Lock It Up!

High School Integrated Chemistry and Physics

SCALE K-12
SCalable Asymmetric Lifecycle Engagement
Precollege Microelectronics Workforce Development

INSPIRE
Research Institute for Pre-College Engineering

PURDUE
UNIVERSITY

Cover Information

Unit Title:	Lock It Up!
Grade Level Range:	High School - Integrated Chemistry and Physics

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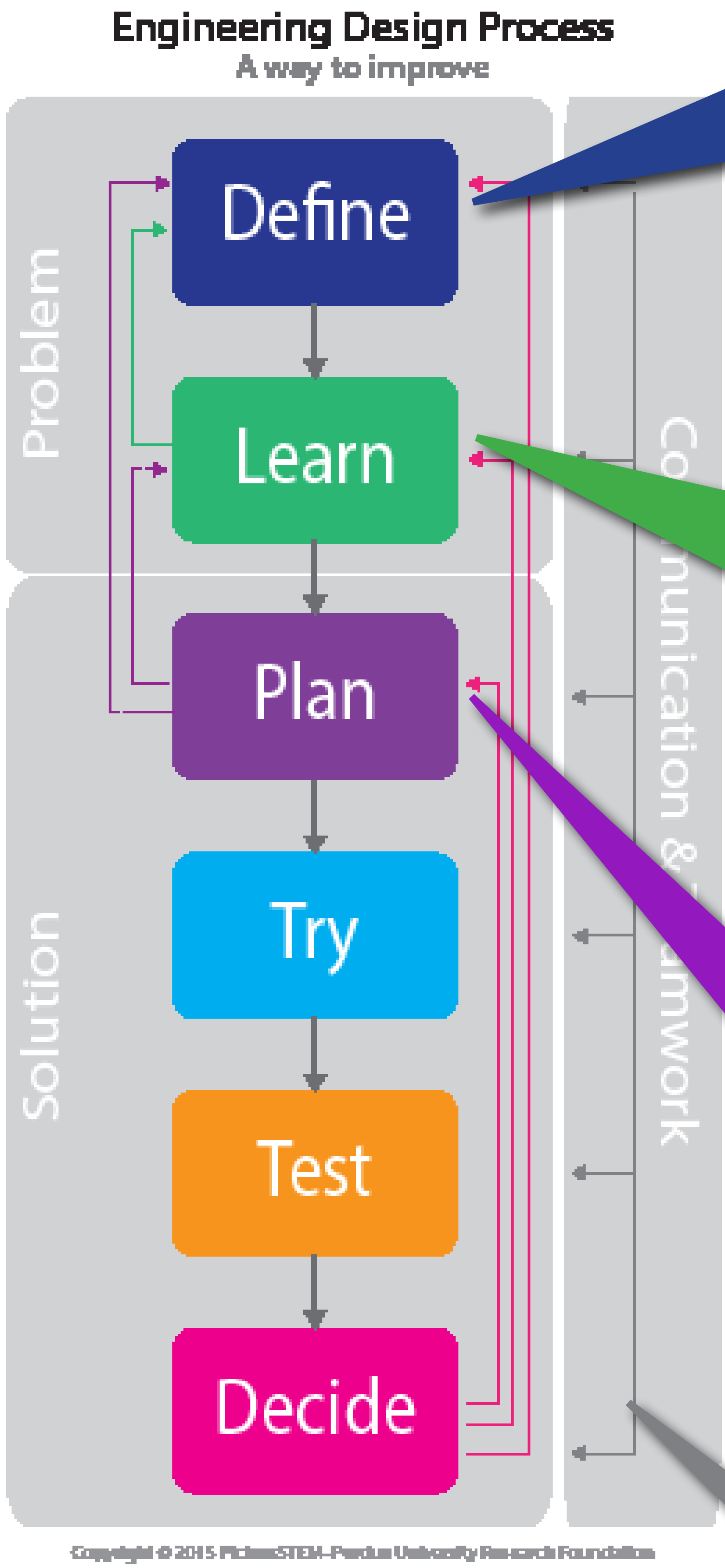
Overview: Engineering Design Process



DEFINE THE PROBLEM

- Who is the **client**?
- What does the client need?
- Why does the client need it?
- Who is the **end user**?
- Why might the end user want it?
- What are the **criteria** (requirements)and **constraints** (limits) of the solution?

Problem Scoping:
WHO needs **WHAT** because **WHY**

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
  - What science/math knowledge will be needed?
  - What materials will be needed?
- What has already been done to solve the problem?
- What products fill a similar need?
- How should we measure success and improvement?

