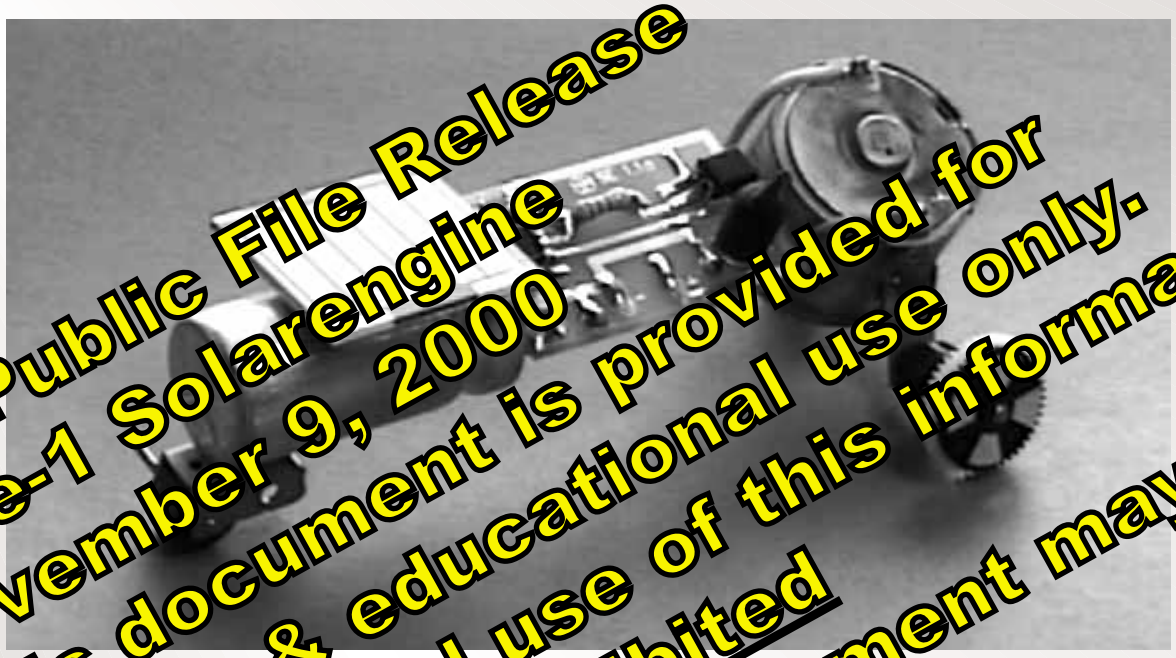
BEAM® Robotics Kit #1:

3rd Edition!

The Type-I SOLARENGINE©



PDF Public File Release
Type-1 Solarengine
November 9, 2000
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We'll build something that eats light and turns it into bursts of movement. Using simple circuitry and a little ingenuity, you'll let's make a BEAM critter that twitches and moves by itself. Make a single solarolle, a SYMET robot, or just something that lives on your windowsill. Construct it well and it should last for years! (Soldering required)

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

Produced by
SOLARBOTICS

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"Resurrection Technology" - Reuse high-tech goodies wherever you can!

Introduction

First off, you should know that BEAM Robotics is a new and untraditonal way to build robots. It's also an acronym for Biology, Electronics, Aesthestics and Mechanics. 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 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. *Please note* that many of the BEAMbots pictured in this manual were made by BEAM enthusiasts using materials not included in this kit. That doesn't necesarily mean you can't build them too, but it means yours will look different because you'll be using different construction stuff. Use your imagination - it's the best building tool you have!

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

- A basic understanding of transistors, resistors, capacitors, and solarcells
- Recognition of fundamental motor drive systems
- How to lay 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 - 2N3904 NPN Transistor (small black thingy with 3 leads)
1 - 2N3906 PNP Transistor (another small black thingy with 3 leads)
1 - 2.2 kilohm resistor (tiny cylindrical thingy with a lead out of each end)
1 - 4700 microfarad capacitor (large battery-like thing with 2 leads)
1 - Flashing LED (small green, yellow, or red bulb-looking thingy)
1 - Piece of Black Heat-Shrink Tubing (Short plastic sleeve thing)
1 - Solarcell (the squarish glass thing)
1 - Printed Circuit Board
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
- Matches or a lighter
- A sense of humour. Otherwise, you'll be finding this book *very strange*.

