

ICE Devices

Conductivity Probe

Your students can learn about the electrical nature of matter, electrolytic and nonelectrolytic solutions by using this conductivity probe on a paint stick. The probe is sensitive enough to show the difference between a strong and weak electrolyte. Background information about soldering appears at the end of these directions.



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Conductivity Probe

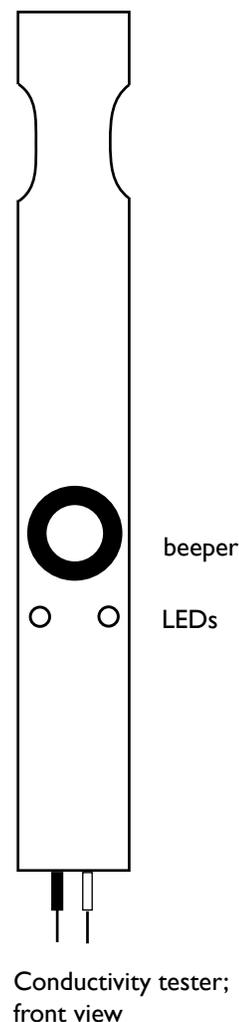
Your students can learn about the electrical nature of matter, electrolytic and nonelectrolytic solutions by using this conductivity probe on a paint stick. The probe is sensitive enough to show the difference between a strong and weak electrolyte. It has been seen in several incarnations, first at the 9th Biennial Chemical Education Conference in Bozeman, Montana in 1986, then in Thomas Russo's article [*J. Chem. Educ.* **1986**, *63*, 981–982]. Another simple tester, in a film canister, can be made following Frank J. Gadek's instructions [*J. Chem. Educ.* **1987**, *64*, 628–629]. The probe described here is a combination of designs by Nüsret Hisim [*unpubl.*] and David Katz/Courtney Willis [*J. Chem. Educ.* **1994**, *71*, 330–332] devised by Kelly Jetzer and Ron Perkins.

The Beeper

The use of a beeper as well as light-emitting diodes (LEDs) makes this device useful in a lecture format. However, in a laboratory setting, with multiple conductivity testers in use, the beeping can become irritating. To make the tester without the beeper, omit the materials and steps below that have been marked with a dagger, †.

Materials

- 1 wooden paint stirrer
- 1 LED, red (Radio Shack #276-036 or other supplier)*
- 1 LED, green (Radio Shack #276-022 or other supplier)*
- 1 † piezo beeper (many suppliers)*
- 1 100 Ω resistor (Radio Shack #271-013 or other supplier)*
- 1 1kΩ resistor (Radio Shack #271-153 or other supplier)*
- 1 † 1 kΩ resistor (Radio Shack #271-153 or other supplier)*
- 1 9" black #14 gauge wire
- 1 9" white or red #14 gauge wire
- 1 9V battery
- 1 9V battery snap connector (clip) (Radio Shack #270-325 or other supplier)*
- electrical tape
- drill and drill bits: 3/16" and †1/16" -dia.
- vise or other means of clamping down the work; scrap wood
- wire cutter and wire stripper
- soldering iron and solder [NOTE: tips and directions for soldering can be found on pages 7A–7C]
- alligator clip
- optional empty 35 mm film canisters for storage (available widely online)

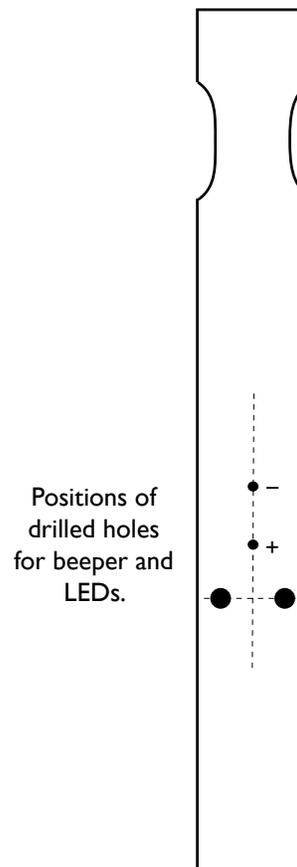


* **Electronics suppliers:** Suppliers of electronics include Radio Shack (www.radioshack.com), Mouser Electronics (www.mouser.com), All Electronics (www.allelectronics.com), in addition to those to be found by an online search.

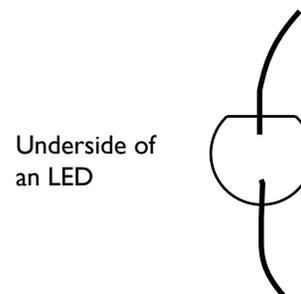
† **Optional materials** used for making the beeper.

