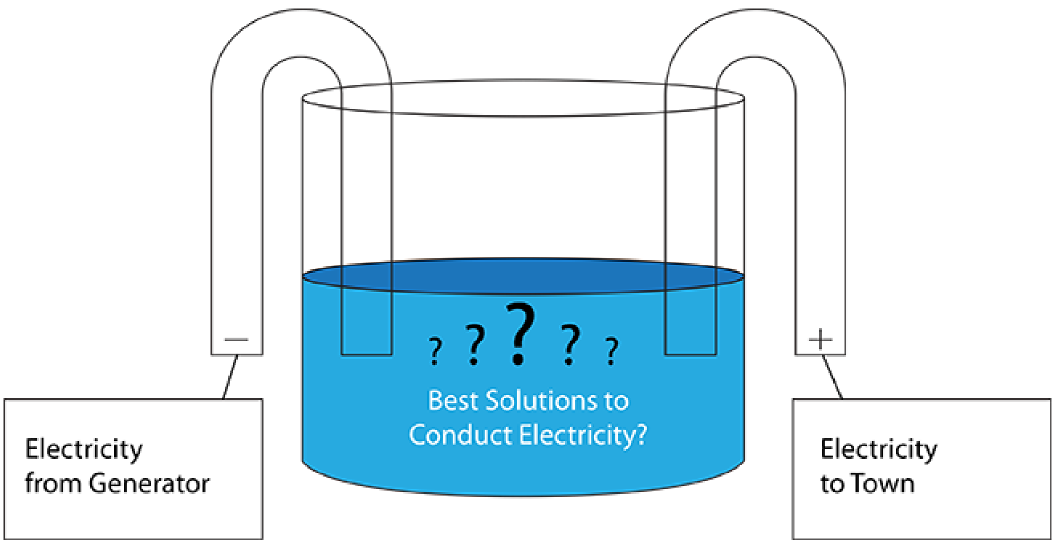
Electricity Lesson 2: *The Make*
Educator's Lesson Plan

Objective
The town of Waterville is low on wires but has an abundance of water. Electricity solutions can use local water sources to light up the town. In *The Make*, students will:

1. Investigate the behavior of electric current in saltwater and pure water solutions.
2. Analyze data to draw conclusions about the best solution to conduct electric currents.
3. On a separate sheet of paper, draw an annotated diagram that compares and contrasts the way electricity flows in the two solutions.
4. Explain their recommendation for the best solution to optimize the flow of electricity in the tank circuit.



Time Required: 180 minutes

Materials

Note: If doing this virtually, no materials are required. Instead, video links of the activities are provided to students in the student guide.

Equipment List

- Appendix A gives the educator background information and full instructions for set-up.
- Note that these same materials will be reused in *The Engineer* lesson.

Each group of 3-4 needs:

- Lab investigation supplies
  - goggles or safety glasses
  - extension materials for 3-D or dynamic model
  - 1000-ml water source (pitcher, beaker, etc.)
  - 2 large, wooden popsicle sticks (available at craft stores)
  - 3 pieces of insulated copper wire, each 4-6 inches (10-15 cm) long
    Note: Strip about 1 cm of insulation off both ends of each wire, using wire cutters
  - 3 or 4 clear plastic cups, 16 ounce (473 ml) size
  - 2 plastic spoons
  - 9-volt battery
  - 9-volt battery cap, usually with red and black wire leads
  - 1 miniature light bulb with socket to match (3.7 volt bulb or similar)
- Research resources
  - computers for research
  - Part A: Student Procedure Card (Appendix B)
  - Part B: Student Self-Check Card (Appendix B)
- 3 or 4 Student Guides
- white paper
- 3 or 4 Post-Its
- colored pencils/markers

Class will share:

- electrical tape
- salt, one 26 oz (737 g) container
- flat-head screwdrivers, to tighten wires in light bulb sockets
- roll of aluminum foil
- distilled "pure" water
- triple beam or digital scale, to measure grams of salt
- measuring cups or graduated cylinders, to measure milliliters of water
- paper towel

For Class Data Display

- Butcher paper for class annotated diagram (Level 1)
- Chart paper for histogram (All levels)

Safety Considerations	Science & Engineering Practices
○ Eye protection (goggles or safety glasses) ○ Without a battery cap the battery will short circuit if the wire ends that are connected to the positive and negative terminals touch. The battery overheats and can cause severe burns. ○ When students put wires together, note that the wires edges can be bent like a hook and taped using electrical tape, or use alligator clips	● Developing and using models ● Constructing explanations or arguments from evidence

