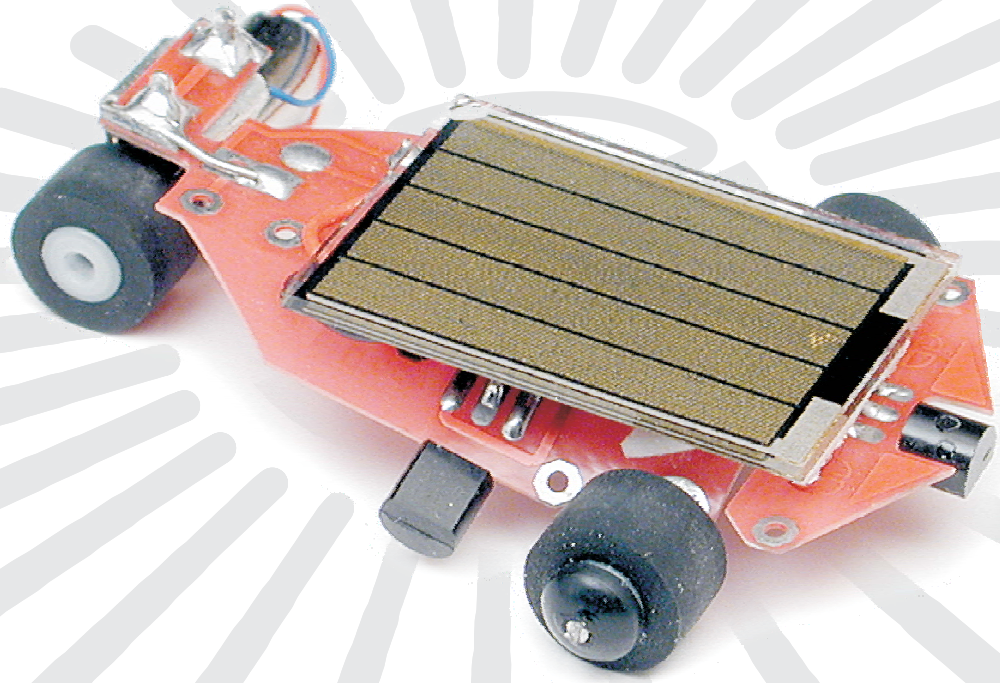
BEAM Robotics® Solar Kit #5:

1 2 3 4 5
Skill Level

The BEAM SolarSpeeder 1.1 Solaroller©



This Solar-Powered Car is designed for high-speed racing, and can zoom over 3 meters (10 feet) in under a minute in direct sunlight! (Soldering skill required)

A Complete BEAM Robotics® Solar-Powered Car Kit Inside

Produced by

SOLARBOTICS™ Ltd.

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Contents

SolarSpeeder 1.1 Parts & Materials List

We *strongly* suggest you inventory the parts in your kit to make sure you have all the parts listed under the sections 'Mechanical Parts' and 'Electronic Parts'. Check off each box as you locate them. If anything is missing, contact Solarbotics Ltd. for replacement parts information.

Mechanical Parts

- ❑ (1) SolarSpeeder 1.1Printed Circuit Board (PCB)
- ❑ (1) High-efficiency Coreless Motor
- ❑ (1) Motor Mounting Clip
- ❑ (3) Rubber Wheels on Nylon Hubs
- ❑ (1) 43mm long 1.40mm diameter (1.7" long, 0.055" diameter) Steel Rod
- ❑ (2) Black Plastic Wheel Retainers

Electronic Parts

- ❑ (1) 0.33F 2.5V Gold Capacitor
- ❑ (1) 3904 Transistor
- ❑ (1) 3906 Transistor
- ❑ (1) 1381 Voltage Trigger
- ❑ (1) 2.2kO Resistor (colour bands Red/Red/Red/Gold)
- ❑ (1) SC2433 24x33mm 2.7V Solarcell
- ❑ (1) Pair Solarcell wires
- ❑ (1) 25mm (1") length 18 Gauge wire

Tools Required

- ❑ A Soldering Iron
- ❑ A pair of Needle-nose pliers
- ❑ Side-cutters or strong Scissors
- ❑ File and/or Sandpaper
- ❑ Glue, Rubber Cement, or Hot-Glue (or Superglue, if you're *very* careful)
- ❑ Safety Glasses - VERY important when clipping and snipping!

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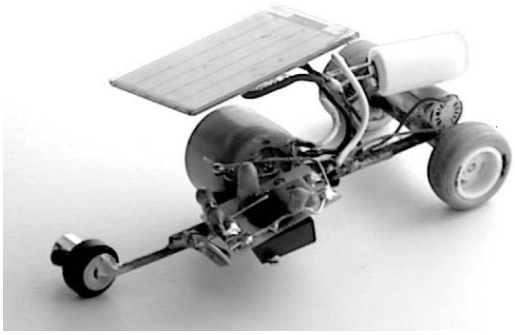
In other words - be careful! We will help you any way we can to assure the successful completion of your kit, but can't be responsible for putting band-aids on any burns and other ouchies you get while soldering, clipping, snipping, etc., etc...

Introduction - The SolarSpeeder 1.1Solaroller

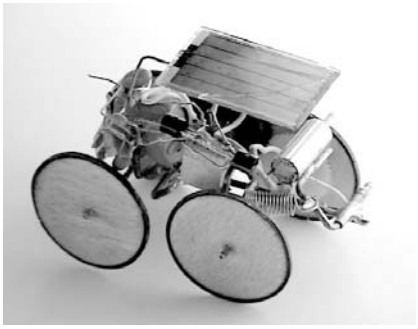
The SolarSpeeder is a design that has a strong heritage in Solaroller Racing, which is a very popular event at all BEAM Robot Games.

