



# Solarize a Toy

Suggested Level: Grades 7 through 10

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## LEARNING OUTCOME

After designing and constructing solar electric power sources for a selection of small electric toys, students are able to determine an electric toy or device’s power requirements, design an alternate solar electric power supply, and appraise the effects of both variable lighting conditions and the size of the solar electric power supply on the operating performance of their toy or device.

## LESSON OVERVIEW

Student working in teams:

- Select a low-power toy, game, or electrical device to “solarize,” or convert to solar power;
- Determine the operating voltage of their chosen device, and design a solar array to provide this level of voltage;
- Determine a series of conditions under which they will test their toy’s performance and, if needed, adjust the size of their solar array to provide more current; and
- Determine under what operating conditions their device draws the most power and evaluate how important it is to operate the device under these conditions.

## MATERIALS

- At least sixteen 1 V, 400 mA mini–solar panels
- Alligator clip wires
- Access to sunlight
- Toys selected by students
- Selection of DC power plugs and wire
- Student handout

## SAFETY

Do not let a student connect any toy or device directly to your school’s AC power supply (a wall socket).

## TEACHING THE LESSON

**Preassignment:** Divide the class into teams. Assign each team the task of identifying a DC-powered toy to solarize. Because of the small size of the mini–solar panels, each toy must either run on one or two AA batteries or operate at one to four volts with current requirements of less than 400 mA.

**Procedure:** Check the power requirements of the toys selected by students. Toys must all run on DC power. Because of the limited number of mini–solar electric panels available, make sure that the toys students select run on one to two watts. If a team has selected a toy that uses an AC adapter, help them find an appropriate DC power plug that can be wired to an array of mini–solar panels.

Distribute the student handout from *Solarize a Toy* and help student teams determine the operating voltage for their device. Hand out to each team the number of solar panels they need to produce the operating voltage for their device.

Have students write down a series of test conditions under which they want to test their toy. These should include adjusting lighting conditions, the size of their solar power arrays, and the operating conditions of the toy or device. Operating conditions refer to such variables as the level of backlit display, the level of volume, the speed of a toy car, or the ability of a small car to climb a ramp.

Teams should have access to direct sunlight to test their solarized toys.

Let students experiment with the amount of current that their solar arrays can provide. Hand out additional solar panels as needed. Teams may need to share limited numbers of panels between them as they experiment with higher current power supplies.

## ACCEPTABLE STUDENT RESPONSES

**Test Conditions:** Test conditions should fully exercise the device's functionality under reasonable lighting conditions. Lighting conditions should include reasonable long-term conditions, such as cloudy, hazy, or sunny days, as well as intermittent conditions, such as a short-term loss of sunlight.

**Electrical Power Needs:** Teams should correctly identify their device's operating voltage. Teams should connect an appropriate number of mini-solar panels in series to provide at least the operating voltage and no more than ½ volt above the operating voltage.

Teams should identify the minimum number of mini-solar panels needed to satisfactorily operate their device.

**Performance of Solarized Toy:** Teams should be able to describe in writing how well their device works with the various solar power supplies tested and under the various lighting conditions tested.

## BACKGROUND INFORMATION

**Selection of Toys or Devices to Solarize:** Due to the low power output of the mini-solar panels and the limited number of panels, it will be most convenient to select toys or devices that run on one or two AA batteries or one to four volts and less than 400 mA DC power packs.

**Maximum Power Needs of a Motorized Toy:** To find the maximum power that will be drawn by an electric motor, multiply the measured current requirements when the motor is locked in place with the voltage specified by the power supply (battery pack or AC adapter).

To measure the current, place a small resistor (say 0.1 ohms) in series with the DC power supply and measure the voltage over this resistor when the motor is locked in place.

$$I_M = V_R / R = V_R / 0.1$$

Where:

$I_M$  = maximum current

$V_R$  = voltage over the series resistor

R = series resistor

Maximum power ( $P_M$ ) needed is

$$P_M = V_P * I_M$$

Where:

$I_M$  = maximum current

$V_P$  = voltage of power supply

**Limiting Current Supply to a Motorized Toy:** In situations where a motor does not need to produce a high level of torque, the motor's requirements for current during steady state operation are significantly less than at start-up. Because of this, a toy or motorized device may operate satisfactorily with an underpowered power supply, although it will take longer for the motor to come up to the steady state speed.