Inquiry Scale
Level 1: **most teacher-driven** (*recommended for grades 4-5)*
Lead *The Make* investigations as a class-wide demo, building the circuit as a demo that is duplicated by students at their table groups of 3 - 4, guided by the Student Guide Planning Organizer (at this level of inquiry replace the Student Guide with Appendix C below). Demos should only include Solution A (pure water), Solution D (medium salt concentration), and Solution G (most concentrated salt solution). Facilitate think-pair-shares after each demo to discuss patterns observed, prompting students to complete the Student Guide Planning Organizer concurrently.
After both demos, students place their group Post-Its on the histogram and then work with their table group to come up with a generalized rule relating to salt concentration and electric current. Students come back together to do the annotated diagram (see the first bullet point on the Electricity *Make* Checklist below) as a class-wide discussion. Students can direct where the teacher draws aspects of the diagram on large butcher or chart paper. Guide students as they then replicate and complete all aspects of the Student Guide Planning Organizer and Assessment Checklist.

Level 2 (*recommended for grades 5-6)*
Students independently build the circuit and complete investigations in their groups of 3-4, guided by the Student Guide Planning Organizer (at this level of inquiry replace the Student Guide with Appendix C below). Investigations should only include Solution A (pure water), Solution D (medium salt concentration), and Solution G (most concentrated salt solution). Analysis questions for the investigation are then conducted as a class-wide discussion.
After each investigation, students place their group Post-Its on the histogram and then work with their table group to come up with a generalized rule relating to salt concentration and electric current. Students then come back together for a class-wide brainstorm for the organization of the annotated diagram (see the first bullet point on the Electricity *Make* Checklist below) before independently creating their annotated diagram in their groups.

Level 3 (*recommended for grades 6-7)*
Students independently build the circuit and complete lab stations, selecting solution A (pure water) and three test solutions of their choice, and then complete analysis questions in their groups.
After each investigation, students place their group Post-Its on the histogram and then work with their table group to come up with a generalized rule relating to salt concentration and electric current.
Students come back together for a class-wide brainstorm about patterns they noticed before independently creating their annotated diagram in their groups.

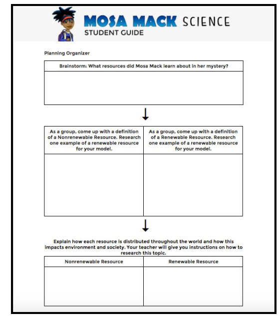
Level 4: **most student-driven** (*recommended for grades 7-8)*
Students will independently build the circuit and complete all aspects of *The Make* process, including lab stations with solution A and three test solutions of their choice, analysis questions, and annotated diagrams.
After each investigation, students place their group Post-Its on the histogram and then work with their table group to come up with a generalized rule relating to salt concentration and electric current. As the facilitator, check in on group progress. Provide suggestions and support to individuals or specific groups, as needed.

Agenda

I. Show PowerPoint to introduce *The Make* Activity (10-15 minutes)

The PowerPoint will review essential concepts learned in *The Solve* and provide context for the students' upcoming *The Make* challenge.

II. *The Make* Activity (160 minutes)



MOSA MACK SCIENCE
STUDENT GUIDE

Planning Organizer

Brainstorm: What resources did Mosa Mack learn about in her mystery?

As a group, come up with a definition of a Nonrenewable Resource. Research one example of a renewable resource for your model.	As a group, come up with a definition of a Renewable Resource. Research one example of a renewable resource for your model.

Explain how each resource is distributed throughout the world and how this impacts environment and society. Your teacher will give you instructions on how to research this topic.

Nonrenewable Resource	Renewable Resource

As guided by the organizer, students will:

1. Investigate the behavior of electric current in saltwater and pure water solutions. If doing this remotely, students will view a video of the currents here Students are provided with the video in the student portal.
2. Analyze data to draw conclusions about the best solution to conduct electric currents.
3. On a separate sheet of paper, draw an annotated diagram that compares and contrasts the way electricity flows in the two solutions.
4. Explain their recommendation for the best solution to optimize the flow of electricity in the tank circuit.

Answers to *The Make*

Part A:

- Tips for troubleshooting malfunctioning circuits: *Check for loose connections or dead batteries.*
- In one or two sentences, explain how electricity is flowing through your circuit.
  Electrons transfer electricity through the wire from the negative end of the battery toward the positive end of the battery. This only works when the circuit is closed.

Part B:

- What solution is the MOST effective to conduct electricity for the brightest light?
  Solution G (300 ml water/20 g salt in water), or the solution with the highest concentration of salt
- What solution is the LEAST effective to conduct electricity for the brightest light?
  Solution A (distilled water)
- As a group, explain which diagram shows the best liquid solution to conduct electricity. Why is it the best?
  The diagram on the left (the salt solution test) shows the best liquid solution to conduct electricity. This is because it has charged atoms from the salt, through which electricity can travel.

III. Exit Ticket (10 minutes)
Students complete the Exit Ticket, which summarizes their understanding of *The Make* and connects students to the upcoming Engineering challenge.
Note: In collaborative classrooms, this serves as the individual accountability in an otherwise group project.

