shall be considered the norm, except in the case of using a solar-walker, where a 37x33mm 5.5 volt Panasonic Sunceram BP3733 is considered the norm. Any solar-cell configuration will be considered valid so long as the effective cell area does not exceed the maximum allowable. Any solarcell not meeting this requirement will disqualify the device. There is no minimum solar cell size restriction.

The Official Solaroller Race Rules
~ continued ~

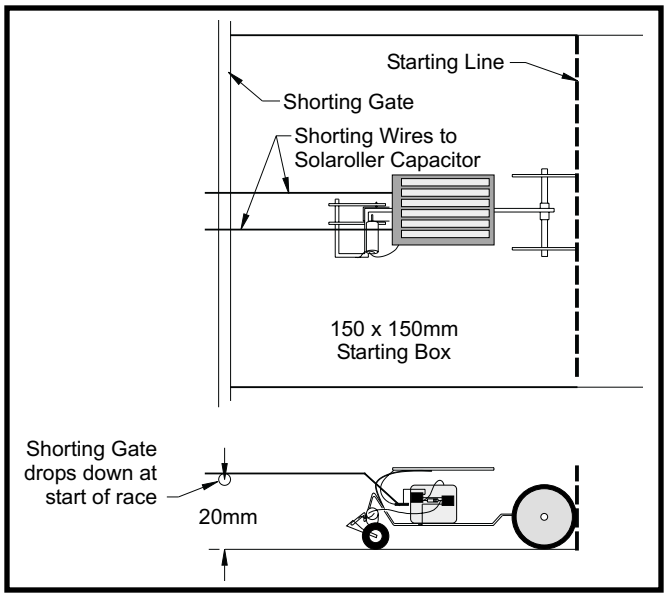
5 - During racing, competitors must not physically touch or attempt to touch each other, however, competitors may attempt to interfere with each others light source by extending vanes or other devices over the 25mm (one inch) lane walls. Vane extensions must still fit within the size guidelines.

6 - Designers are not allowed to augment their competitor performance by the use of external light sources, or even subtle reflections off of watches or eyeglasses. Devices will be illuminated by a minimum light source of two 500 watt halogen lights placed 50cm (19.7") above the race platform, to a maximum of up to pure noon-time, unobstructed sunlight. In the case of halogen lighting, the first light is placed aimed straight down directly in front of the starting box. The second light is aimed straight down, 66cm (26") from the starting line.

7 - Competitors should be able to withstand heat excesses up to a radiant 50° C (122° F) from the competition light sources. Melting competitors will be disqualified.

The Race:

The single-heat race begins when the judge says "go" and lets a charge build up in the two competitors. This is done by the judge lowering the conductive metal rail at the rear of the starting box that is shorting out the circuitry in the competing racers. Care shall be taken to insure that competitors are released fairly and with as little disturbance as possible. It is the competitor's responsibility to install suitable wires for this purpose.



Once the contacts are open and the devices allowed to charge, the race has started. To insure the devices follow the "self-starting" rule, competitors must remain immobile for at least three seconds following the start of the race. If one or both move within that time, a false start is called and the race is re-run. If the Solaroller again false-starts, it will be disqualified.

The race is run until the frontmost vertical edge of a competitor crosses the finish line at the end of the 1 meter lane, until a designer concedes, or until a full 3 minutes has elapsed (at which point the racer travelling furthest wins). The exception to this is when a Solaroller changes it's shape, and must fully cross the finish line.

During the run, competitors are allowed to touch the surrounding walls as necessary but should not damage or climb the walls. If a Solaroller becomes stalled against the wall, it cannot be interfered with. In the case of a dual stall, the furthest travelled competitor shall be considered the winner of that heat.

If clear, unobstructed sunlight is available or the halogen light option is used, the times of the individual runs will be kept track of. All running times shall be registered and recorded.

Reference Material
(take this to the library):

Periodicals (Magazines & Newspapers)

Discover Magazine, Sept 2000, Pg 87-88 (”BioBots”)

Smithsonian Science Magazine, February 2000 (BIG, excellent, article with many pictures)

Electronics Now, Sept 1998, Pg 49 (Satbot Technology)

Reader's Digest (Canadian Edition), April 1998, Pg 57 (edited version of Dec '96 Equinox article)

"Chaotic Robots”
Wired, Sept 1994 Page 106 (Advanced BEAM critters)

"Mini-robot armies are gathering strength"
"Don't Throw out that old calculator - Mark Tilden wants it for a mini-robot that might come alive"
"Is it an ant? A cockroach? Or simply a squiggle?"
Globe & Mail Newspaper, Saturday January 9th 1993, Pg A1 (LOTS of neat BEAM stuff)

"Photovores"
Scientific American, September 1992, Pg 42 (Mark Tilden stuff)

"At the Robot Olympics"
Whole Earth Review, Spring 1992, Pg 80-85 (The 1991 BEAM Robot Olympics)

"'Mad' inventor uses whimsy and weirdness"
Vancouver Sun Newspaper, November 1 1991, Pg B6 (Mark Tilden stuff)

Books
"Getting Started in Electronics"
Catalogue # 276-5003. Written exclusively for Radio Shack by Forrest M. Mimms III. An excellent beginner reference on electronics.

"Engineer’s Mini-notebooks"
An assortment of specific booklets by the same above author and available from Radio Shack. Some titles include "555 Timer IC Circuits," "Digital Logic Circuits," "Op Amp IC Circuits," and "Science Projects."

"Vehicles - Experiments in Synthetic Psychology"
By Valentino Braitenberg, MIT Press 1984, ISBN 0-262-02208-7, and recently available in paperback. This book has defined in theory what BEAM robots can do in practise. It illustrates basic behavioural principles and how they inter-relate. Excellent if you want to do some heavy "inspirational" BEAM reading.

For an updated list, visit our website at http://www.solarbotics.com, and visit the “What’s BEAM?” or “BEAM Philosophy” pages.

Closing Notes...

We hope that you've found your Solarengine kit a fun & satisfying way into BEAM robotics - after all, that's what we wrote it for. But feel free to disregard our instructions and try your own techniques. Some of the world's best inventions came from people disregarding instruction manuals...except those same people still have no idea how to program their VCR.

We've been told that there should be a chapter on "Dumpster Diving 101 - how to salvage cool garbage and still maintain dignity." Well, it's an acquired skill, taking years of practice and dedication. Actually, it's as easy as keeping an eye peeled at work or while in the neighbour's garage. "Hey - you ever gonna use that broken walkman?" or "Mind if I take that trashed typewriter home with me tonight?" will take you far without ever having to manually dig through refuse (but that works too!). Also keep an eye open when you're at a second-hand or surplus store. What is junk or overstock to other people can be excellent BEAMbot material. Related to Dumpster Diving is the "Rip it Apart" ethic, which states:

1 - Always rip things COMPLETELY apart, and
2 - Never put them back together the same way.

You'll find the "Hey - that's cool!" factor goes waaaay up doing this.

For kits, parts and further technical support, feel free to contact:

Solarbotics Ltd.

Fax: (403) 226-3741
info@Solarbotics.com
www.solarbotics.com