Read the complete manual before starting construction, as this will reduce the potential of errors. Also *always* use proper safety equipment when working on your kit.

Circuit 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:

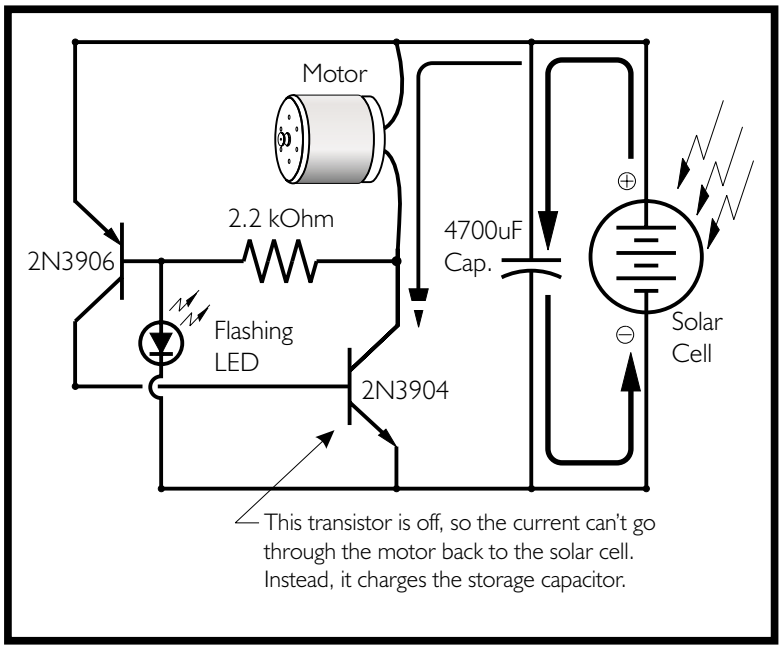
- Resistors - These are devices that "resist" the flow of electric current. Think of them like a narrow neck in a river.
- Capacitors - Capacitor acts much like a small rechargeable battery, except that they charge and discharge much more efficiently. Think of these like water buckets that can be filled then quickly emptied.
- 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.
- Flashing LED - The Flashing LED (FLED) is much like other little lights you see on electronic items, except it has a tiny, internal chip that makes it flash. Since it is a simple and reliable way of triggering the circuit, we use it in this kit. It is otherwise known in this circuit as a thingy that turns on the transistors when a certain power level is reached.
- Solarcell - Solarcells 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.

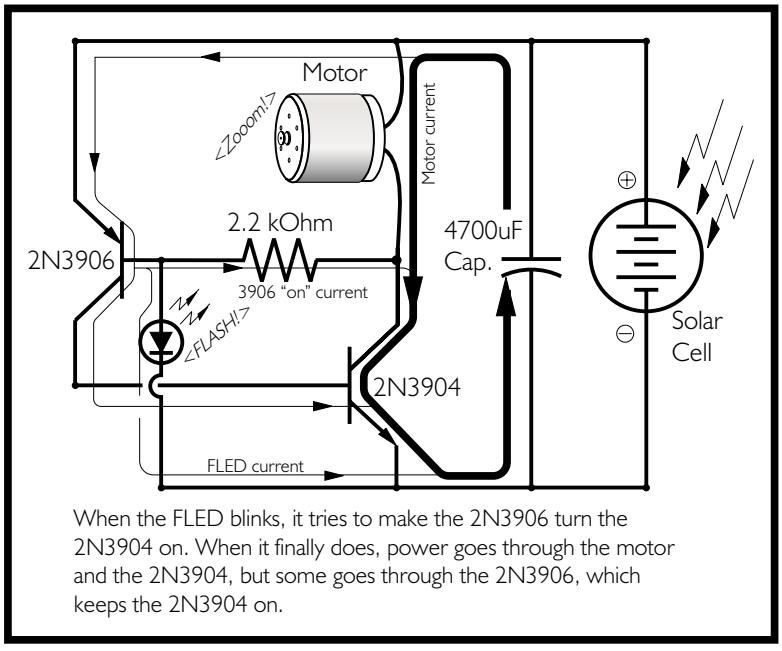
The two transistors and a resistor make up what could be called "a modified SCR with Supercritical Feedback." Translated in English, this means an electronic switch that stays on until it runs out of power or is manually turned off / squashed underfoot.