Exit Ticket Answer Key
1. How is the flow of electricity different in saltwater than in pure water?
Fresh water is a weak conductor of electricity. Saltwater is is a strong conductor of electricity.

2. How did the strength of the electric force change when you changed the salt concentration of the water? Use data to back up your claim.
The strength of the electric force increased when we increased the salt concentration of the water. This was shown by the light bulb lighting up brighter at 20 mg of salt versus 5 mg of salt, or the solution with the highest concentration of salt.

3. Why is saltwater a better conductor of electricity than pure water?
Because electricity needs charged atoms to travel on, and these are present in the saltwater. There are no strongly charged atoms in pure water.

4. What materials are good conductors of electricity, and therefore probably contain charged atoms?
Water with charged atoms in it conducts electricity. Metals (for example, wires) also conduct electricity. All of these must have charged atoms to conduct electric current.

5. Electricity is an incredible resource for our society. Are there any dangerous aspects of electricity that you have heard of?
Answers will vary. Some students may talk about the danger of being electrocuted or the danger of electromagnetic fields contributing to disease.

***The Make* Assessment:** Project Grade and Rubric Score Sheet - Electricity

Project Submitted by ____

Electricity Make Checklist: Content Concepts and Practices
Your Challenge: Design a solution for the town of Waterville with the best water to conduct electricity.

Project Completion:

- ❏ Electric Circuits Investigations:
  - ❏ Electric circuit established to light bulb
  - ❏ Four circuitry tests conducted including:
    - ❏ Amount of salt used in solution
    - ❏ Observations
    - ❏ Light brightness
    - ❏ Ranking of water solutions
    - ❏ Histogram of class data
    - ❏ Analysis and conclusions based on data
- ❏ Waterville Design Solution:
  - ❏ Includes drawing of electricity flow with water solution based on test data
    - ❏ Describes what an electric current is
    - ❏ Explains how electric current moves through proposed circuit in design solution
    - ❏ Explains why water solution was chosen for efficient electric current and why
    - ❏ Diagram design is well-organized, neat, and in color with relevant annotations
    - ❏ Diagram depicts how electricity flows out of station to the town so that it can be used in homes and businesses.
    - ❏ Extra credit: Depicts circuits as a 3-D or dynamic model

DCI Standards Checklist:

- ❏ Electric Circuit Investigations:
  - ❏ Accurately depict closed circuit
  - ❏ Data accurately supports brighter bulbs with higher salt concentration in water
- ❏ Waterville Design Solution:
    - ❏ Design solution accurately describes what electric current is and incorporates a closed circuit, utilizing a water solution
    - ❏ Accurately conveys understanding of electric current based on concentration of salt in solution
    - ❏ Design solution could accurately be used to provide electricity to Waterville homes and businesses

Science & Engineering Practices Rubric

	Emerging (1)	**Developing (2)**	**Proficient (3)**	**Advanced (4)**
Developing and Using Models	Drawings, diagrams, or visual models include major misconceptions or have missing parts. Explanation of the	Drawings, diagrams, or visual models include minor misconceptions or have missing parts. Explanation of the model is minimal.	Drawings, diagrams, or visual models are complete, but contain a minor misconception. Explanation of the	Drawings, diagrams, or visual models have no misconceptions and contain all details. Explanation of the

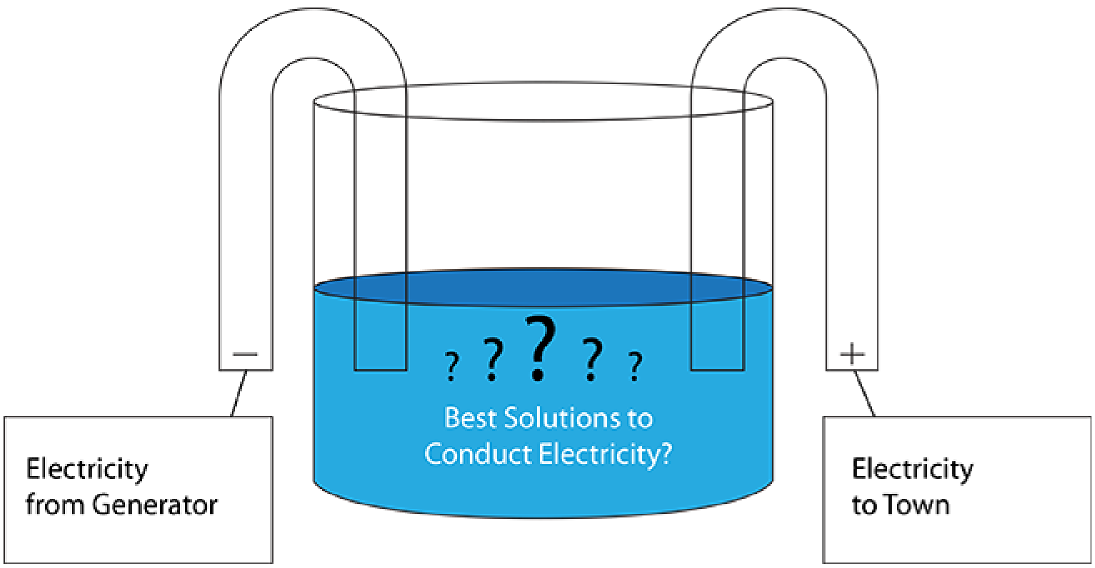
	model is minimal or not present.		model is complete but lacking complexity.	model is complete and complex.
Constructing Explanations or Arguments From Evidence	Constructs an explanation with no clear sources of evidence.	Uses scientific principles and/or data from at least one source to construct or evaluate an explanation, but explanation contains minor misconceptions.	Uses accurate but incomplete scientific principles and/or data from multiple sources to construct or evaluate an explanation.	Uses accurate and complete scientific principles and/or data from multiple sources to construct or evaluate an explanation.

