

# Peering Into the Electric Eye: What is a Photoresistor?

<b>Subject Area(s)</b>	Physical Science, Science and Technology
<b>Associated Unit</b>	None
<b>Associated Lesson</b>	None
<b>Activity Title</b>	Peering into the electric eye: What is a photoresistor?
<b>Header</b>	Insert image 1 here, right justified to wrap

### Image 1

ADA Description: Students assembling a photoresistor circuit

**Caption:** Students integrating a photoresistor circuit with an autonomous robot

**Image file name:** ldr\_image1.jpg

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**Grade Level** 8 (9-12)

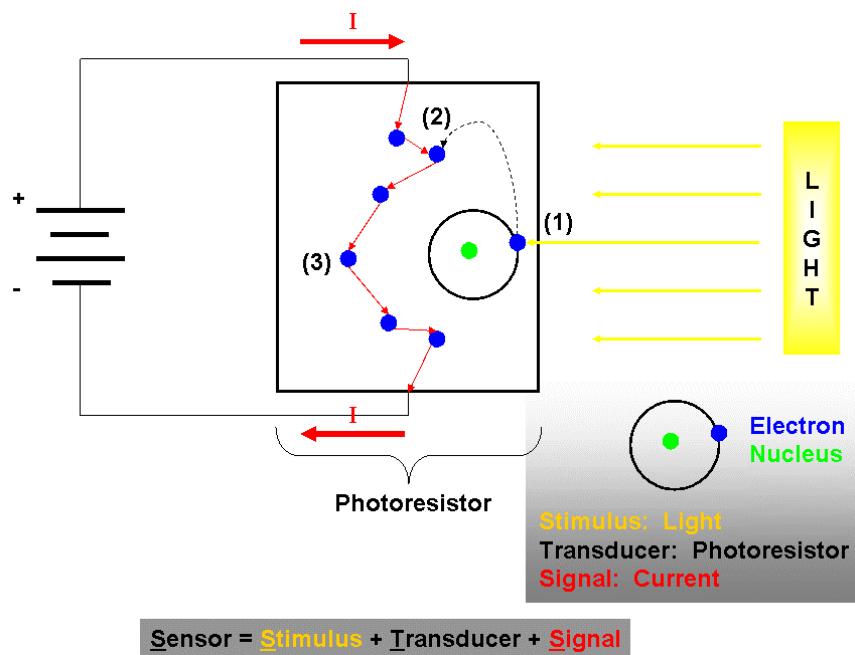
**Activity Dependency** None

**Time Required** 90 minutes

**Group Size** 3 – 5

**Expendable Cost per Group** \$15

Insert Figure 1 here, centered



**Figure 1**

**ADA Description:** Principle of operation of a photoresistor

**Caption:** Working of a photoresistor presented according to the anatomy of a sensor

**Image file name:** ldr\_figure1.gif

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## Summary

This activity aims to introduce to students a photoresistor, which is often used in a light dependent voltage divider circuit. A photoresistor is part of a larger family of devices or sensors known as photodetectors. A photodetector's resistance to electrical current changes when it is exposed to light. Photodetectors are commonly used as light sensitive switches; for examples common streetlights that turn on at dusk employ photoresistor circuits. As depicted in Figure 1, the basic anatomy of a sensor can be used to explain the operation of a photoresistor. The following mnemonic is used: Sensors = Stimulus + Transducer + Signal (STS). That is, a sensor is a device that detects an external stimulus, and it changes that stimulus to a detectable signal, by means of a transducer. For our photoresistor, when light (the stimulus) is detected, the semiconductor material responds by becoming a conductor of electricity (transducer), and the resulting current flow is the sensor response (signal). A photoresistor, which consists of cadmium sulfide, responds to visible light similarly to the human eye, and it can be thought of as an electronic analog of the human eye.