PLAN A SOLUTION

- Continue to specify the criteria/ constraints
- Generate ideas of possible solutions
- Develop multiple solution paths
- Consider **constraints, criteria**, and **trade-offs** (criteria that compete with one another)
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages, etc.)

COMMUNICATION

- Communicate the solution clearly and make sure it is easily understandable
- Use **evidence** to support why the client should use your solution

Overview: Engineering Design Process

TRY A SOLUTION

- Put the plan into action
- Consider risks and how to optimize work
- Use criteria/constraints and consider trade-offs from the problem/plan to build a **prototype** (a testable representation of a solution), **model**, or **product**

TEST A SOLUTION

- Consider testable questions or hypotheses
- Develop experiments or rubrics to determine if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

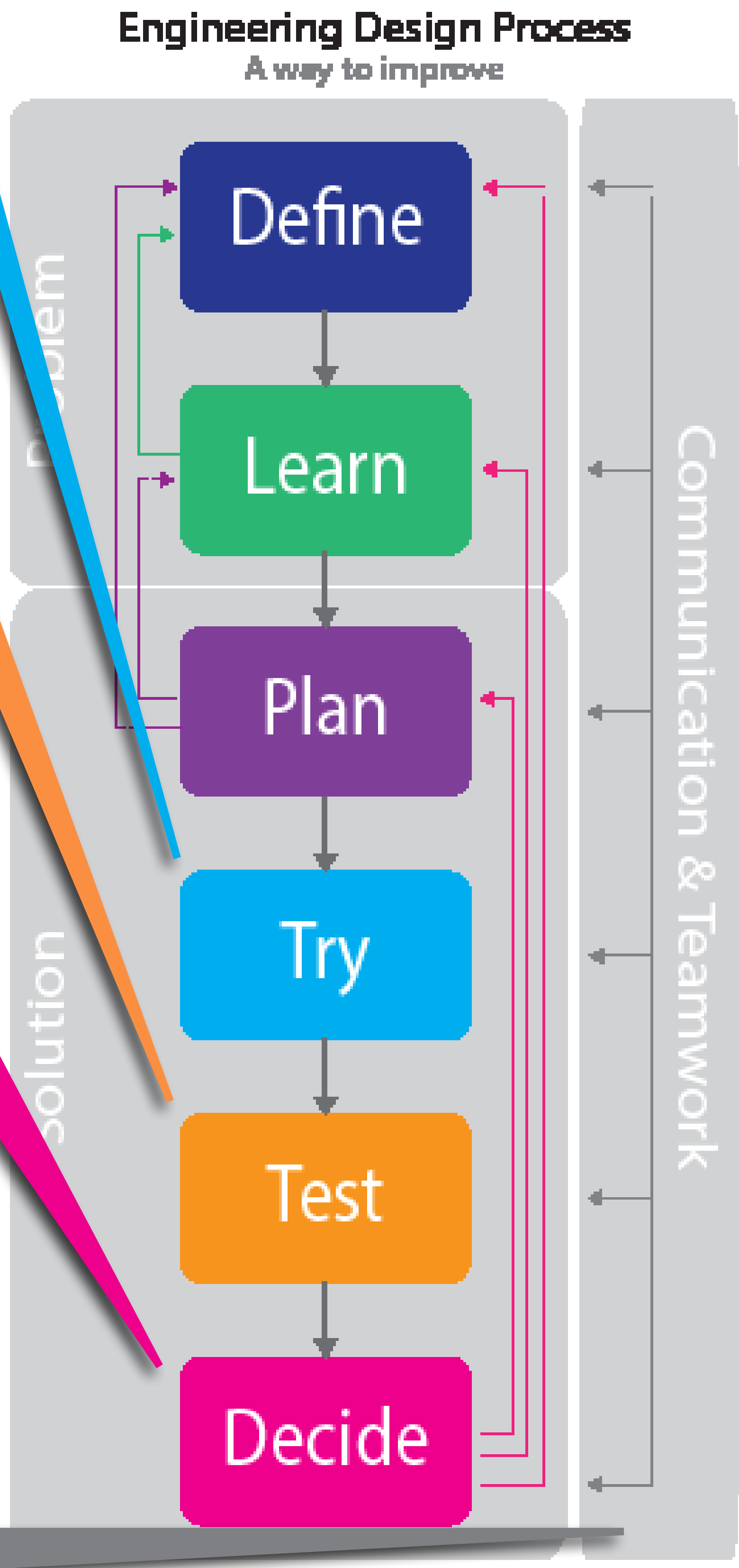
DECIDE IF THE SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does the design meet the criteria and constraints?
- How could the design be improved based on test results and feedback from the client/user?