Teacher Comments:

Final Score: Final Grade:

Appendix A: Teacher Preparation Guide (1 hour)

Rationale
For a liquid to conduct electricity, it must contain a high concentration of charged atoms. Distilled water is a relatively poor conductor because it has very few charged atoms. Adding ionic solids (such as table salt) to a liquid will increase its conductivity. River water is generally a very good conductor because it has plenty of charged atoms. Ocean water is a great conductor because it is salty and full of charged atoms.



Part A: Material Preparation

1. For each group, make two (2) copies of the Student Procedure Card in Appendix B (place at lab stations).
2. For each group, make two (2) copies of the Student Self-Check Card in Appendix B (distribute to student groups when they complete Part A of *The Make*).
3. For each group, prepare the insulated copper wire by stripping about 1 cm of insulation off both ends of each wire, using wire cutters.

Part B: Material Preparation

1. Label cups. Each group will need labeled cups for the number of solutions they are testing.
   If doing this remotely, use the video link.

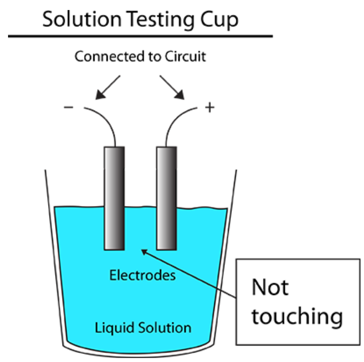
Solution A 300-ml pure water (H_2O)	**Solution A** 300-ml pure water (H_2O)	**Solution A** 300-ml pure water (H_2O)	**Solution A** 300-ml pure water (H_2O)
Solution B 300-ml water (H_2O) 0.5 g salt (Na+ Cl-)	**Solution B** 300-ml water (H_2O) 0.5 g salt (Na+ Cl-)	**Solution B** 300-ml water (H_2O) 0.5 g salt (Na+ Cl-)	**Solution B** 300-ml water (H_2O) 0.5 g salt (Na+ Cl-)
Solution C 300-ml water (H_2O) 1.0 g salt (Na+ Cl-)	**Solution C** 300-ml water (H_2O) 1.0 g salt (Na+ Cl-)	**Solution C** 300-ml water (H_2O) 1.0 g salt (Na+ Cl-)	**Solution C** 300-ml water (H_2O) 1.0 g salt (Na+ Cl-)
Solution D 300-ml water (H_2O) 5.0 g salt (Na+ Cl-)	**Solution D** 300-ml water (H_2O) 5.0 g salt (Na+ Cl-)	**Solution D** 300-ml water (H_2O) 5.0 g salt (Na+ Cl-)	**Solution D** 300-ml water (H_2O) 5.0 g salt (Na+ Cl-)
Solution E 300-ml water (H_2O) 10.0 g salt (Na+ Cl-)	**Solution E** 300-ml water (H_2O) 10.0 g salt (Na+ Cl-)	**Solution E** 300-ml water (H_2O) 10.0 g salt (Na+ Cl-)	**Solution E** 300-ml water (H_2O) 10.0 g salt (Na+ Cl-)
Solution F 300-ml water (H_2O) 15.0 g salt (Na+ Cl-)	**Solution F** 300-ml water (H_2O) 15.0 g salt (Na+ Cl-)	**Solution F** 300-ml water (H_2O) 15.0 g salt (Na+ Cl-)	**Solution F** 300-ml water (H_2O) 15.0 g salt (Na+ Cl-)
Solution G 300-ml water (H_2O) 20.0 g salt (Na+ Cl-)	**Solution G** 300-ml water (H_2O) 20.0 g salt (Na+ Cl-)	**Solution G** 300-ml water (H_2O) 20.0 g salt (Na+ Cl-)	**Solution G** 300-ml water (H_2O) 20.0 g salt (Na+ Cl-)