## **Engineering Connection**

The engineering connection here is twofold. First, a basic circuit that uses the photodetector is built, and the real-life applications are stressed. The circuit is composed of a voltage source in series with a potentiometer and a photoresistor. The voltage across the photoresistor is used to power a light bulb, in parallel. The potentiometer is used to manipulate the circuit's sensitivity, and the photoresistor is used as the sensor-based switch. Second, the students are allowed to switch the order of the photoresistor and the potentiometer to make the presence of light *turn off* the circuit, as opposed to *turn on* the circuit. Finally, the students are allowed to determine the sensitivity of this switch circuit by varying the potentiometer value. An engineering-type exploration exercise involves comparing the electric eye circuit to a real human eye.

## **Engineering Category**

Category 3: Engineering Analysis or Partial Design

### **Keywords**

Photoresistor, potentiometer, current, voltage, electric eye, light sensor, anatomy of the human eye, learning by analogy

## **Educational Standards**

New York State Math:

- 8.N.6 Justify the reasonableness of answers using estimation
- 5.N.24 Rounding numbers to the nearest hundredth and up to 10,000
- 6.N.7 Express equivalent ratios as a proportion
- 6.N.9 Solve proportions using equivalent fractions
- 6.A.5 Solve simple proportions within context

### **Pre-Requisite Knowledge**

Knowledge of electrical current and voltage is helpful but not necessary. A useful analogy to understand these concepts is to relate current to the rate of flow of water in a pipe and to relate voltage to water pressure (see reference 8). Present the definition of a sensor using a functional mnemonic.

### **Learning Objectives**

After this activity, students will be able to:

- Explain what a photoresistor is in the context of “a sensor’s anatomy”
- Relate the common name “electric eye”, to the human eye by analogy
- Name two applications of photoresistor switches
- Design a practical application that uses photoresistor switches

## Materials List

Each group needs:

- Universal Solderless Breadboard
- 9 Volt battery holder
- 9 Volt Alkaline Battery
- Cadmium Sulfide (CdS) Photoresistor (Model/Type: 276-1657)
- 10K potentiometer
- 9v/50ma incandescent light bulb
- Insulated wire

To share with the entire class:

- Multimeter

## Introduction / Motivation

At the beginning of the lesson the following question is posed “why do street lights come on at night throughout the year, when the sun sets at different times?” The follow up question would be “which is more practical a device that predicts the time that the sun will set, or a sensor that can react to light?”

As a further means of solidifying the sensor concept and the analogy to the human eye, a video clip showing how the pupil of the human eye reacts to different light intensity (please see “How Light Enters the Eye”, references 2).

## Vocabulary/Definitions

Word	Definition
Resistor	An electrical component that resists the flow of electricity and dissipates electrical energy as heat; frequently used for current control in electrical circuits
Photoresistor	A light-sensitive resistor; it lowers its resistance to current flow when exposed to light
Potentiometer	A variable resistor whose resistance can be changed by turning a mechanical control knob
Voltage Divider	A voltage divider is an arrangement of resistors that gives an output voltage as a fraction of the input voltages. This fraction is determined by the values and placement of the resistors.
Sensor	A device that can detect a phenomenon and produce a specific signal, or other response as a result. A sensor is a combination of stimulus, transduction, and a signal or other specific response. Photoresistors and potentiometers are both sensors.
Transducer	A device that converts a measured stimulus into a measurable response. For example, the mercury in a thermometer is a transducer when held inside a tube.
Incandescent Light Bulb	A device that produces light as electricity flows through a resistor-like Tungsten filament. The brightness of the light bulb is related to the

applied voltage.

## Procedure

Students will build a light dependent resistor voltage divider circuit, and use it in a light sensor switch application.

## Background

Photoresistors have resistance values that depend on the amount of light that reaches the surface. The values generally fall in the range of around several 100k ohm in the dark, to around 1k ohm in a brightly lit room. For the type of photoresistor used, we can assume the resistance is around 200 kohm in the dark and 500 ohm in a brightly lit room.

Potentiometers are useful, because they allow you to “dial” in a particular resistance. They have three pins; one of the pins is connected to the negative terminal of the battery, and the other is connected to the positive terminal. The pin in the middle is called the wiper. This pin is where the current travels once a resistance value is chosen.