When you combine the FLED and the switch, you end with a "relaxation oscillator," which charges up, then discharges. Here, we're charging up using the solarcell, then discharging through the motor (zoom!). The process goes something like this:

When light initially falls on the solarcell, it starts charging the large 4700 µF capacitor (the power storage thingy). When the voltage level reaches about 2.3 volts, the FLED starts flashing. When the voltage finally hits about 2.5 volts, the FLED has enough power to finally trigger the switch into latching "on." Now that the switch is on, it remains on, sending power to the motor until the voltage falls to about 0.7 volts. Why 0.7 volts? Well, all electronics won't operate below a certain voltage, kinda like you won't operate below a certain...oxygen level.

The switch stays on because of the way the two transistors are laid out. The 2N3904 transistor is the one that conducts the power to the motor, while the 2N3906 is there just to keep the 2N3904 on. Some power from the 2N3904 is split from the motor to keep the other transistor on, which keeps the other transistor on, and so on, and so on. Check out the following diagrams:

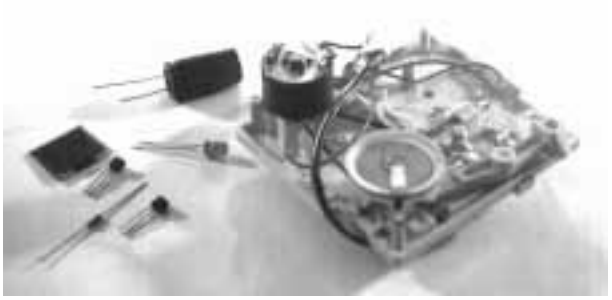




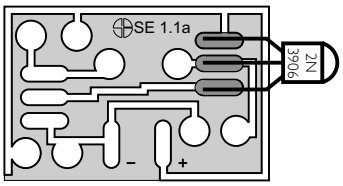
Building It!

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

From this...

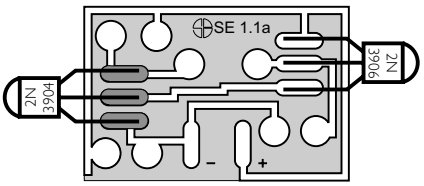


1 2N3906 Transistor



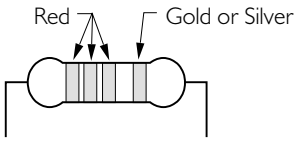
Solder PNP Transistor (2N3906) in place as shown. Solder only to the dark pads on the illustration. Take care to ensure that the transistor numbers are facing upwards.

2 2N3904 Transistor



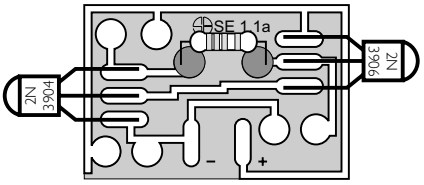
Solder NPN Transistor (2N3904) in place as shown. Take care to ensure that the transistor numbers face upwards.

3 2.2K Ohm Resistor



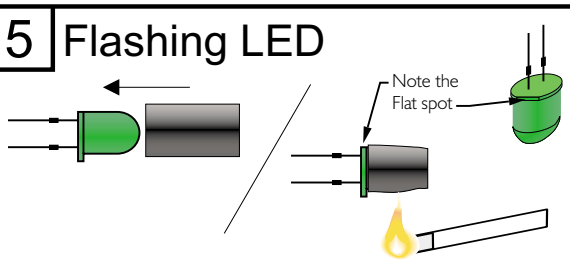
Bend the resistor leads down on both sides of the body. You can leave them full length or trim them to neaten the Printed Circuit Board (PCB).

4 Adding the Resistor



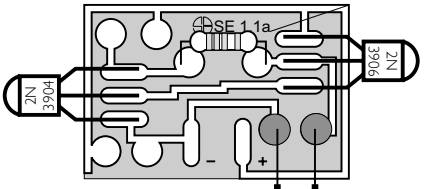
Solder the 2.2 kOhm resistor in place as shown. The resistor can be mounted in either direction.