Solaroller racing requires two solar-powered drag-racers that race side-by-side down a 1 metre (3.3ft) track. When Solaroller Racing began, the 1 metre times were in the 10 and 20 minute ranges. As the electronics and mechanics advanced, the times lowered to 6 minutes, 2 minutes, and now there are Solarollers capable of a metre in under 30 seconds! The SolarSpeeder uses many of these new technology advances in it's design, which allows a well-built SolarSpeeder to travel 3 metres (10ft) in under 60 seconds of direct sunlight.

"Sluggy, Too" - Ex-champion Solaroller with a 2 minute 9 second metre record.

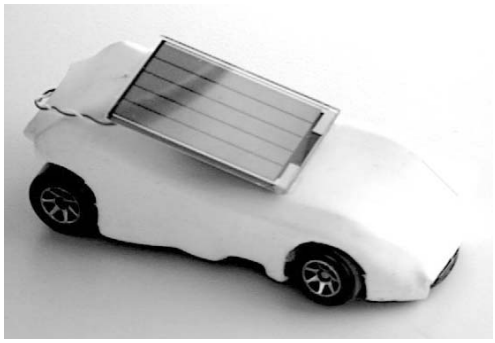


"Scooter" - Best competition time of 1 minute 4 seconds, narrowly beating out 3rd place by only a second. 1st and 3rd place were won by 11 year old boys!



"Herbie" - A 4-wheel drive Solaroller designed for the rough-terrain Class-B event. Almost as fast as "Sluggy, Too"!

"SC-1" - A modified Slot-Car racer. One of the first to use the new technology to make it quite quick.



"SolarSizzler" - This one is one of the prototypes for the SolarSpeeder. It uses a soft rubberized shell as it's body.

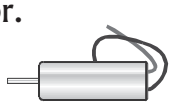
Circuit Overview

The heart and soul of the SolarSpeeder is the high-performance Solarengine. The three components that are most responsible for the increased performance of the Solarengine are the 0.33 Farad capacitor, the 1381 trigger, and the coreless motor.

The 0.33F storage capacitor is very strong for its size. To put it in perspective, this storage cell holds 100 times the power of regular capacitors 5 times the physical size. These capacitors are specially designed for low-voltage, high power applications - perfect for Solarollers!

The transistors are the actual electronic switches that route the power from the storage capacitor to the motor. The transistor's left and right legs (the "emitter" and "collector") are the actual pathways for the majority of the current, while the middle leg (the "base") is where you put the tiny signal current to turn the transistor on. The SolarSpeeder uses 2 types of transistors, an NPN (2n3904), and a PNP (2n3906). The only difference is that one is turned on by current being pushed into it, and the other by pulling the current out.

The resistor is simply an electrical constrictor, which resists the flow of electrons. In the SolarSpeeder kit, it is used to divide the current between the transistor switches and the motor.

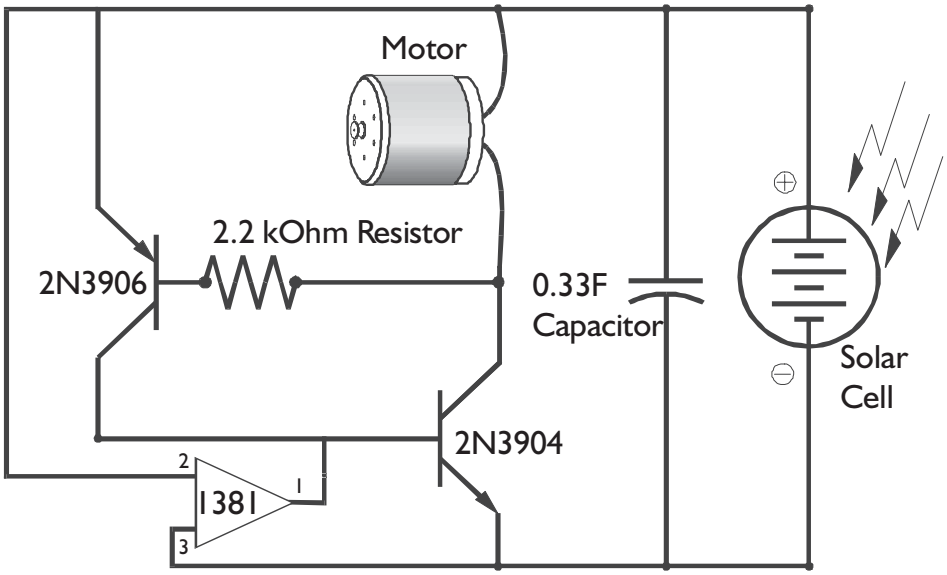


The coreless motor is a very small, efficient device that is specifically designed to run at approximately 1.5 volts. Since the Solarengine is designed to run at a maximum of 2.5 volts, this places the motor almost exactly in the range we want it to run. And being so small and compact, it is ideal for this BEAM application.

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. It uses very little power to monitor the voltage, making it much more efficient than older trigger devices like zener diodes or flashing LEDs.

The 1381 voltage trigger makes your SolarSpeeder wait until there is sufficient charge stored up in the 0.33 Farad capacitor before it starts. This means that you can expect to get much more action in direct sunlight than under an incandescent or halogen desk-lamp. This doesn't mean that you are restricted to placing it under concentrated light, as your SolarSpeeder will be able to work under light levels suitable for reading (but you will have to be patient).

The solarcell converts light energy into electrical energy. Although not very powerful (about as strong as a watch battery), they have a very long lifetime, up to 20 years. The solarcell included with your kit is designed to generate about 2.9V at 16 milliamperes.