Resistors in general dissipate electrical energy as heat energy. When a resistor is connected to say a 9V battery energy is dissipated, and there is less than 9V available to other devices that come after the resistor. This voltage drop across the resistor is what allows one to build a voltage divider. The simplest way to view a voltage divider is as a circuit arrangement that divides the source voltage, where a certain voltage drop occurs across the resistor and the remaining voltage is available to other devices. There is a simple equation that describes voltage division, see Figure2.

Insert Figure 2 here, centered

$$V_{AB} = \left( \frac{R_2}{R_2 + R_1} \right) V_{In}$$

**Figure 2**

**ADA Description:** Voltage division equation

**Caption:** Voltage division equation

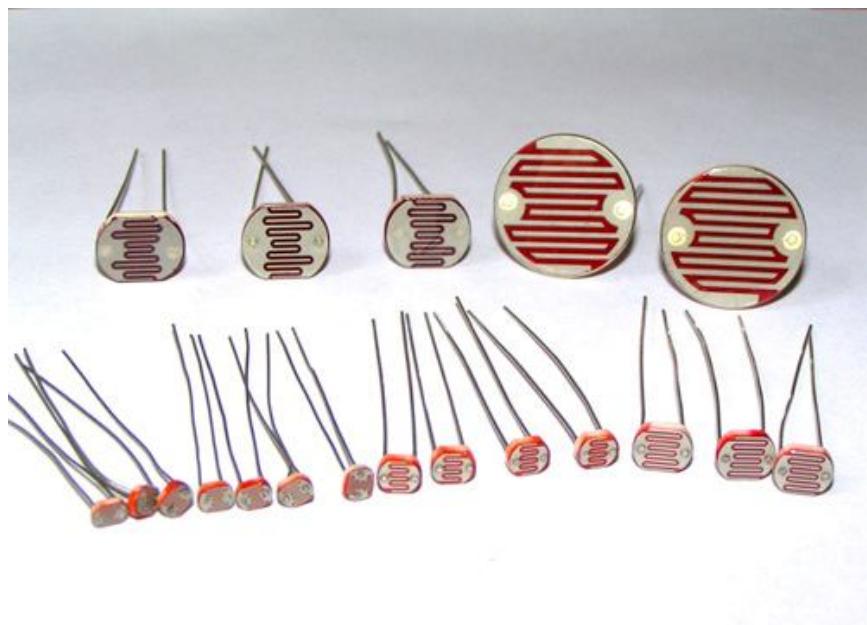
**Image file name:** voltage\_division\_equation\_figure2.gif

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## Before the Activity

A group discussion is held, where the anatomy of a sensor is reinforced. Ask the students “why do street lights come on at night throughout the year, when the sun sets at different times?” The follow up question would be “which is more practical a device that predicts the time that the sun will set, or a sensor that can react to light?” Solicit examples of how a light sensitive sensor could be used for this purpose. The photoresistor can be passed around and the variation in size noted (Image 2).

Insert Image 2, centered



**Image 2**

**ADA Description:** Image of photoresistors, showing variation in size

**Caption:** Image of photoresistors, showing variation in size

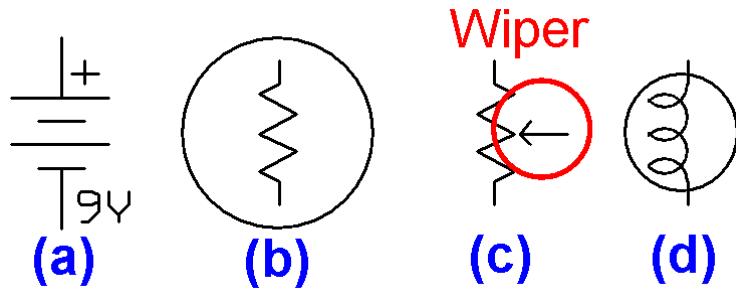
**Image file name:** ldr\_image2.jpg

**Source/Rights:** Open Source, commons.wikimedia.org/wiki/File:Photoresistor

## With the Students

The class should be given a brief explanation of how a multimeter is used, and how a solderless breadboard should be used (see reference 5). The electronic components used in this activity should also be introduced, referring to Figure 3.