5 Flashing LED

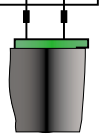


Trim the Flashing LED (FLED) leads so they are about the same length. This makes soldering it to the PCB easier. Then slip the small length of Heat-shrink tubing over the top portion of the FLED and shrink it down with a match or lighter (*very* impor-

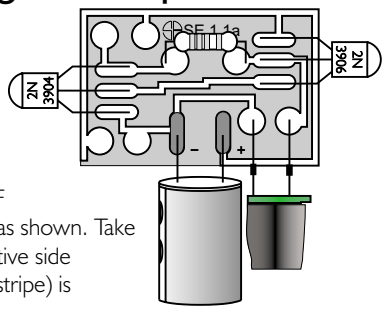
6 Adding the FLED



Solder the Flashing LED in place as shown. Take care that the negative side (the one with the flat spot) is soldered to the *left* pad.

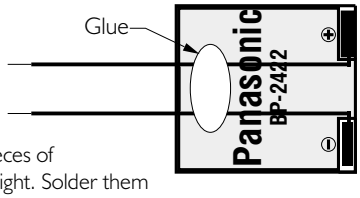


7 Adding the Capacitor



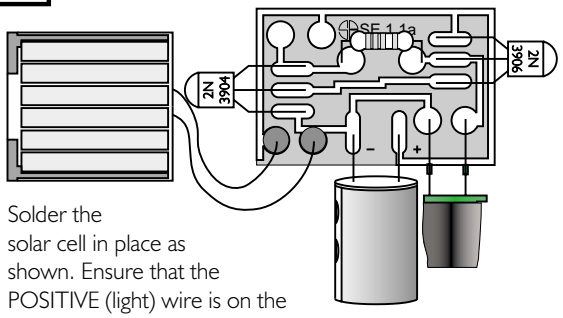
Solder the 4700uF capacitor in place as shown. Take care that the negative side (marked with the stripe) is

8 Solar Cell Preparation



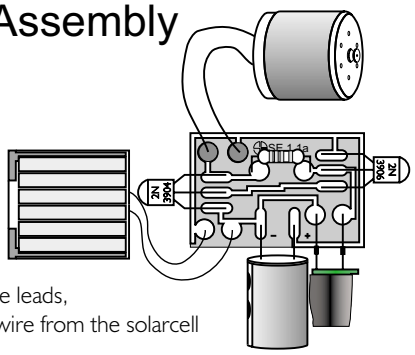
Cut two 5cm (2") pieces of wire, one dark, one light. Solder them to the solder pads on the back of the solar cell, light wire on positive (+), dark wire on negative (-). Be quick when soldering to the cell, as the pads may burn off if you're not careful. Glue the wires across the back of the solar cell to protect

9 Adding the Solar Cell



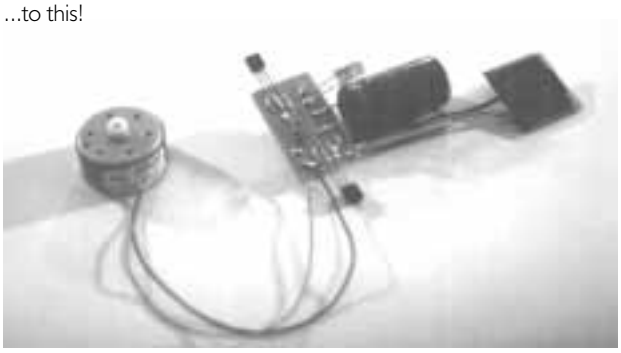
Solder the solar cell in place as shown. Ensure that the POSITIVE (light) wire is on the

10 Final Assembly



Solder the motor leads to the pads as shown. If your motor doesn't have leads, cut two pieces of wire from the solarcell

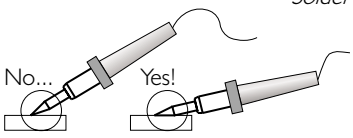
...to this!



There! It should look pretty close to this. 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!

Hint Box

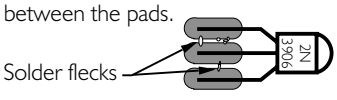
Solder only on HIGHLIGHTED pads in each step box.



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.