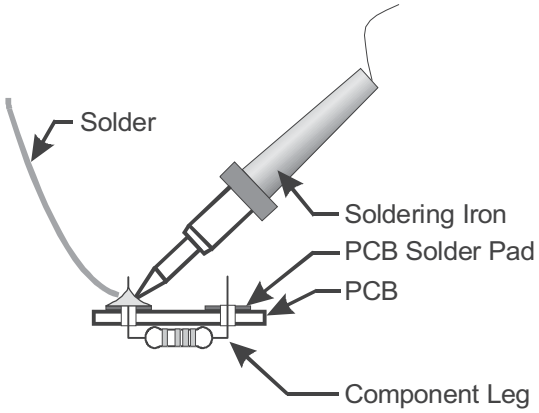


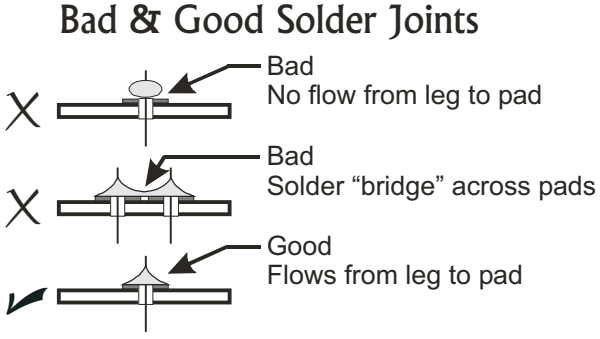
When the circuit starts charging, the 2N3904 transistor is off, so the current can't go through the motor back to the solar cell. Instead, it charges the storage capacitor. While this is happening, the 1381 monitors the voltage climb through its pins 2 and 3. When the voltage level matches a preset point in the 1381, it sends a pulse out to the 2N3904 transistor, turning it on. As soon as it turns on, some power splits off through the 2.2k resistor and goes into the 2N3906 transistor. This transistor keeps the 2N3904 on even when the 1381 turns back off, and keeps the whole circuit running until the power runs out.

Construction - Soldering

The most important skill needed to successfully construct your device is soldering. Make sure you start by using *electronics solder,* **not** plumber's solder. The main trick to getting a successful solder connection is to heat the junction up before applying the solder to the heated area. Do NOT try to melt some solder onto the tip of the iron and smear it onto the joint - you won't get a strong joint.

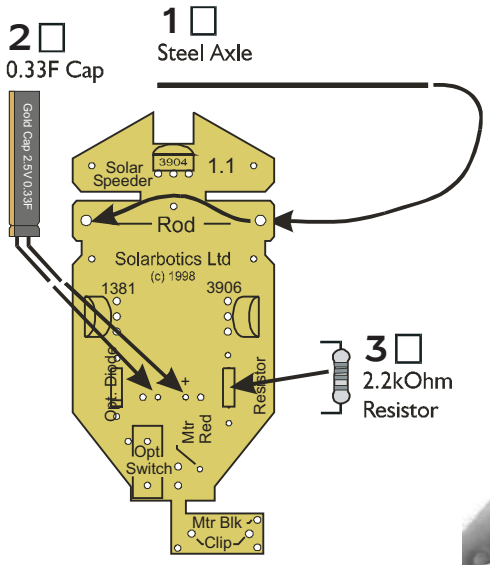
If the heat is applied unevenly, you will get solder blobs (see below). To better apply heat, keep your soldering iron tip clean by wiping it frequently on a damp sponge or cloth. The tip should always be shiny, and not covered in burned flux.





Construction - Electronics

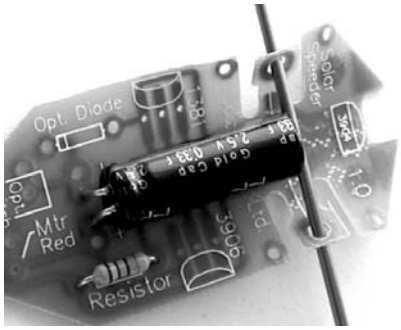
Now is the time to gather your tools together and warm up your soldering iron. Remember, good soldering technique means you heat up both the component *and* the solder pad before applying the solder. Assembly is quite straightforward - simply go through the numbered steps, checking off each box as you go. That way, you'll be sure not to miss any steps.



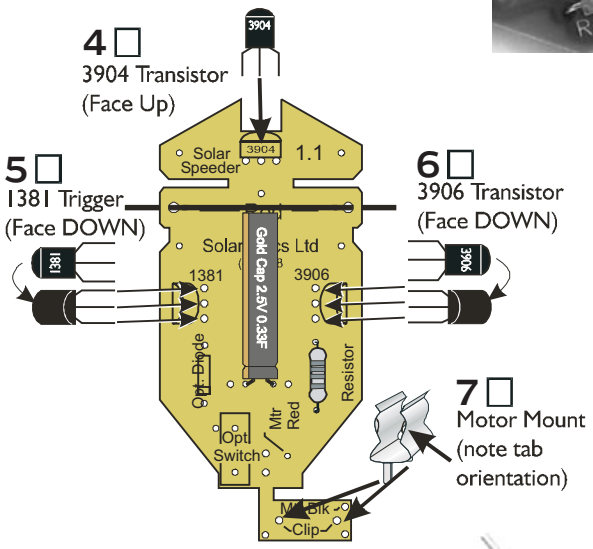
Step 1: Slide the **axle** through the holes labeled "rod" so it's about centered.

Step 2: Bend the leads of the **0.33F capacitor** 90° down right against it's body and place the leads into the printed circuit board (PCB) as shown. Make sure it goes in with the stripe side (negative) on the left. Turn the PCB over and solder the leads to the solder pads. Trim off the excess leads.

Step 3: Put the **2.2kOhm resistor** in place as shown on the PCB. Same as in step 2, solder it in, and trim off the leads.