Insert Figure 3 here, centered



**Figure 3**

**ADA Description:** Circuit components

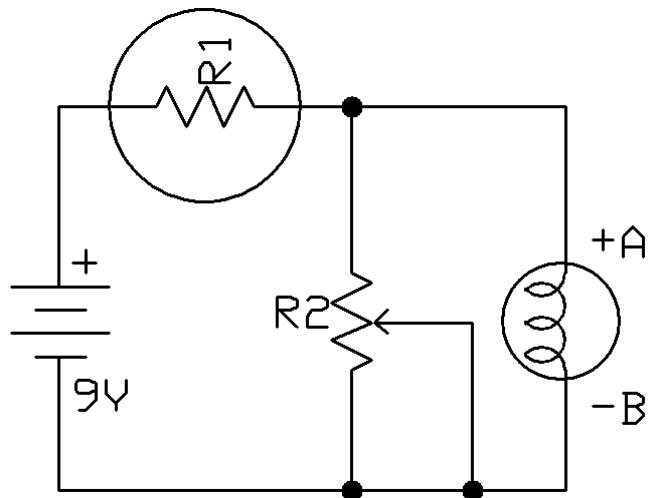
**Caption:** Circuit components

**Image file name:** circuit\_components\_figure3.gif

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In circuit schematics, symbols are used as representations of the actual components. The components are shown in Figure 3 as (a) the 9 Volt voltage source, (b) the photoresistor, (c) the potentiometer and (d) the incandescent light bulb. In figure 4, these components are combined in a voltage divider circuit with the photoresistor functioning as the sensor. The terminals of the light bulb are connected across points A and B.

Insert Figure 4 here, centered



**Figure 4**

**ADA Description:** Operation of a photoresistor in a voltage divider circuit (1)

**Caption:** Operation of a photoresistor in a voltage divider circuit (1)

**Image file name:** ldr\_circuit\_1\_figure4.gif

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Step 1: Find and identify all items from the material list.

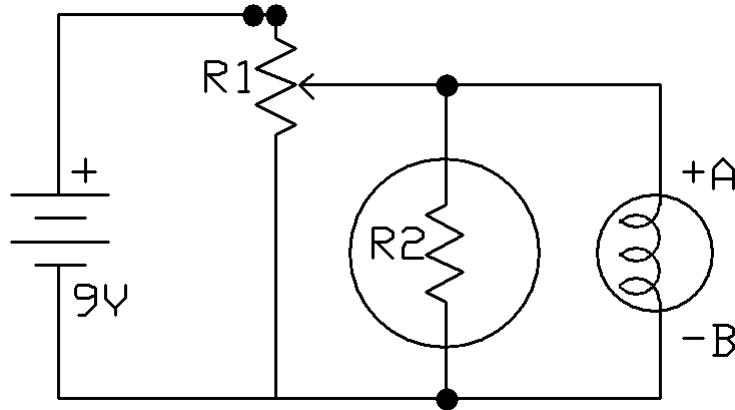
Step 2: Connect the battery to the battery holder, noting the polarity. Connect the wire from the 9 Volt battery holder to the breadboard connector pins.

Step 3: For the potentiometer identify the wiper terminal and make sure that this properly connected as shown in Figure 4.

Step 4: Connect the remaining circuit components as shown in the schematic.

Figure 5 shows an alternate circuit design for the light dependent switch. The construction procedure is identical to that of the circuit depicted in Figure 4.

**Insert Figure 5 here, centered**



**Figure 5**

**ADA Description:** Operation of a photoresistor in a voltage divider circuit (2)

**Caption:** Operation of a photoresistor in a voltage divider circuit (2)

**Image file name:** ldr\_circuit\_2\_figure5.gif

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## Attachments

[circuit\\_components\\_figure3.gif](#)  
[ldr\\_circuit\\_1\\_figure4.gif](#)  
[ldr\\_circuit\\_2\\_figure5.gif](#)  
[ldr\\_figure1.gif](#)  
[ldr\\_image1.jpg](#)  
[ldr\\_image2.jpg](#)  
[poly-nyu-logo.jpg](#)  
[pre-activity\\_assesment\\_what\\_is\\_a\\_sensor.doc](#)

voltage\_division\_equation\_figure2.gif

### **Safety Issues**

- The students must be made aware that a battery's terminals should never be connected without a resistive load. This could result in injury.