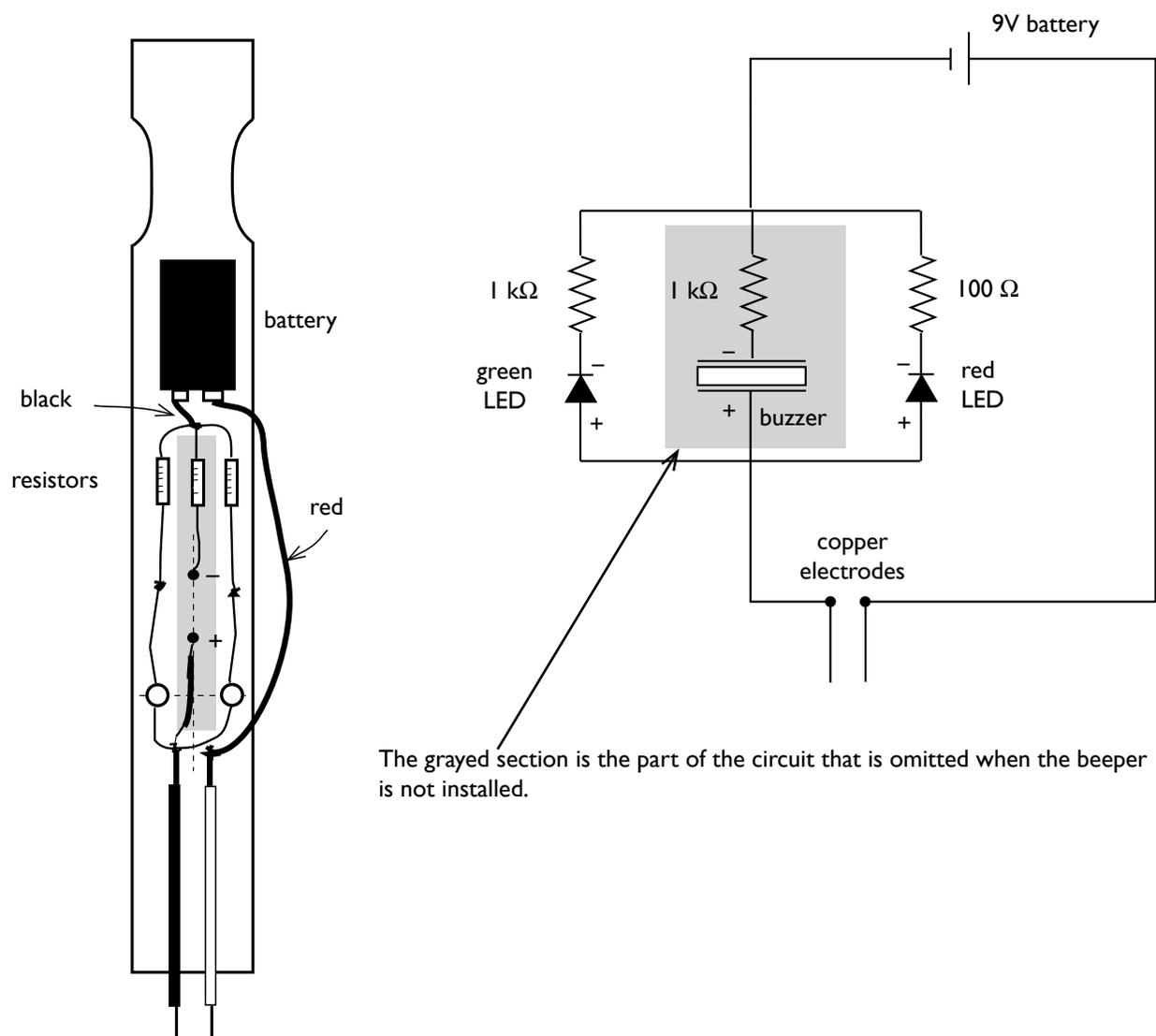
Preparation

- †1. Position the beeper at about the middle of the paint stick, so that a line drawn between its wire leads is parallel to the long edge of the stick. Mark the points at which the leads touch the stick. Drill $1/16''$ holes at these marks. Label the holes on both sides of the stick + and - as shown at right.
2. Draw a line perpendicular to the first line, about $3/4''$ away from the + hole. Mark two points, $9/16''$ apart, symmetrically placed along the line. At these marks, drill $3/16''$ diameter holes. (If you are omitting the beeper, position the holes at about the middle of the paint stick.)
- †3. Poking through the front of the paint stick, insert the positive lead of the piezo beeper into the hole marked + and the negative lead into the hole marked -. It is important to get each of the leads into the proper hole or the beeper will not work.
- †4. Because the wire leads of the beeper are too short to be worked with comfortably, we will attach a small piece of wire to the positive terminal: Cut a $1.75''$ length from one of the wires of the battery snap-on connector. Strip about $1/4''$ of insulation from both ends.  Solder one end of this wire to the positive terminal of the beeper. (Soldering tips can be found on pages 7A-7C.)