This is what it should look like when you've finished steps 1, 2, and 3.

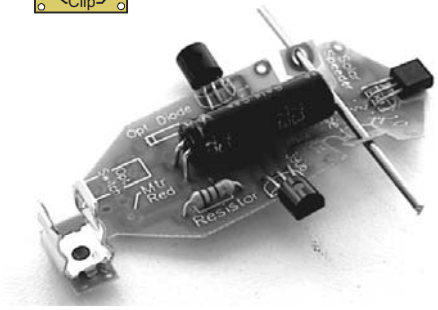


Step 4: Place the **3904 transistor** in place as shown, with the transistor facing upwards so you can read the numbers. Solder & trim the leads.

Step 5: Place the **1381 trigger** in place on the PCB, but **flip it over** so you can't read the numbers. It's shown face up on the diagram so it's easier to identify. Solder & trim the leads.

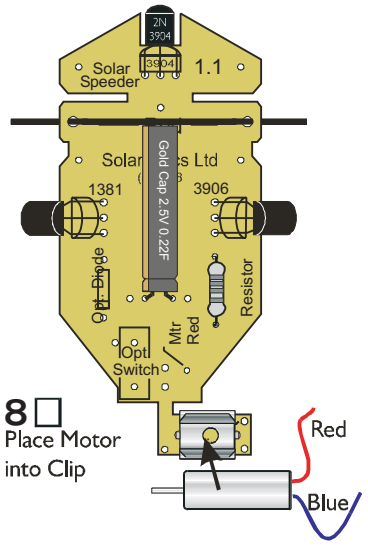
Step 6: Insert the **3906 transistor** into position, and again (just like the 1381 trigger), **flip it over** so you can't read the numbers. Solder & trim the leads.

Step 7: Push the **motor clip** into the holes labelled 'Clip', making sure that the **tabs are facing to the left**. This will align the motor when you install it into the clip.



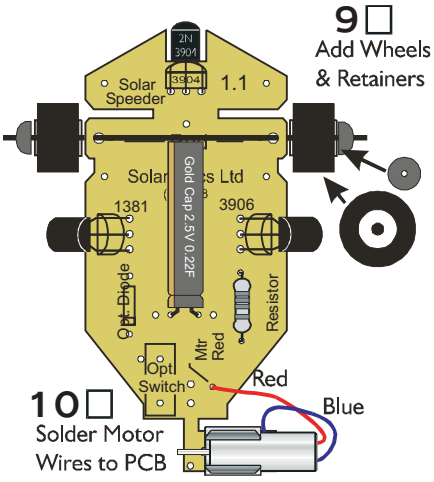
Completion of steps 4 through 7 looks like this.

Construction - Wheels, and the Motor



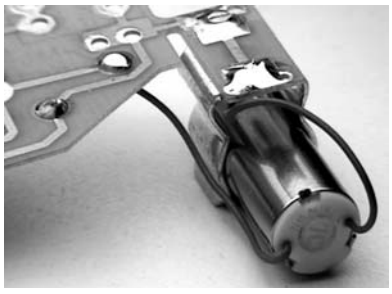
Step 8: Snap the **motor into the motor clip** as shown. Rotate the motor body in the clip until the red wire is closest to the PCB (makes it easier to solder later). Be sure to push the motor as far to the left as you can so it's pushed up right against the tabs on the clip. If the clip is too wide for the motor, pinch it closer together with your fingers, then check how the motor fits in the clip again.

Push the motor up against the mounting tabs



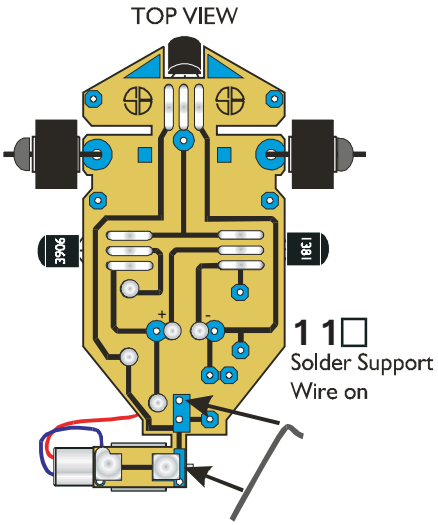
Step 9: Place a **wheel** on the axle and give it a spin. Make sure the wheel isn't rubbing the PCB. If so, trim a bit off the PCB. When it's spinning nice and free, slide the **retainer** on. *Be careful!* It's easy to poke your finger with the axle when doing this!

Step 10: Solder the red wire to the pad labelled "Mtr Red", and the blue to one of the holes right near to the motor clip.



Motor Soldering Detail

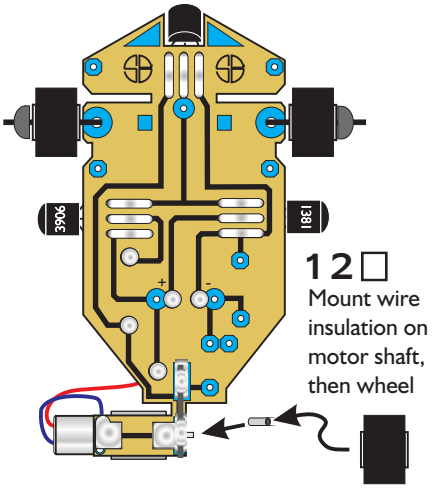
Construction - Motor Mount Support & Drive Wheel



Step 11: Find your small thick piece of wire, and pull the insulation off **(SAVE the insulation - you'll need it!)** so you are left with a small piece of solid copper wire.