2. Prepare the solution

   A. Mix one (1) of each saltwater batch concentrations for solution supply:
      1. Batch Solution A: 1200 ml pure water only (control)
      2. Batch Solution B: 1200 ml water and 2.0 grams salt
      3. Batch Solution C: 1200 ml water and 4.0 grams salt
      4. Batch Solution D: 1200 ml water and 20.0 grams salt
      5. Batch Solution E: 1200 ml water and 40.0 grams salt
      6. Batch Solution F: 1200 ml water and 60.0 grams salt
      7. Batch Solution G: 1200 ml water and 80.0 grams salt

   B. Pour 300 ml of each solution into its corresponding cup.

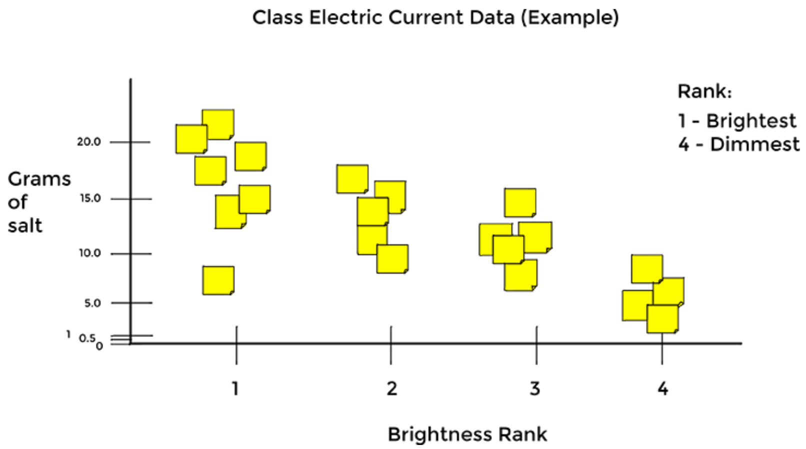
3. Distribute the prepared materials



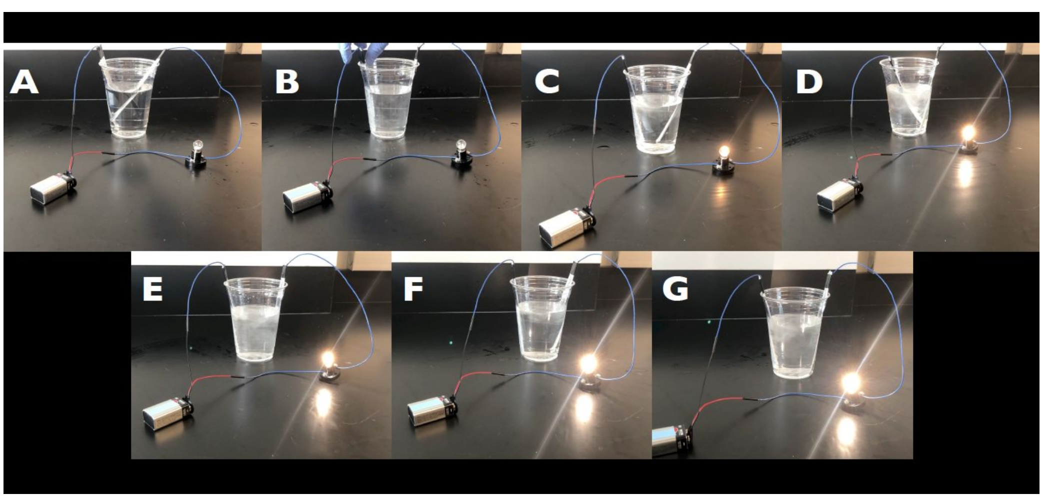
A. Arrange the cups in a designated retrieval area for student pick-up.
    a. Each group will choose three different saltwater solutions for testing.
    b. Each group gets Solution A (pure water).

B. Prepare chart or butcher paper with axes, title and key (all highlighted in example) for the class data histogram. Post in an easily accessible area so that groups can stick on their Post-It results.