5. Insert the LEDs through the big holes. The LEDs should fit snugly. The bulbs should be on the same side of the paint stirrer as the beeper. All the wires should be pointing through to one side of the stirrer. Inspect an LED from the wire side. Notice that one edge of the bulb is shaved off to be flat. The wire closest to this edge is the *negative* lead. (As is the beeper, the LED is a polar device and will work only if hooked up in the correct orientation.) Orient the bulbs so that the negative leads are closest toward the top, the handle of the paint stick.
6. Cut each of the #14 gauge wires so that they reach from the LED leads to about $4''$ beyond the end of the paint stick. Strip $1/2''$ of insulation from both ends of the wires. Secure the wires with electrical tape to the paint stick.





7. The figure and the circuit diagram above will aid in steps 7 and 8. Join together the positive leads of the LEDs, the black #14 gauge wire † and the wire extension that you made for the positive terminal of the beeper. Make sure that you have a good mechanical connection, ⚠ then solder the wires together. (Soldering tips can be found on pages 7A–7C.)
8. ⚠ Solder the connections as shown in the circuit diagram:
 - a. negative lead of red LED to 100 Ω resistor (attach an alligator clip to the LED lead to act as a heat sink—overheating the LED will damage it)
 - †b. negative lead of beeper to 1 kΩ resistor
 - c. negative lead of green LED to second 1kΩ resistor (attach an alligator clip to the LED lead to act as a heat sink—overheating the LED will damage it)
 - d. loose ends of all resistors and black lead of battery clip
 - e. red lead of battery snap connector (clip) to white or red #14 gauge wire.

9. Connect the 9V battery to the battery clip. Use electrical tape or a rubber band to attach the battery to the paint stick.
10. Test the conductivity tester by touching the two #14 gauge wires to each other. Both LEDs should light † and the beeper should beep. If it does not work, recheck the polarities of the beeper and LEDs; make sure that all the soldered connections are fast; check that the battery is at full charge.

Presentation

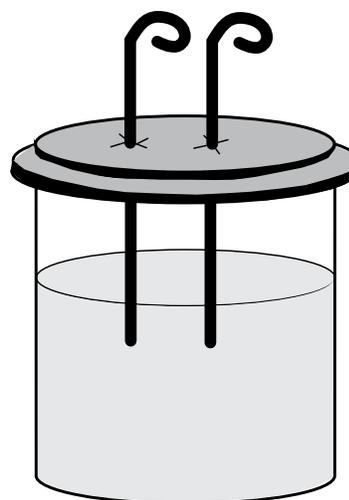
Place both leads of the conductivity tester onto the solid or into the liquid to be tested. The LEDs will light up and the beeper will beep according to the degree of conductivity.

Solutions to test can include household chemicals such as vinegar, sudsy ammonia and window cleaner, dish detergent, rubbing alcohol and beverages, as well as various waters: sparkling, distilled, tap, mineral, “drinking”.

One can test how the conductivity changes when salt or sugar is gradually added to distilled water. This device is sensitive enough to detect a single salt crystal dissolved in a few drops of distilled water.

Other solutions to test would be strong acid and base solutions (about 2M), weak acids and bases (2M), and various polar and nonpolar solvents. (Note that 2M nitric acid will react with the copper electrodes.) Solids to test could be metals, silicon, glass and leaded glass or crystal, and an insulating solid such as a plastic.

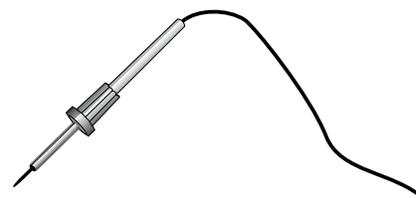
If the tester will be used by a large number of students, you may wish to keep the liquids being tested in leak-tight containers, such as the one shown here. Transparent film cans/canisters make good “vials”. (These are the containers in which photographic film used to be sold. They continue to be available from online sources.) You will need as many vials as you have solutions, a spool of heavy-gauge copper wire, wire cutters, and pliers. A hammer and a nail (smaller in gauge than the wire) can be used to make holes in the lid of the vials for the wires to pass through.