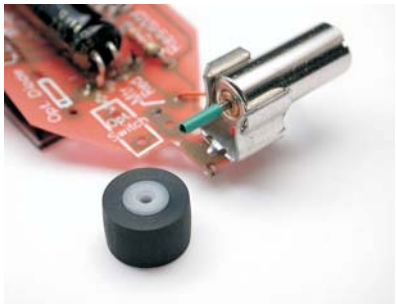
Bend one end 90 degrees down, and **solder the wire onto the pads** shown on the illustration. This gives your motor mount more strength, and allows you the option of aligning the motor so you can adjust where your SolarSpeeder goes.

Close-up of stripped copper wire soldered onto motor mount support pads



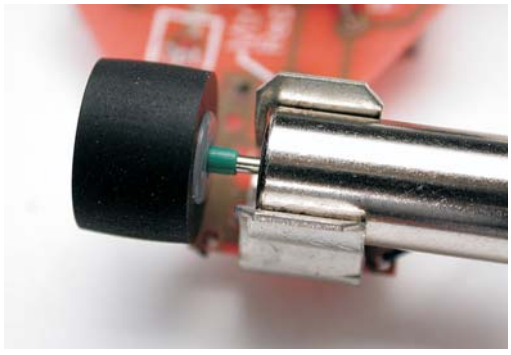
Step 12: Time to mount the wheel; Let's start by taking that insulation you saved from the last step, and cutting it down to a short length about 5/32 long (here-make it as long as this line: —). Slide it onto the motor shaft, making sure you **don't** shove it all the way to the side of the motor (it rubs, and slows it down).

Slide the wheel on top of the sleeve, and glue the sleeve, wheel, and motor shaft together with the *tiniest* amount of glue. You don't need much, and you don't want to accidently glom up the motor with too much glue!



Slide the sleeve onto the motor shaft…

…then add the wheel. A drop of glue in the wheel hole to secure the works, and you're done!

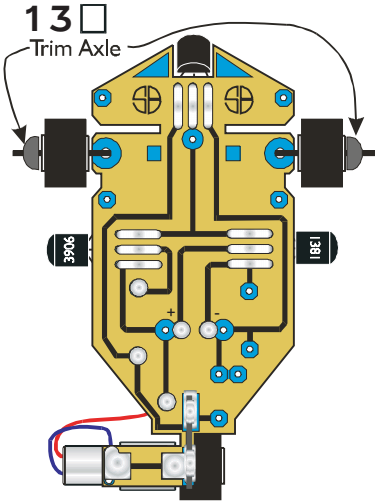


This is how it looks finished… almost. We've pulled the sleeve and motor apart a bit so you can see how they go together. When finished, the wheel sits right on top of the sleeve.

Note that there's a space between the sleeve and motor body, so there's no chance of rubbing!

Construction - Axles Trimming and Solarcell Preparation

13 ☐ Trim Axle



Step 13: All that you have to do here is trim the extra axle off with your snips. Then file or sand the edges rounds so it isn't sharp anymore, or pull the wheel retainers over the end of the wire so it covers up the sharp points.

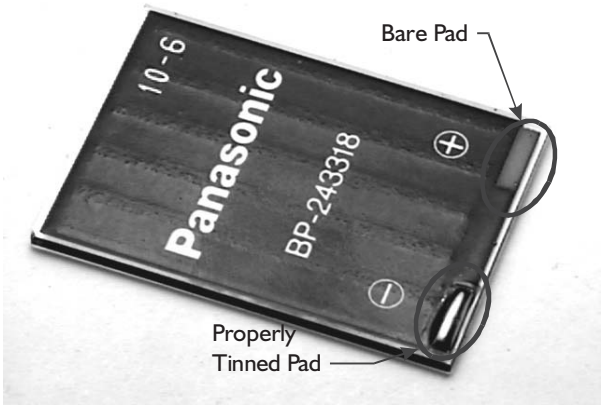
If you find that your wheel retainers are a little loose on the axle, now would be a good time to glue them down, but only apply the glue on the side away from the wheel, so it doesn't get gummed up.

Step 14: If your solarcell doesn't have pre-tinned solder pads (ie: the solder is already on it), you'll have to do it yourself. This can be potentially the most delicate part of building your SolarSpeeder, so take your time.

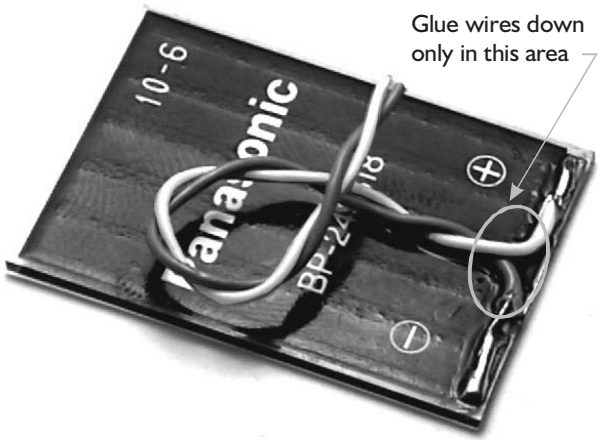
Pre-tin the pad by melting solder to the pad in a quick, smooth motion. You don't want to apply too much heat to the pad, or you'll ruin it. You can tell when this happens, as it gets dark and no solder will stick to it.

Step 15: Solder the wires to the solarcell , red to '+' and the black to '-', and secure it to the solarcell by gluing it down to the back. THIS IS IMPORTANT. You can easily rip the wires off the solarcell if you don't!

