Overview:

In this TI-Nspire™ CX lesson, students will build a conductivity probe and use the device to investigate the purity of water. This project is an application of the prior skill builder “Getting Analog Input”. The project can be constructed with a cork or stopper; or optionally, students may design and 3-D print their own electrode mount. Additional, students are introduced to the concept of electrolyte solutions and make observations of solutions using the sensor they have built.

Goals:

1. Apply the skill of getting analog input from the TI-Innovator™ Hub to measure a voltage.
2. Design and build a water quality sensor using common materials.
3. Design a 3-D print of an electrode mount (optional).
4. Author a TI-Basic program on the handheld that reads, scales, and displays analog input.
5. Engage in argument from evidence observed during investigations using sensor.

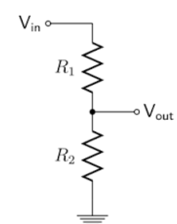
Background:

An electrolyte is a chemical substance that dissolves when added to water. The dissolved chemical then breaks apart into charged particles called ions that move freely throughout the solution. Some of the ions are positively charged, called cations; others are negatively charged, called anions.

The total positive charge of all of the dissolved cations and the total negative charge of all of the dissolved anions are equal, resulting in an overall neutral or zero charged solution. One feature of an electrolyte solution is the solution is an electrical conductor; that is, electricity can move through it.

Recall that electricity is actually a flow of electrons; this flow is called electrical current. The dissolved ions in the solution are free to move around within the water. When the electrodes (stripped 26AWG magnet wire) of the sensor are placed into the solution, electrons hop off of the negatively charged electrode and onto an ion. This ion then moves toward the positive electrode (opposite charges attract) and when it reaches the positive electrode the extra electron hops off and onto the electrode, thus completing the electrical circuit and allowing the current to flow through the entire circuit.

The circuit in the diagram to the right is a voltage divider, what was used in Unit 4 skill builder. The difference is, the electrodes of the sensor are in the place of R_1 and the 1k Ohm resistor is R_2. The V_{out} is read by the ANALOG.IN, just as it was in the Skill builder 4. Since the electrode will be immersed in a conductive electrolyte solution, the resistance of that solution becomes the value of R_1 and thus will affect the V_{out} that is measured by the TI-Innovator Hub.



$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$

As the conductivity increases, the resistance (R_1) decreases, and the V_{out} becomes larger. Thus, the sensor can be used to check the purity of water by measuring conductivity. Pure water will have a high resistance (low conductivity) and thus small V_{out}. An impure sample of water containing electrolytes will have a lower resistance (high conductivity) and a higher V_{out}. Therefore, the V_{out} is a measure of conductivity.

Once the electrode has been built and the software has been written, you should verify that it works correctly. To do this, fill the test tube with tap water, place the electrode all the way into the tube, and run the program. Note the V_{out} value on the handheld.

Next, repeat the process using tap water with a pinch of table salt added to the water. The table salt is an electrolyte and will dissolve in the water and increase the conductivity, thus lowering the resistance. The lower resistance on the salt water should yield a larger V_{out} on the handheld. In other words, large V_{out} is high conductivity while low Vout is low conductivity.

Now you are ready to test various water samples available to you. Try comparing several different bottled waters, tap water, and distilled water. Measure the V_{out} for each, and prepare a bar graph for your results. Make an argument from evidence which sample is the cleanest!

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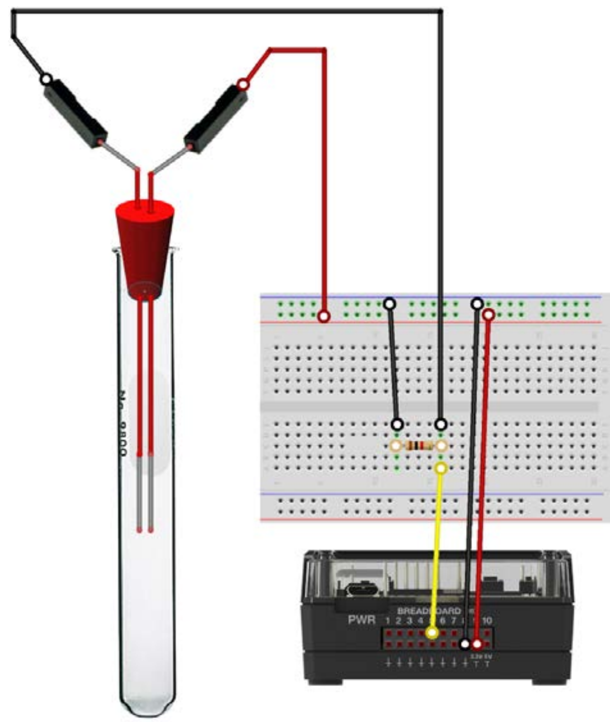
Materials and Tools:

- TI-Nspire CX Technology
- TI-Innovator™ Hub with USB Cable
- TI-Innovator Breadboard Pack:
  - ➢ Breadboard
  - ➢ Male to Male jumper wires
  - ➢ Male to Female jumper wires
  - ➢ Resistor 1K Ohm (brown, black, red)
- 26 AWG magnet wire
- Needle nose pliers
- Hot glue gun or sealant
- Cork or stopper (optional)
- Test tube
- Different types of bottled water
- Distilled water

Build the Hardware:



1. Cut two ~8 cm lengths of 26 AWG magnet wire.
2. Use sandpaper to strip about 2cm of enamel insulation from each end.
3. Carefully insert the two pieces of wire through a cork or stopper or an optional 3D-printed holder.
4. Apply a small amount of hot glue or sealant to hold the wires in place and seal them against leakage and shorting.
5. Insert each piece of stripped wire into a red and a black Male to Female jumper wire. Hot glue or tape the stripped wire into the Female receptacle of the jumper wire.
6. Insert entire unit into appropriate test tube.
7. Insert a 1k Ohm resistor into the breadboard. Be sure the two ends are not electrically connected in the breadboard.
8. Insert the red Male to Female Jumper wire containing the magnet wire into the red 3.3V power rail on the breadboard.
9. Insert the black Male to Female Jumper wire containing the magnet wire, into one end of the 1k Ohm resistor.
10. Use a black Male to Male Jumper cable to connect the other end of the resistor to the blue ground rail on the breadboard.
11. Use a yellow Male to Male Jumper to connect the end of the resistor that is also connected to the Male to Female Jumper cable with magnet wire inserted, to the analog input on BB5 of the TI-Innovator Hub.
12. Use a red Male to Male Jumper to connect the red power bus on the breadboard to the 3.3V on the TI-Innovator Hub.
13. Use a black Male to Male Jumper to connect the blue ground bus to any ground on the breadboard connector of the TI-Innovator Hub.
14. Plug the B end of the “unit to unit” USB cable into the TI-Innovator Hub and then the A end into the handheld device.
15. For consistent readings, do not leave the probe immersed in water, rinse with fresh water, and pat dry between uses. Also, do not allow the wires to touch or bend.

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Write the Software for the TI-Nspire CX:

Write a TI-Basic program that…

1. connects an ANALOG.IN object to BB5.
2. sets the RANGE of ANALOG.IN from 0 to 100.
3. will READ ANALOG.IN one hundred times with a .1 second delay.
4. displays the ANALOG.IN value.

Example Code for the TI-Nspire CX:

```
Define pj4()=
Prgm
Send "BEGIN"
DelVar iostr.str0
GetStr iostr.str0
Disp iostr.str0
Send "CONNECT ANALOG.IN 1 TO BB 5"
For n,1,200
Send "READ ANALOG.IN 1"
Get a
Disp "ANALOG in = ",a
Wait 0.1
EndFor
EndPrgm
```

Task: Test water purity with your device:

1. Choose three different bottled waters, tap water, and distilled water.
2. Pour a sample of each into test tube, and record the value.
3. Make a graph of the results.
4. Write brief presentation of results and argue from evidence your choice of the "cleanest" water.

Data Table:

Sample	Analog reading

Sample Answer: Answers will vary. Distilled ~<3 Tap water ~5, salt water~30

Extra For Experts:

1. Prepare solutions of .1M, .2M, .3M, .4M and .5M solutions of NaCl (table salt).
2. Measure and record the analog out reading for each solution in a data table.
3. Plot the five ordered pairs on a scattergram with analog out on the horizontal axis and concentration on the vertical axis.
4. Create a mathematical model that best fits the data.
5. Overlay the model on the data to check for fit.
6. Mix another .35M "unknown" NaCl solution.
7. Measure the analog out for the unknown, and use the model to predict an unknown concentration of NaCl.

Teacher Tip: Instead of mixing the solution molarity, a uniform addition of table salt may be added to the solution.

Teacher Tip: The prepared table salt solutions are no more salty than ocean water. Please consult your local lab safety guidelines for the appropriate use of table salt solutions in your classroom.