Example of Class Post-It Histogram

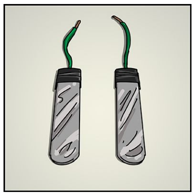
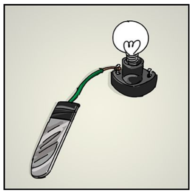
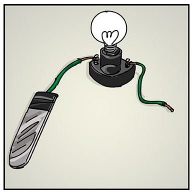
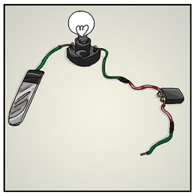
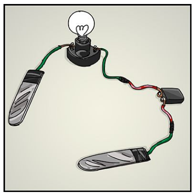
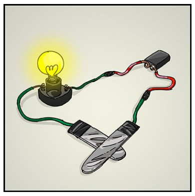


Example with Each Concentration

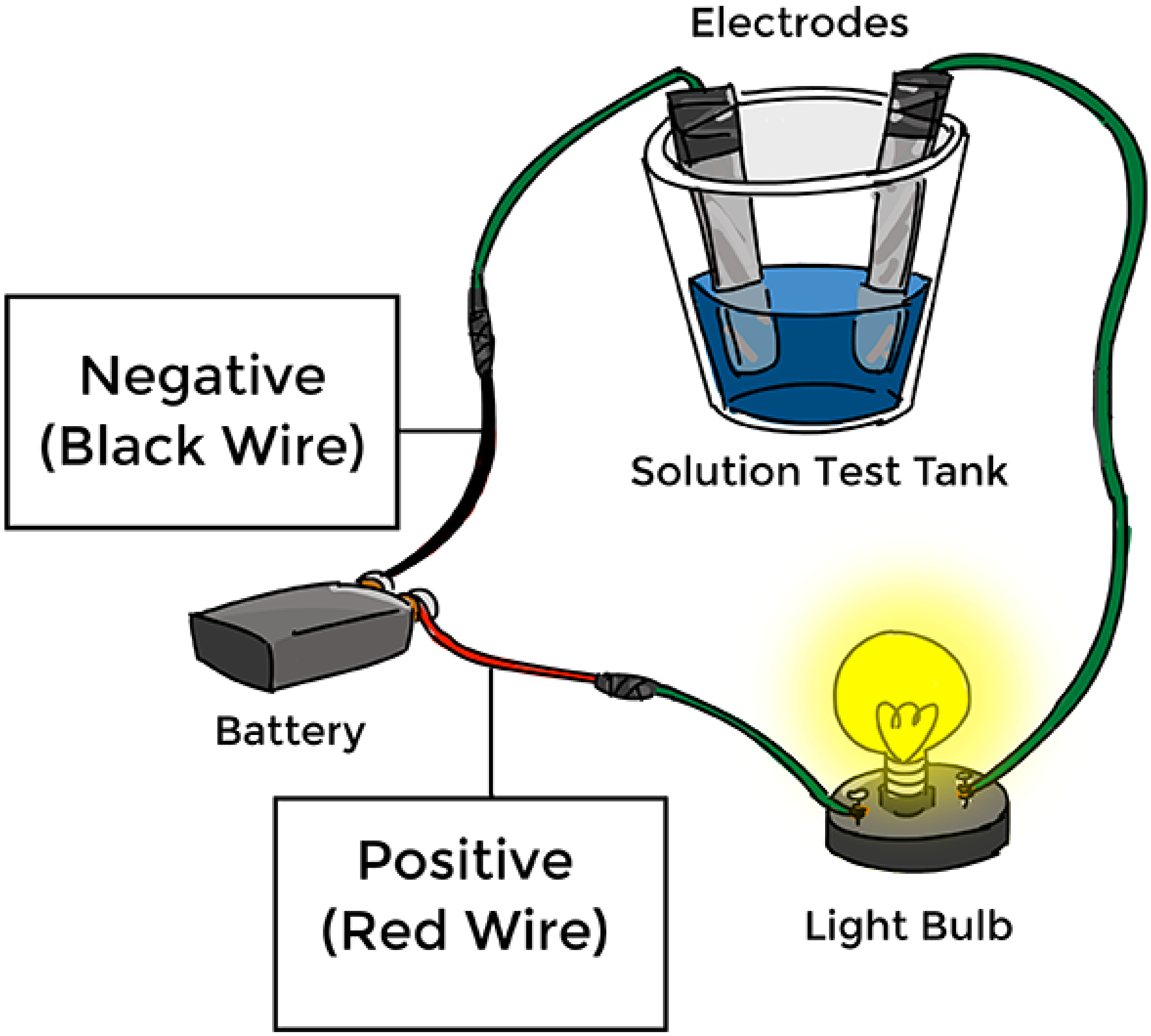


Appendix B: Student Resource Cards

<u>Part A: Student Procedure Card</u>
Build your electric circuit. This will be your water solution testing equipment.