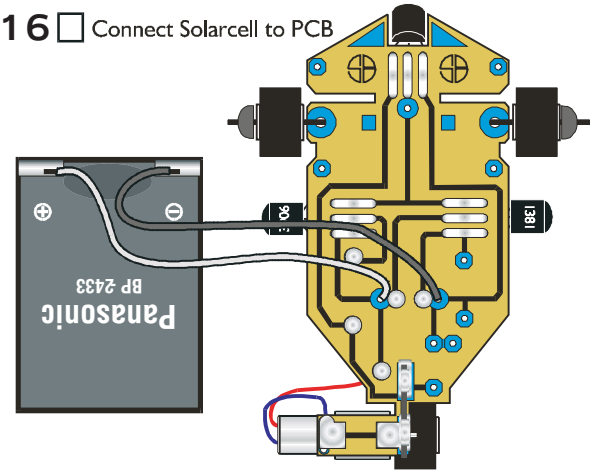
14 ☐ Prepare Solder Pads



15 ☐ Glue Wires Down



16 ☐ Connect Solarcell to PCB



Step 16: Connect the solarcell wires to the PCB, red to '+', black to '-', just like in the illustration. Once you've done that, your SolarSpeeder is "ALIVE", but not finished - you have to glue the solarcell to the PCB with epoxy, or similar gap-filling glue (use hot-glue only as a last resort - it softens under the heat of a desklamp).

Secure the solarcell to the PCB only after you're sure it works. Make sure it doesn't rub on the wheels, and that the solder pads on the solarcell don't touch any of the solder pads on the PCB.

Running, Tuning, and Upgrading

Running

Your SolarSpeeder is *very* quick for a solar-powered device, but it is slow compared to a battery powered car of about the same size. When it's first finished, you will have to be patient for it to make it's first mad dash across the table. Our tests show that your SolarSpeeder should activate from a dead startup (absolutely no power) in approximately 3 minutes when lit by a 100Watt incandescent bulb 20cm (8") above it. In direct sunlight, it should trigger in under 1 minute, and then under about every 40 seconds after that. Your times may vary a bit because the storage capacitors are rated 0.33 Farads, minus 20% to plus 80%. This means your 0.33F capacitor can range between 0.264F and 0.594F! Being smaller than 0.33F isn't a bad thing - it just means it will trigger more often, but not travel as far. And being larger than 0.33F...well, that means you'd better have quick feet to catch up to it!

If you have a voltmeter and you care to monitor the SolarSpeeder as it charges, you will notice that it will always trigger around 2.2 volts, which is the voltage the 1381trigger is preset to. After its first cycle of charging and triggering, it will dump all it's energy until the voltage drops to 0.7 volts, which is the voltage where most electronics naturally stop working. This is why all cycles after the first have shorter charging times - that 0.7V stays in the storage capacitor.

If you want to make your SolarSpeeder do donuts or run in curves, feel free to adjust the alignment of the motor. Don't worry about breaking the thin PCB neck - the thick copper wire we soldered in will be more than sufficient to support it after the PCB cracks.

Tuning

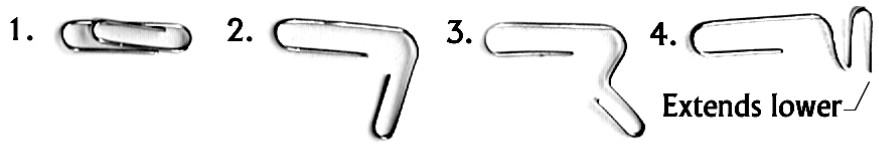
The design of the SolarSpeeder does not allow for much tuning, but if you are so inclined, you can experiment with changing the solarcell and bias (2.2kOhm) resistor. Changing the solarcell will make an obvious difference to the charge time, but the distance it travels should remain approximately the same. Changing the resistor for a 10kOhm trim pot or simply for a different resistor will modify the efficiency of the Solarengine. Higher values make the electronics more power efficient, but will decrease the initial amount of energy it can provide to the drive motor. Lowering the resistance will give the motor much better starting torque (like spinning the tires on a car when you floor the gas pedal), but at the expense of a shorter distance run. The resistor we've included in the kit is a good compromise between power and endurance.

Upgrades

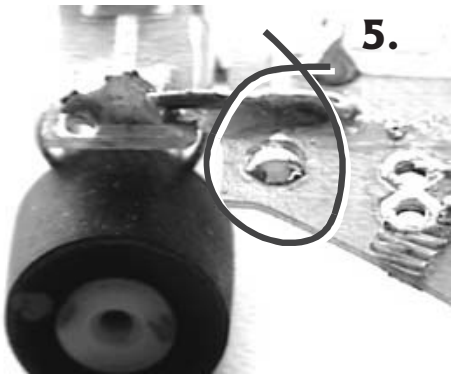
The SolarSpeeder has been designed to be upgraded with two extra options, one being the "Impatience Switch" (for those who just can't wait for the SolarSpeeder to trigger on it's own), and the other being the "Diode Voltage Upgrade" to supercharge your SolarSpeeder, at the expense of a longer charge time.

The "Impatience" Switch

Are you the type of person that reads the last page of a detective novel first? Or opens all your Christmas gifts in early November? If so, the Impatience switch will be a *must-have* option to install on your SolarSpeeder. It simply is a manual trigger that activates your SolarSpeeder, bypassing the voltage trigger. Kinda handy when you need to show off your creation to an impatient audience. And it's easy to build - got a paperclip? Good - let's start!



Step 1 - 4: Pretty straightforward - just follow the steps so that your paperclip looks like this one. The only thing to watch is that the right end of the paperclip in step 4 should extend down a bit so that it can go in the hole of the SolarSpeeder PCB.