Iterative nature of design: Always consider which step should be next!

TEAMWORK

- Discuss in teams how the solution meets the criteria and needs of the client
- Consider different viewpoints from each teammate



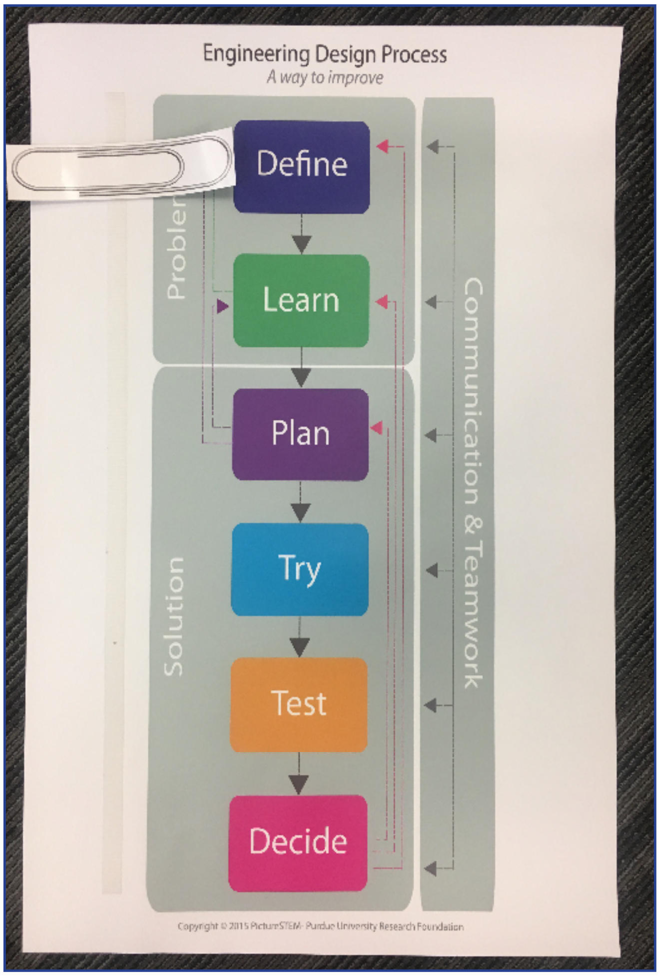
Overview: How to make EDP sliders

How to create the poster

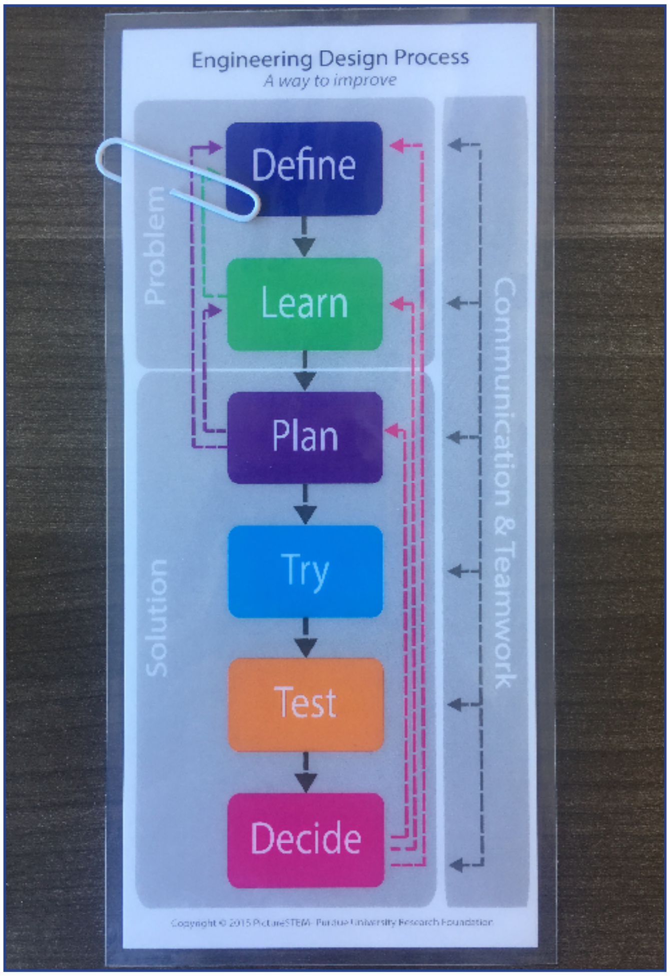
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the side of the poster so that the paper clip can be placed to point at all 6 sections of the slider.