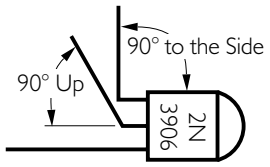


If your PCB has holes in the mounting pads, put the component legs through it to hold it in place while you solder. Just remember to trim off the excess leg underneath. ***BE SURE*** *that solder flows from the pad to the component legs! A good test is to wiggle each component - if a leg looks like its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

No PCB
How to "Free Form" a Solarengine

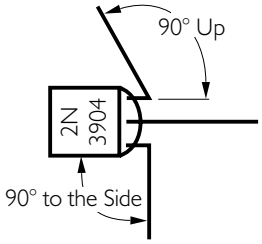
If you want to save space by not using the PCB, or you want to build another solarengine, use this sheet. It will be lighter and work exactly the same.

1 2N3906 Transistor



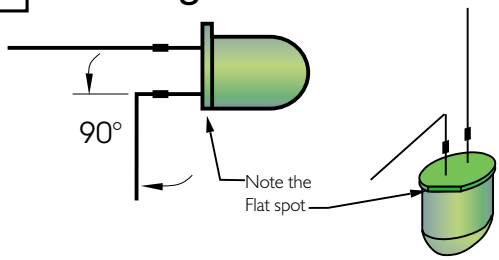
Bend the centre lead of the 2N3906 up at a 90° angle, and the left lead 90° to the left side.

2 2N3904 Transistor



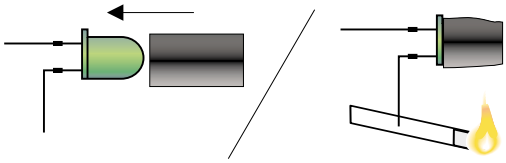
Bend the right side lead 90° up, so it points at you.
Bend the left side lead 90° to the left side.

3 Flashing L.E.D.



Bend the leg closest the flat spot of the LED 90° to the side.

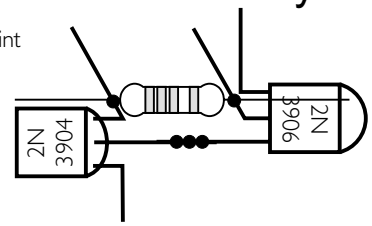
4 Flashing L.E.D.



Fold the leg closest to the flat spot over to the side. Then slip the small length of Heat-shrink tubing over the top portion of the FLED and shrink it down with a match or lighter (***very*** important!).

5 Transistor Assembly

● = Solder point

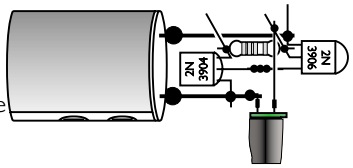


Solder the middle lead of the 2N3904 to the right lead of the 2N3906 with about 5mm (3/8") overlap. Solder the resistor across the two vertical legs, and trim the excess off.

6 Circuit Assembly

● = Solder point

Mount the transistor assembly across the capacitor leads as shown. Make sure the striped (-) capacitor lead is on the bottom.



Solder the Flashing LED to the capacitor lead and 2N3906 as shown.
Make SURE that none of the leads touch each other except

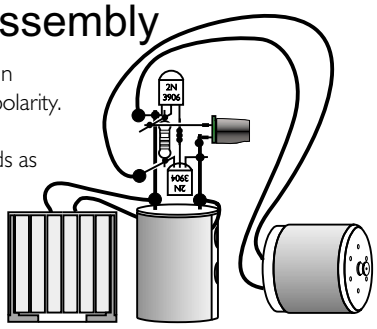
7 Final Assembly

Solder the Solar Cell in place, observing the polarity.

Solder the motor leads as shown.

Trim any excess wire.

You are now DONE!



● = Solder point

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.