### **Troubleshooting Tips**

The multimeter should be used to verify the bread board is correctly wired (see references 5).

### **Investigating Questions**

None

### **Assessment**

#### **Pre-Activity Assessment**

Complete the What is a Sensor Worksheet.

#### **Activity Embedded Assessment**

1. Why is a potentiometer a sensor? What is the “stimulus” and the “signal”?
2. Why is a voltage divider circuit important?
3. Ask students to calculate the output voltage, using the voltage divider equation, for each circuit in Figures 4 and 5, and have them compare these to the measured value.
4. What could be a possible sources of error?
5. What are the differences and benefits of circuit 4 versus circuit 5?
6. How can a potentiometer be used to design a light dependent switch with a particular output voltage, if the photoresistor's response to light is not known exactly?
7. How can accuracy be improved using a multimeter to measure the voltage across each component and using those values in the calculations?

#### **Post-Activity Assessment**

Ask students to design and describe two applications that make use of the light dependent resistor, voltage divider circuit that was built. If this is difficult initially, remind students of the importance of tracking light, and relate that to satellite positioning. Satellites must maintain an orbit where sunlight can reach the solar panels that provide power. Remind them also that photoresistors are a part of a larger family of photodetectors. Photodetectors are used extensively in chemistry and physics to characterize materials; UV spectrophotometers are an example. Mention that autonomous robots make use of photodetectors in light sensors. These light sensors function as “eyes” and are often used for navigation.

### **Activity Extensions**

None

### **Activity Scaling**

- For lower grades, the idea of the anatomy of a sensor could be introduced initially as outlined above. The circuits could be prebuilt and used for demonstration. The background on using a breadboard and a multimeter would not be completed. The photoresistor, could be passed around, however, and the voltmeter used in a demonstration where the output voltage is measured, while varying the ambient light intensity. This would reinforce the idea of the light responsive behavior of the cadmium sulfide material, that behaves similarly to the human eye. The post activity assessment of designing a device that uses a light dependent resistor voltage divider is still used.

### **Additional Multimedia Support**

### **References**

1. Electronics Primer: Using a Multimeter. Science Buddies. Accessed September 03, 2009. [http://www.sciencebuddies.org/science-fair-projects/project\\_ideas/Elec\\_primer-multimeter.shtml](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_primer-multimeter.shtml)
2. How Light Enters the Eye. Youtube. Posted November 02, 2006. Ignite Learning Inc. Accessed September 03, 2009. <http://www.youtube.com/watch?v=15P8q35vNHw>.
3. How People Learn - Brain, Mind, Experience, and School. National Research Council. Washington, D.C.: National Academy Press, 1999.
4. How Students Learn - History, Mathematics, and Science in the Classroom. National Research Council. Washington, D.C.: National Academy Press, 1999.

5. How to Use a Breadboard. Science Buddies. Accessed September 03, 2009.  
[http://www.sciencebuddies.org/science-fair-projects/project\\_ideas/Elec\\_Breadboard.shtml](http://www.sciencebuddies.org/science-fair-projects/project_ideas/Elec_Breadboard.shtml).
6. Incandescent Light Bulb. Wikipedia. Accessed September 03, 2009.  
[http://en.wikipedia.org/wiki/Incandescent\\_light\\_bulb](http://en.wikipedia.org/wiki/Incandescent_light_bulb).
7. Voltage Divider. Wikipedia. Accessed September 03, 2009.  
[http://en.wikipedia.org/wiki/Voltage\\_divider](http://en.wikipedia.org/wiki/Voltage_divider).
8. Water Analogy to Electric Circuits. CNS (Center for Nanoscale Systems); Cornell University. Accessed September 05, 2009.  
<http://www.cns.cornell.edu/cipt/labs/documents/webWaterCircuits.pdf>

**Other**

None

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