Encourage students to experiment with different power supplies recording how the toy performs with each.

## (STUDENT HANDOUT FOLLOWS)

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## Solarize a Toy

Before you try to solarize a toy or electrical device, let your teacher check whether your selection runs on direct current (DC). If it does not, you will have to select a different device. Converting the direct current (DC) provided by a solar panel to alternating current (AC) goes beyond the scope of this activity.

### Test Conditions:

Write down a series of conditions under which to test your device. These should include various lighting conditions and the operating conditions of the device.

Lighting conditions refer to the brightness and consistency of a light source. Think about long-term conditions, such as cloudy, hazy, or sunny days, as well as intermittent conditions, such as a short-term loss of sunlight.

Operating conditions may refer to such items as the brightness level of a backlit display, the level of volume, the speed of a toy car, or the ability of a small car to climb a ramp. Determine the operating conditions that pertain to your device.

After designing a solar power supply for your device, you will test your toy or device under these different conditions and write down how well your device performs in each situation.

### Electrical Power Needs:

Determine the electrical power needs of the toy, game, or electrical device you have chosen to solarize.

### Toys that require batteries

- A. **Operating Voltage:** Determine the operating voltage from the number of batteries connected in series required by the device. Determine the number of mini-solar electric panels connected in series that are required to produce this voltage. If you need to exceed the normal operating voltage, do not do so by more than  $\frac{1}{2}$  volt.
- B. **Operating Current:** Begin with a chain of panels connected in series so as to obtain the required operating voltage. Use this power supply to run your device. Test your toy or device under these conditions, and write down how well your device performs under each test condition you have specified.

If your device seems to be underpowered, add a second chain of mini-solar panels connected in parallel with the first chain. Again, record how well your device works at this increased power level. If your device still seems underpowered, add additional chains of mini-solar panels connected in parallel with the previous chains. Each time, write down how well your device responds to the different test conditions.

## Toys that use motors

Motors draw their highest current when they are increasing speed (rpm) or are working to overcome a force that is working to slow them down. For applications where the motor is often changing speed or is often working to overcome a force (such as a toy electric car running up a steep ramp), the need to provide this high level of current may be critical to the satisfactory operation of the device. In cases where this type of performance is not required, it may be acceptable to reduce the level of current available to the motor. This may allow you to reduce the number of solar panels in parallel needed to power the device.

## Toys with AC adapters—those black “bricks” that plug into electric wall sockets

Some toys include AC adapters that convert the AC power provided by an electric wall socket into the DC power needed to operate the toy or device. The DC power is generally provided to the device through a thin cable with a round electric jack known as a DC power plug that plugs into the device. The DC operating voltage and current are often specified on the AC adapter or on the device itself where the DC power plug plugs into the device.

- A. **Operating Voltage:** Determine the number of mini-solar electric panels connected in series that are required to produce the specified voltage. If you need to exceed the normal operating voltage, do not do so by more than  $\frac{1}{2}$  volt.
- B. **Operating Current:** Determine the number of mini-solar electric panels connected in parallel that are required to produce the specified current. It is OK to provide more current than specified because the device will not draw more current than it needs. On the other hand, this may end up using more solar panels than you need to.

You may want to begin with one chain of panels and see how well your device works. Test your toy or device and write down how well your device performs under each test condition you have specified.

If your device seems to be underpowered, add a second chain of mini-solar panels connected in parallel with the first chain. Again, record how well your device works at this increased power level. If your device still seems underpowered, add additional chains of mini-solar panels connected in parallel with the previous chains. Each time, write down how well your device responds to the different test conditions.

## Minimizing power requirements

Try to determine which function of your device uses the most power. Is this function critical to the satisfactory operation of the toy? Can this function be turned off or turned down in order to reduce the power requirements of your device?