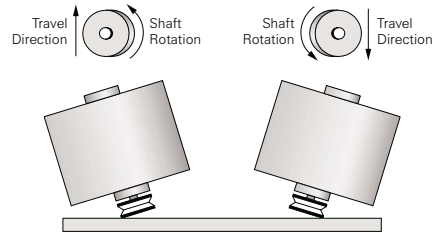
Check For:	Remedy:
• Heat-shrink tubing on Flashing LED?	• This is *critical* to having a reliable solarengine. If you don't shield the Flashing LED, it may "lock up" due to excess light falling on it.
• Solder not contacting part lead	• *Very* possible, especially when using the holes to mount the components. Make sure solder flows from the pad to the part - not just around it!
• Transistors installed the wrong way around	• Make sure the 2N3906 transistor is on the right side and the 2N3904 is on the left side. Be sure that the numbers face up on both transistors.
• Backwards polarity on the Solarcell or Capacitor	• Make sure the positive wire from the Solarcell goes to the pad at the bottom left of the PCB, and the stripe on the side of the Capacitor faces towards the left side.
• Broken connection on the pad of the Solarcell	• Uh oh. This takes some extra effort to correct. Reattach it with "Automotive Defogger Repair Paint", available at Car supply stores. This is a special paint that will dry to a conductive film.
• Flashing LED is in backwards	• The Flashing LED must be soldered on so that the flat side of the FLED itself is facing to the left.
• Solder Bridge (solder crosses copper traces on PCB)	• Examine the PCB to see if any solder has "bridged" from one trace to another. This is fixed by remelting the solder and then sharply tapping the PCB against a hard surface.

Let's Get Moving!

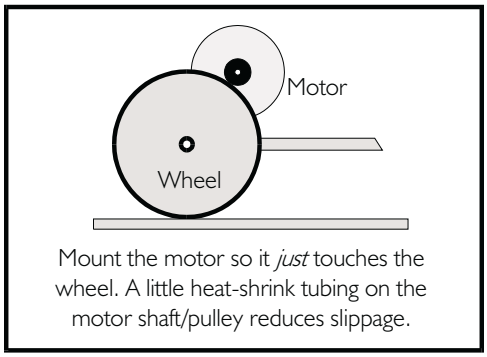
The fact that you're reading this means you have a working solarengine (or you're bored and just filling time until the TV commercials pass to the next program). This section is designed to help you get something moving across your desk/floor/sibling/significant other. All the following locomotion ideas 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.



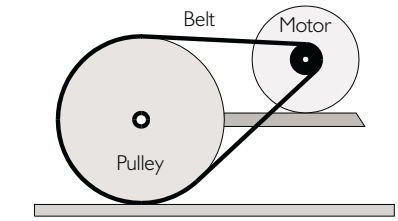
Mount the motor so it *just* touches the wheel. A little heat-shrink tubing on the motor shaft/pulley reduces slippage.

Friction Drive

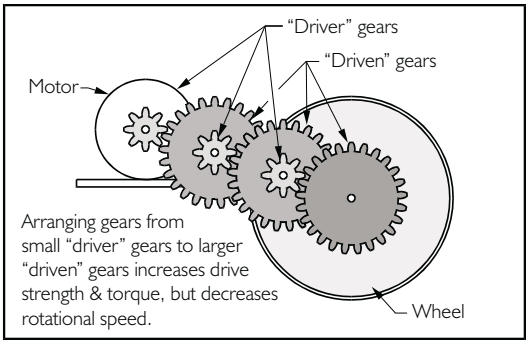
By removing the pulley and placing the shaft of the motor right up against a wheel, you can motivate your BEAMbot with a friction system. This arrangement results in straighter-travelling BEAM critters, but reversing direction becomes a problem. Slippage between the shaft and the wheel becomes a concern, 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.

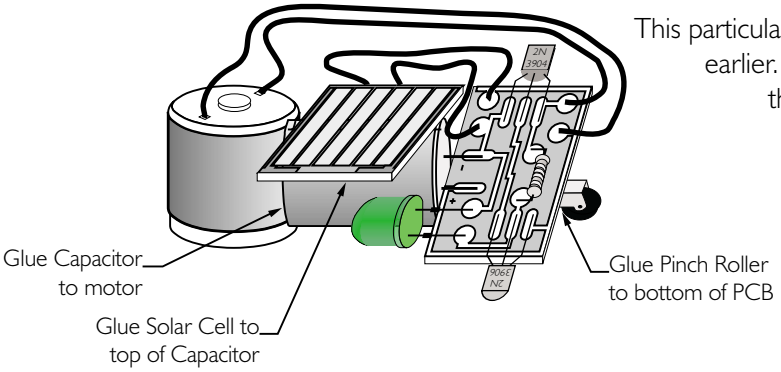
Gear Drive

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.