Step	Directions	Illustration
1	Individually wrap two large popsicle sticks in aluminum foil. Connect one wire to the end of each popsicle stick using electrical tape, making sure that the bare end of the wire touches the aluminum foil under the tape. These are your electrodes.	
2	Connect the opposite end of the wire from one electrode to one terminal of the light bulb socket. Insert the bare wire around the socket terminal and tighten with a screwdriver. Add a piece of electrical tape to secure the connection.	
3	Connect a wire to the opposite terminal of the light bulb socket. Again tighten with a screwdriver and cover with a piece of electrical tape.	
4	Use electrical tape to connect the wire from the light bulb socket to the RED wire of the 9-volt battery cap. Next, use electrical tape to connect a wire to the BLACK wire of the 9-volt battery cap.	
5	Use electrical tape to connect the free wire of the battery cap to the free electrode.	
Test	Test your circuit by touching the two electrodes together. Record your test results in your Student Guide Planning Organizer.	

Part B: Student Self-Check Card



Appendix C: Levels 1 and 2 Student Guide Planning Organizer

Planning Organizer

Part A: Build an electric circuit that will be your water solution testing equipment

Build Your Electric Circuit Use **Part A: Student Procedure Card** to build your electric circuit. This will be your water solution testing equipment.
Test Your Electric Circuit **Directions**: Test your circuit by touching the two electrodes together. 1. If the bulb lights up, your circuit is working. 2. If it does not light up, check your wire connections to make sure they are all secure. Try again. **Check one:** ❏ Circuit worked on first try. ❏ Circuit didn't work at first. We fixed it, tested it again, and it worked.
Set up your circuit for solution testing **Directions:** Insert the electrodes into an empty cup to see how you will test your solutions. Your electrodes must not touch during testing.
Equipment Set-Up Drawing
Check your drawing using the **Self-Check Card** provided by your teacher. Correct your set-up as needed.
In one sentence, explain how electricity is flowing through your circuit.

↓

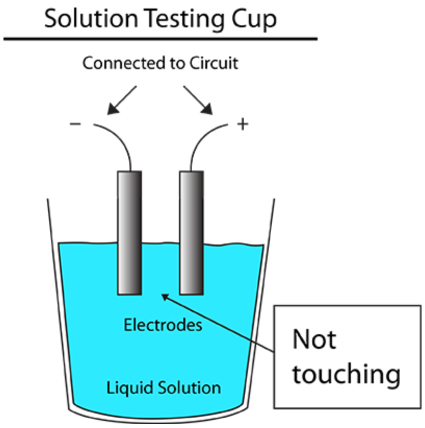
Part B: Test solutions using your electric circuit testing equipment

<u>Choose your Test Solutions</u>

Follow your teacher's directions to choose water and salt solutions for testing.

<u>Test Your Solutions to See Which Best Conducts Electricity</u>

1. Insert both electrodes in one test solution at a time.
    a. Make sure the electrodes do not touch each other.
    b. Wipe off electrodes with paper towel after each trial.
2. Observe the brightness of the light bulb.
3. Record observations below.



<u>Test #1</u>

Solution A: 300 ml of distilled water with 0 grams salt

Observations:

Light Brightness:

▢ No Light ▢ Very Dim ▢ Dim ▢ Bright ▢ Very Bright

Test #2

Solution D: 5 grams salt in 300 ml of water

Observations:

Light Brightness:

▢ No Light ▢ Very Dim ▢ Dim ▢ Bright ▢ Very Bright

Test #3

Solution G: 20 grams salt in 300 ml of water

Observations:

Light Brightness:

▢ No Light ▢ Very Dim ▢ Dim ▢ Bright ▢ Very Bright

Rank the Solutions from Dimmest to Brightest by Visual Observation

Brightness Rank	Grams of Salt
1 Highest	________ g
2 Medium	________ g
3 Lowest	________ g

Fill Out Three Post-Its

Show your results like this (fill in the blanks):