Soldering

The notes on pages 7A–7C provide background information on these facets of soldering:

- Equipment
- Soldering Procedure—Soldering wire leads to a PC board, soldering wire leads to a wire, and soldering wire leads to multistrand wire
- Wire Stripping



Appendix: Soldering

Text by Carl Houtman, Illustrations by Christine L. Cargille

NOTE

To see a useful video about soldering, go to:

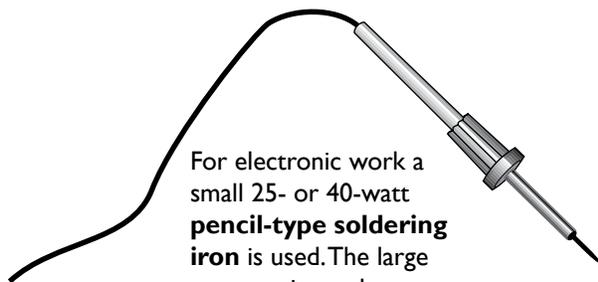
www.youtube.com/watch?v=BLfXXRfRIzY

⚠ CAUTION ⚠

The tip of a soldering iron is extremely hot. Soldering is inherently a three-hand job: you need to hold the soldering tool and both pieces to be joined. However, it is best to use a vise or a clamp for the third hand, rather than a human assistant.

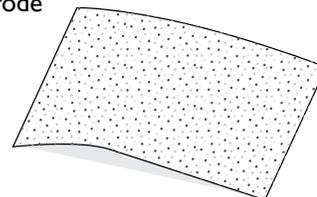
The equipment

Soldering is a way to join two metal surfaces. For the “glue”, one uses a low-melting-point alloy. For electronic or electrical work an alloy that is 40% tin and 60% lead is best, in contrast to the 50/50 solder that is used for plumbing connections. **Electronic solder** often has a rosin core to act as a flux to improve the “wetting”, or coating, of the metal surfaces to be joined.



For electronic work a small 25- or 40-watt **pencil-type soldering iron** is used. The large gun-type irons do not have a fine enough tip.

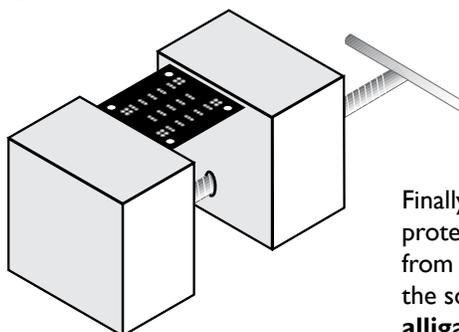
To clean and re-tin the soldering iron tip, use **tip cleaning paste** for electronic work from an electronics store. Do not use acid cleaners or acid flux—they will corrode your work. You can also gently **sand** the surface of the soldering iron tip until you have exposed the base metal.



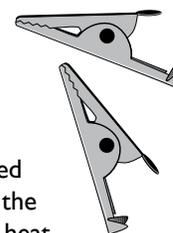
You will need **tweezers or pliers** or some other tools to hold small, very hot, delicate objects.



It will infinitely simplify your task if you have a **vise** or a **C-clamp** to hold one of the parts that you will be soldering—either the printed circuit (PC) board, if you are soldering components to it, or one of the wires, if you are soldering to a wire.



Finally, you may need to protect certain components from overheating during the soldering process. Small **alligator clips** can be clamped between the component and the joint to be soldered to act as heat sinks.



Soldering procedure

1.  Clear away a work space on a flameproof surface. **Put on safety goggles** to protect your eyes from hot rosin which might spatter.
2. **Take a sponge, or fold a paper towel** into quarters or eighths and **wet it**; place it next to the soldering pencil.
3. Plug in the soldering pencil and allow it a few minutes to get hot. **Check the tip:** Touch the tip of the soldering pencil to some solder. It should melt and coat the tip. If the solder rolls off the tip and does not coat it at all, you may need to clean the tip as described above. Then the solder will wet the tip surface.

While soldering, **wiping the tip** on the damp paper towel (or sponge) will help clean it by removing the oxide that forms on the surface of molten solder. Wiping on a damp towel also keeps the tip from overheating and oxidizing. To wipe the tip, simply stroke it over the folded paper towel that is lying on the table.