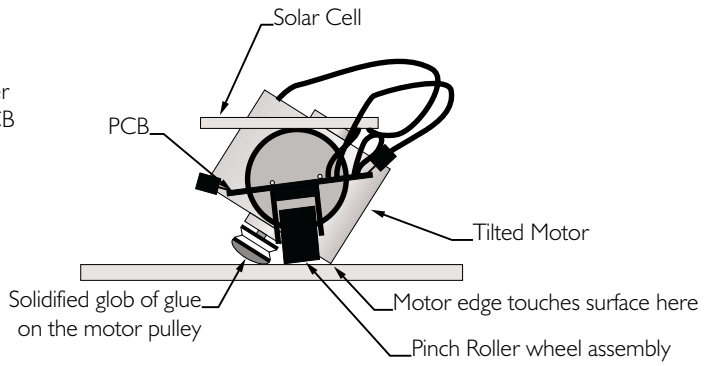
Ideas for your Solarengine

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 these two following ideas.

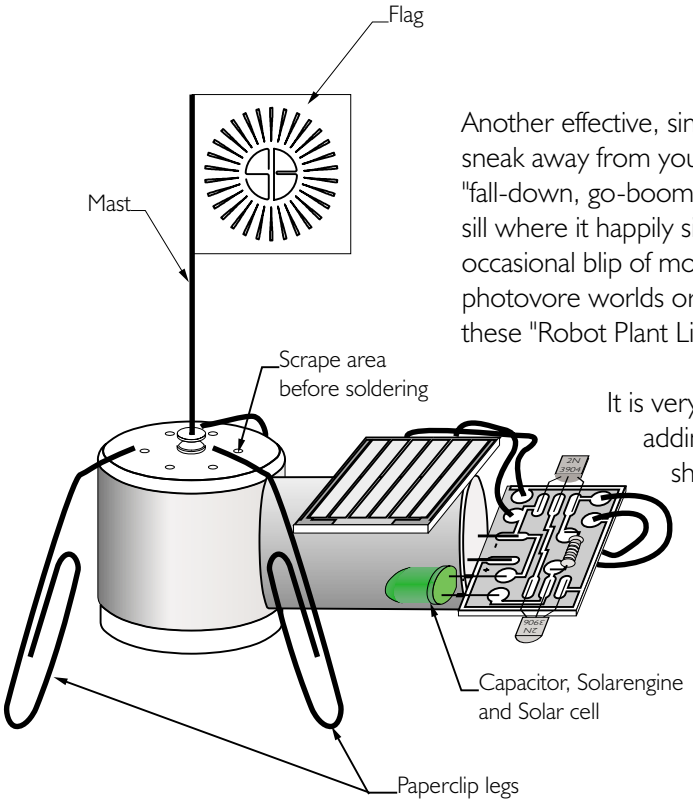
The first is a basic Solaroller built completely from the components in the kit. By adding some minor enhancements from a broken toy car or junk-drawer, you will be able to greatly enhance it's performance.



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



FRONT VIEW



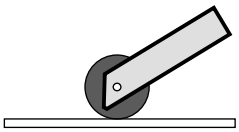
Another effective, simpler idea is the *Solar Flag Waver* (SFW). This BEAM critter won't sneak away from you and experience "Sudden De-acceleration Trauma" (that means "fall-down, go-boom!") like the Solaroller can. It is also neat to have on your window-sill where it happily sits, signalling its presence to the rest of the world with its occasional blip of movement. It's 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!

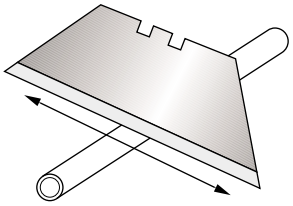
Hint Box

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!

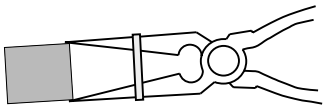
Keep super-glues away from anything you plan to solder - it results in some nasty fumes when



Rubber pinchrollers from cassette deck mechanisms make GREAT wheels.

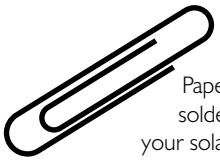


Brass tubing (commonly available at hobby shops) can be cut without crimping by rolling it with a razor blade. Dull blades work too.