Rank #1	Rank #2	Rank #3
________ g salt	________ g salt	________ g salt

Add Data to Histogram

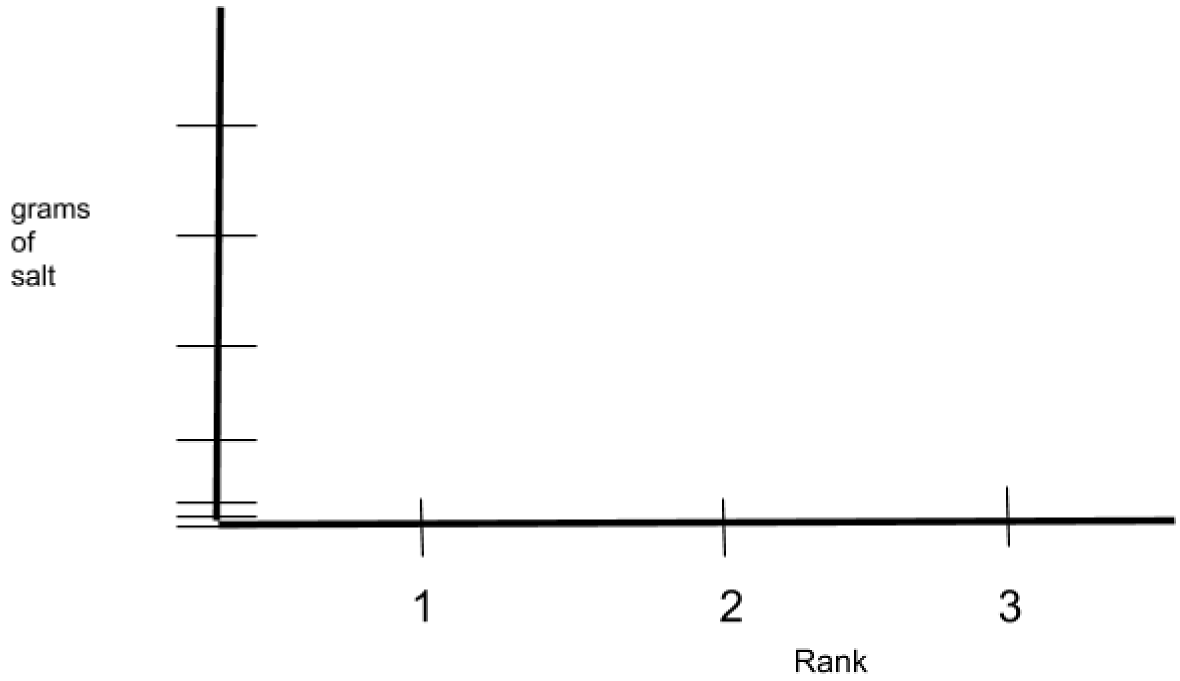
Follow your teacher's directions to put your team's Post-It on the class data histogram.

↓

Part C: Draw Conclusions

Analyze Class Data

Copy class Post-It histogram data below:



Results

As a group, answer these questions.

Which solution is the MOST effective to conduct electricity for the brightest light?

Which solution is the LEAST effective to conduct electricity for the brightest light?

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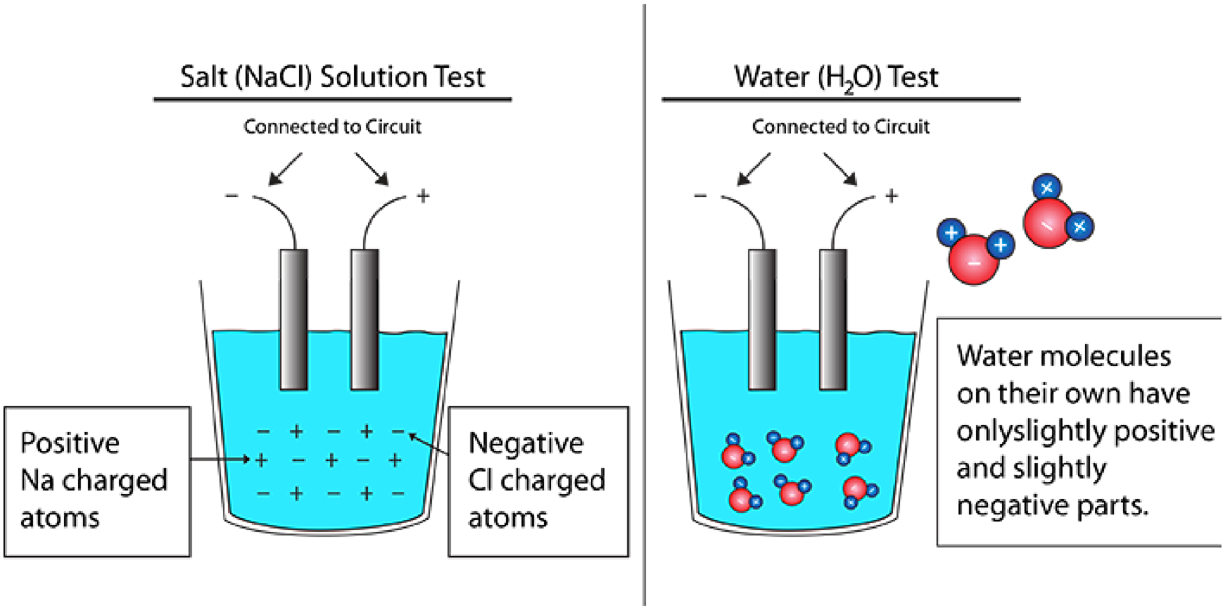
Salt vs. Water to Conduct Electricity

When salt goes into water, it breaks down into positively-charged atoms and negatively-charged atoms.



As a group, explain which diagram shows the best liquid solution to conduct electricity. Why is it the best?

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Sketch your idea for the design of an electricity station with an electricity flow tank filled with the best liquid solution to conduct electricity.

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Work with your team to construct a full-color annotated diagram of an electricity station that has the best electricity flow tank.

Include in your diagram how the electricity flows out of the electricity station to the town so that it can be used in homes and businesses.