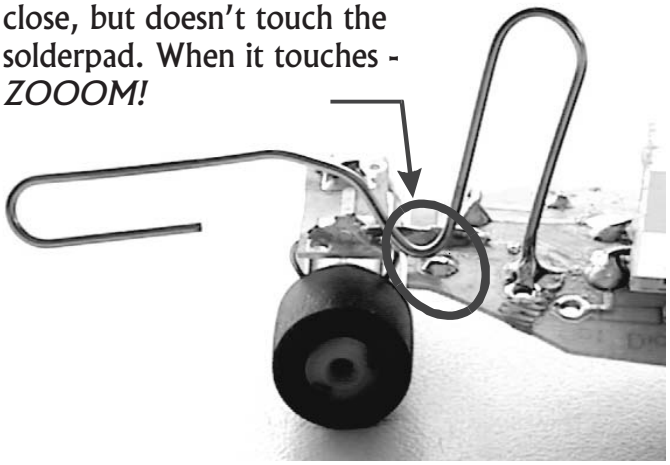
Step 5: The next step is to place a solder blob on the pad indicated. This will be the contact pad that the switch will touch to activate the SolarSpeeder.

Step 6: Solder the clip to the pad shown. Bend the clip so it just clears the pad you put a solder blob on in step 5. The closer it is without touching, the better.

There - now to activate your SolarSpeeder manually, simple press down on the end of the paperclip. The elbow bend in the clip will contact the solder blob, and activate the SolarSpeeder.

This clip also acts as a shorting gate for solaroller racing. Hold it down to drain *all* the power from your Speeder, and release it to start the charging cycle.

6. The wire elbow comes close, but doesn't touch the solderpad. When it touches - *ZOOOM!*

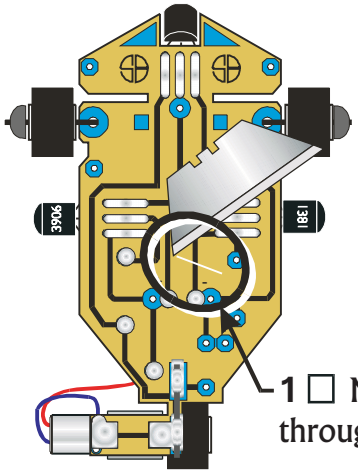


Diode Voltage Upgrade

This option allows you to trick your SolarSpeeder into storing more energy than usual before it triggers. This means instead of 3 meter runs, you'll be going somewhat farther, more like 4 meters or more, but at the expense of a longer charge time. If you're looking to get as much performance out of your SolarSpeeder as possible, this upgrade is for you!

You have two options when performing this upgrade, one being to use a regular old diode (little glass cylinder with a stripe on one end), or a regular old Light Emitting Diode (LED). Both can be easily found in practically any discarded electronic device. Each one offers a difference effect in what they will do for your SolarSpeeder. By itself, the SolarSpeeder will wait until it has stored about 2.2 volts before firing. A regular diode will trick the SolarSpeeder into waiting for 2.4 volts, and a LED will force it to trigger at about 2.8 volts. More stored power means a quicker and longer running SolarSpeeder, but also means a longer charge time.

TOP



1 ☐ Make cut through trace

<u>Step 1:</u> Using a sharp knife or razor, trim through the vertical trace under the green soldermask that runs up from the "-" pad. Make sure that trace gets fully cut through. Hold it up to the light to see if you can see fully through where the trace is cut.

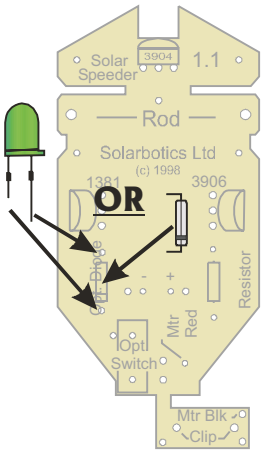
Doing this disconnects the 1381 voltage trigger from "viewing" the voltage being stored.

<u>Step 2:</u> Install the LED (adds ~ 0.7 volts), OR the diode (adds ~ 0.3 volts).

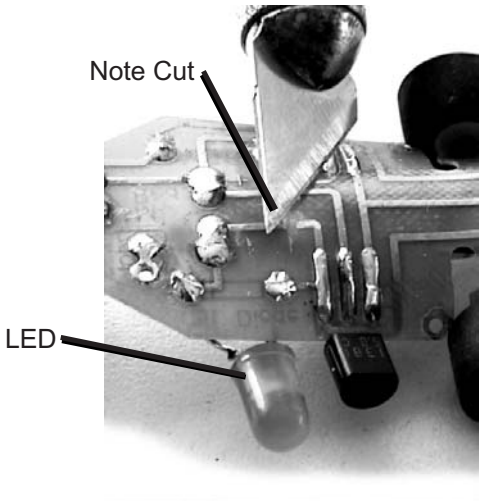
If you are installing the LED, make sure the shorter leg (the one nearest the flat spot on the LED) goes into the lower hole. If you don't have enough space to fit the LED under the PCB, you can solder it on the topside, or bend it out to the side where it won't rub the ground.

If you are installing the diode, make sure the end with the stripe around it goes into the lower hole.

BOTTOM



2 ☐ Install the LED or diode



There - that's it. Assuming your SolarSpeeder worked before this modification, it will now store up a bit more power before activating.

If it has stopped working, chances are your LED/diode is in backwards, or you have a bad solder connection.

"It Doesn't Go!"

Since your SolarSpeeder uses a relatively simple circuit, there are only a few things that can go wrong. Go through the list and see if any of these answers fix it:

• Transistor/Trigger Placement and Orientation. **Make sure** that they're facing the correct directions, as they all don't face up. With your SolarSpeeder sitting on its wheels, make sure that:

- The transistor at the nose is the 3904 and facing **down.**
- The transistor on the left is the 3906 and facing is facing **up.**
- The transistor on the right is the 1381 trigger facing **up.**

• Perform a 'wiggle' test on all the components. That is, grip each of the components on the PCB and give it a firm wiggle. Closely watch where the wire legs are soldered to the PCB. They all must be firmly soldered to the pads, and not sliding through the holes at all. THIS WILL DETECT THE MAJORITY OF PROBLEMS!