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

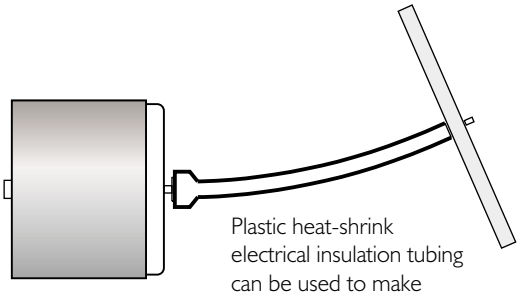


Paper clips can be a cheap source of solderable wire for making frames for your solarengine. Keep an eye out for the copper/brass type.

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

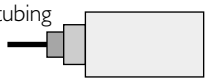
Mount your motors on flexible wire frames. This allows you to tweak the motor installation to optimize

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



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

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



Build your Device for Competition
The Official Solaroller Race Rules

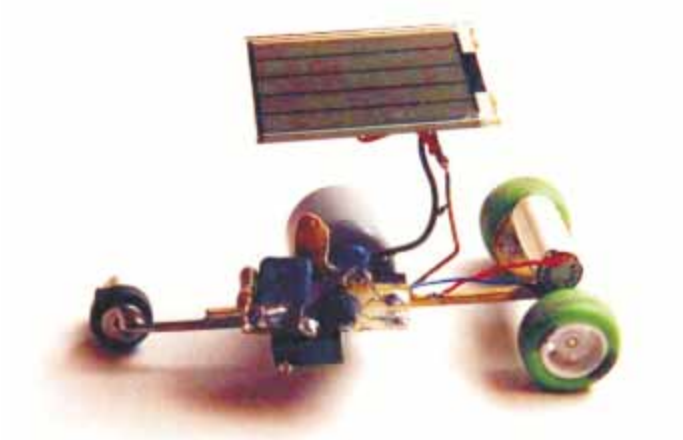


Fig 1: Solaroller "Scooter" (Dave Hrynkiw, 1995)

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 ~

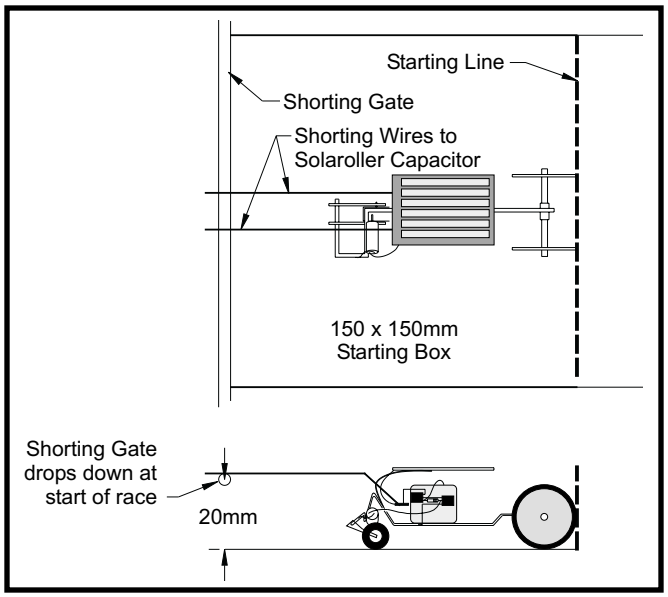
5 - During racing, competitors must not physically touch or attempt to touch each other, however, competitors may attempt to interfere with each others light source by extending vanes or other devices over the 25mm (one inch) lane walls. Vane extensions must still fit within the size guidelines.

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)

"Junkyard 'bots"
Equinox Magazine, No. 90 December 1996, Pg 38-45

"These Guys are Junk and to Mark Tilden Tha't's Just the Point"
The Wall Street Journal, New York, Aug 16, 1996. Pg A1-A2. Center column.

"Tech Update"
Popular Mechanics, Sept 1996 Page 15 (BEAM Butterfly Satellites)

"These Guys Are Junk And to Mark Tilden That's Just the Point"
The Wall Street Journal Newspaper, Friday August 16th 1996, Pg A1

"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 BEAMGod 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 BEAMGod 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.

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. As for what to look for, keep looking for small efficient motors & mechanisms. Stay away from TV's and old stereos, as they are potentially dangerous and really don't have much neat stuff inside. But do look for VCR's and Cassette Players, as they usually have great motors and lots of capacitors you can use. And remember - 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 waay up doing this.

This kit is a collaborative effort between Solarbotics and AM Innovations. For kits, parts and further technical support, feel free to contact us at:

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"Turbot 2.0" - A very capable photovore