4.  Do **NOT** pick up the towel and rub it over the tip! If you do, you will severely burn your fingers.
4. The most important step in obtaining good solder joints is to **clean all the surfaces** carefully. Solder does not wet oxidized surfaces. When working on a printed-circuit board, rub the metal surfaces with fine steel wool. Other electronic components typically have non-oxidizing wires that don't need cleaning. Copper wires may need to be stripped to expose fresh metal. For help in wire stripping, see the relevant section below.

The next few steps will describe how to solder a wire lead of an electronics component to a printed-circuit (PC) board and how to solder a wire to a post or to another wire. An important point to remember when soldering *any* joint is that it is not sufficient to melt the solder and drip it all over the joint as one might do with glue. The pieces to be joined must be at the same temperature as the molten solder in order for the bond to be strong. Thus, *the soldering iron is used to heat the pieces to be joined, which in turn heat the solder.*

A. How to solder wire leads to a PC board

5. **Insert the wire leads** of the electronics component into the appropriate sockets of the PC board.
6. **Secure the board** in a vise or clamp.
7. If necessary, **clamp an alligator clip** between the joint and the (heat-sensitive) electronics component to minimize the heat transferred up the wire lead.
8. A *small* amount of solder should be on the tip of the soldering pencil to aid the flow of heat to the surfaces. Hold the soldering pencil in one hand and the solder in the other. Touch the hot tip of the soldering pencil to one side of the wire lead and to the soldering trace on the board. When the surfaces are hot (after about 30 seconds or so), touch the solder (not the pencil) to the other side of the wire lead. Do not let the solder touch the soldering pencil directly.

After about 25 seconds, the heat from the soldering pencil should penetrate through the wire lead and melt the solder. The solder will flow onto the wire and onto the copper trace. The solder only flows onto hot surfaces.

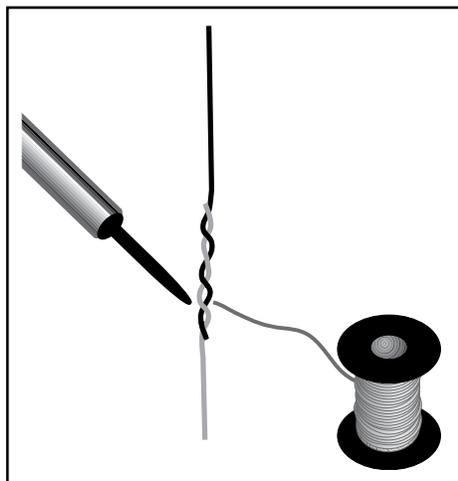
9. Do not use too much solder or it will overflow onto adjacent leads or traces, creating a “solder bridge”. If you make a solder bridge, first rub off any excess solder from the pencil tip on a damp paper towel. Reheat the joint to melt and remove the bridge. If this does not work, heat the joint until *all* the solder is molten and then tap the board on the table. If the solder is molten you should be able to shake it from the board.

B. How to solder wire leads to wire

10. Make a **firm mechanical connection** by twisting or crimping the wires together. Then, follow instruction number 8 above.

If you do not make a good mechanical connection, you may make what is called a “cold solder joint”.

Cold solder joints form when the wires are moved as the solder is cooling. One can spot cold solder joints because they often have a rough surface while good joints have a smooth surface. Simply reheating a cold solder joint will correct the problem.



C. How to solder wire leads to multistrand wire

11. Strip 1–1.5” of insulation from the multistrand wire. Twist the strands so that they spiral together. “Pre-tin” the strands: Hold the tip of the soldering pencil to one side of the wire and the solder to the other side. When the wire is hot enough, the solder will melt and penetrate among the strands. Allow to cool. Then, follow instruction number 10 above.

Wire Stripping

“Stripping” a wire refers to removing the insulation casing and exposing the copper wire. The easiest way to strip wire is to use wire strippers. These are designed to cut the insulation but leave the metal wire intact—they are like scissors with a small notch in the cutting edge. Care is required, however, since many wires are bigger than the notch.

Place the wire in the jaws of the stripper at the position where you want to remove the casing. Squeeze the stripper carefully. [If you are uncertain about how hard you need to close down the stripper, practice by trying to remove a very short piece (1 cm) of insulation.] You may want to rotate the stripper around the whole wire to get an even cut all the way around the insulation.

Once the insulation is cut, shove the stripper along the wire towards the end to push the casing off the bare wire inside. This is like taking off a sock by pushing it down from the top instead of pulling it by the toe.