• There **cannot** be anyjumpers between the solder pads. These are blobs of solder that cross from one pad to the next and short out the electronics. Examine the sets of three pads that each of the transistors are attached to - these are most likely to have solder jumpers.

• Make sure that the red motor wire is soldered to the correct pad on the main body of the PCB.

• Are the wire connections to the solarcell still good? A *gentle* tug on the wire will be enough to check this. If it comes loose, you probably have a wrecked solarcell solder pad. If you want to try to salvage the solarcell, try using automotive defogger paint, or a conductive ink pen.

• Lift the solarcell off the surface of the PCB - does it work now? You may be accidently shorting the electronics with one of the solarcell solder pads. Cover it with some tape or make sure it's insulated from the PCB with glue.

• Prop the SolarSpeeder up so the drivewheel is suspended off the ground. Does it run now? If so, check the drag on the other two wheels. You should be able to give your SolarSpeeder a flick with your finger and it should roll at least 15cm (6").

If nothing else, you can send it back to Solarbotics for free repair (or replacement if necessary). We stand 100% behind our products, and will do everything we can to make your kit perform like it should.

"It Doesn't Roll Smoothly!"

If something is rubbing, chances are it will be the storage capacitor. You can make more clearance underneath your SolarSpeeder by bending the drive motor downward.

Final Notes

We sincerely hope you had fun building your SolarSpeeder, and you have just as much fun giving your local neighbourhood cat something to chase after. But if you want to try your hand at Solaroller racing, here are the basic rules:

- Maximum solarcell area of 8.06 cm^2 (1.25 $inches^2$). Your SolarSpeeder's solarcell is 7.68 cm^2 (1.19 $inches^2$), 95% of the maximum allowed.
- The Solaroller must fit in a cube measuring 15.24cm a side (6 inch cube).
- The track is 1 metre long (3.3 feet) with two lanes separated by a lane wall 2.5cm (1 inch) tall, with a 15.24cm (6 inch) starting and finishing square at each end for each lane.
- The Solaroller must have shorting wires coming out from it that can cross a shorting bar that is placed at the back of the starting square. This ensures the competitors are fully discharged until the moment the race begins when the shorting bar is removed.
- Light is guaranteed to be a minimum of one 500 Watt halogen lamp placed 50cm (19.7 inches) above the race platform (often there is much more light).
- Devices must conform to a 2 second stationary rule which means the solaroller cannot move for a full two seconds after the race has begun. This is to ensure some sort of electronics have been implemented rather than NASA-quality solarcells connected directly to ultra-precision motors (it's been done!).

Your SolarSpeeder won't technically qualify for 'Official' Solaroller racing, as the general rules specify that kit-built devices (unless modified) are not elegible for competition. But with what you learn building the SolarSpeeder, you should be able to build your own!

Solarbotics often sponsors a SolarSpeeder race at many of the robot games we attend. If you can aim your SolarSpeeder to roll through a10cm wide gate 2.4 meters away, you have a shot at some great Solarbotics prizes!

If you are interested in finding out more about BEAM Robotics, the BEAM Robot Games, and what other products we have to offer, please contact us at:

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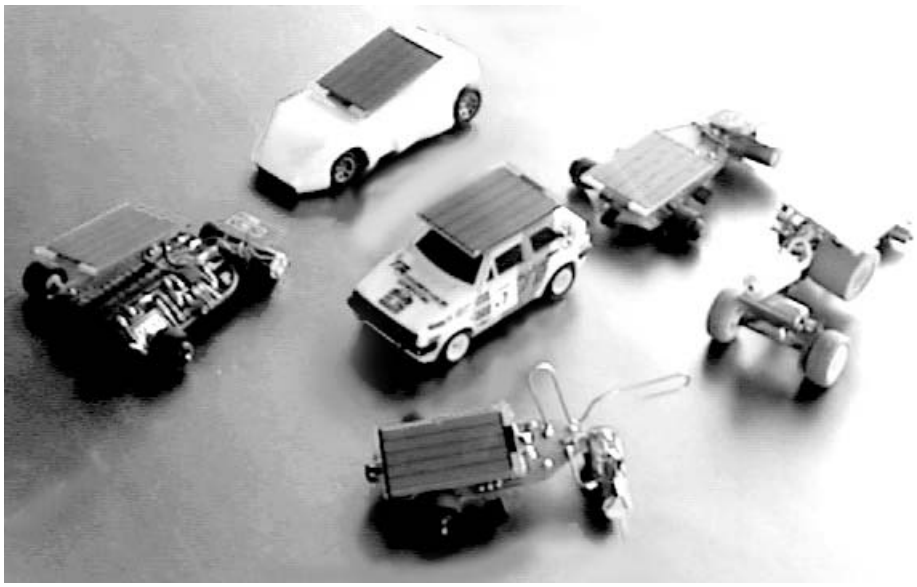
The Solarbotics *SolarSpeeder 1.1* is a high-performance Solar Racer, using simple and efficient electronics to store up light energy and release it in a burst of power that results in a 3 meter (10 foot) zoom!

This Racer design is the result of several years of Solaroller racing at the BEAM Robot Olympics®, combining a high-quality motor, lightweight frame, and optimized electronics. All that's needed to complete it is some basic handtools and a soldering iron!



The Solaroller family, with some of the many designs that finally resulted with the SolarSpeeder (front row, center).

For more information about our kits and products, please contact us at:

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