How to create individual sliders

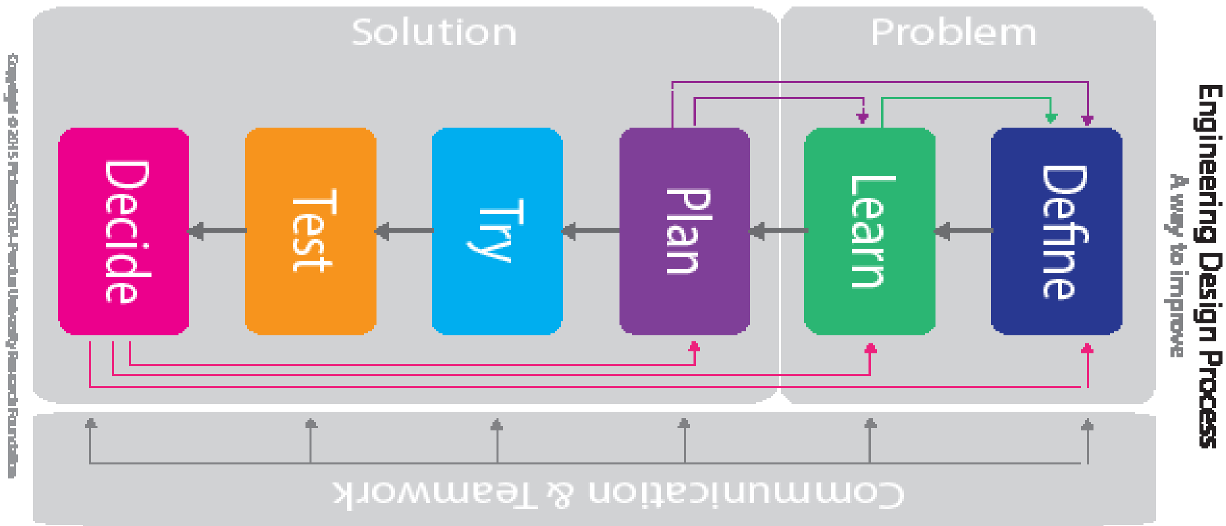
1. Print the sliders on the opposite page - enough for one slider per student in your class.
2. Cut the sliders apart.
3. Laminate the sliders individually.
4. Use a jumbo paper clip as the pointer for each slider.

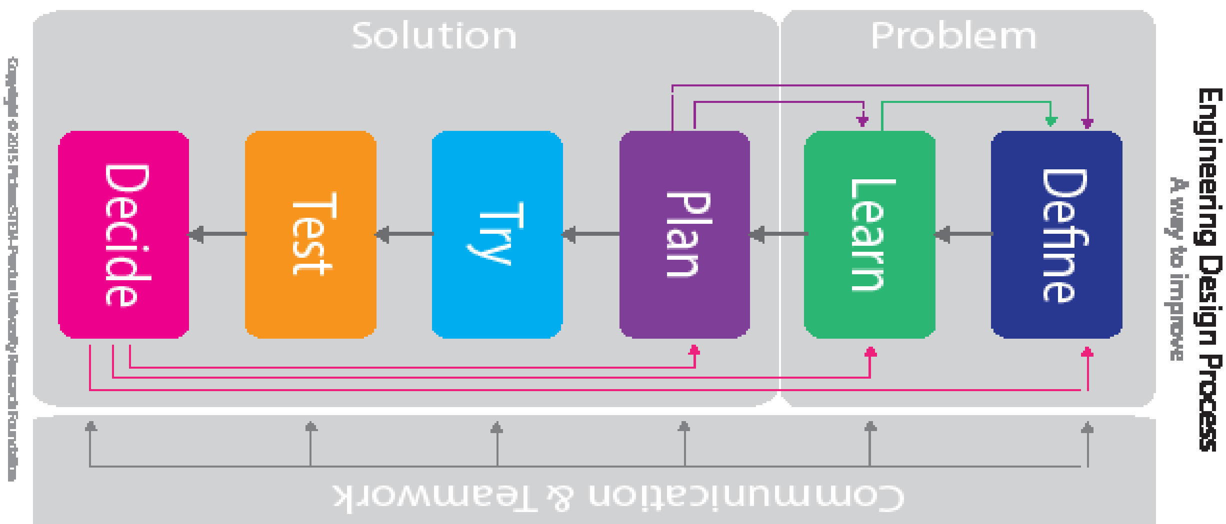


Poster



Individual slider


Engineering Design Process
A way to improve
Problem
Solution
Define
Learn
Plan
Try
Test
Decide
Communication & Teamwork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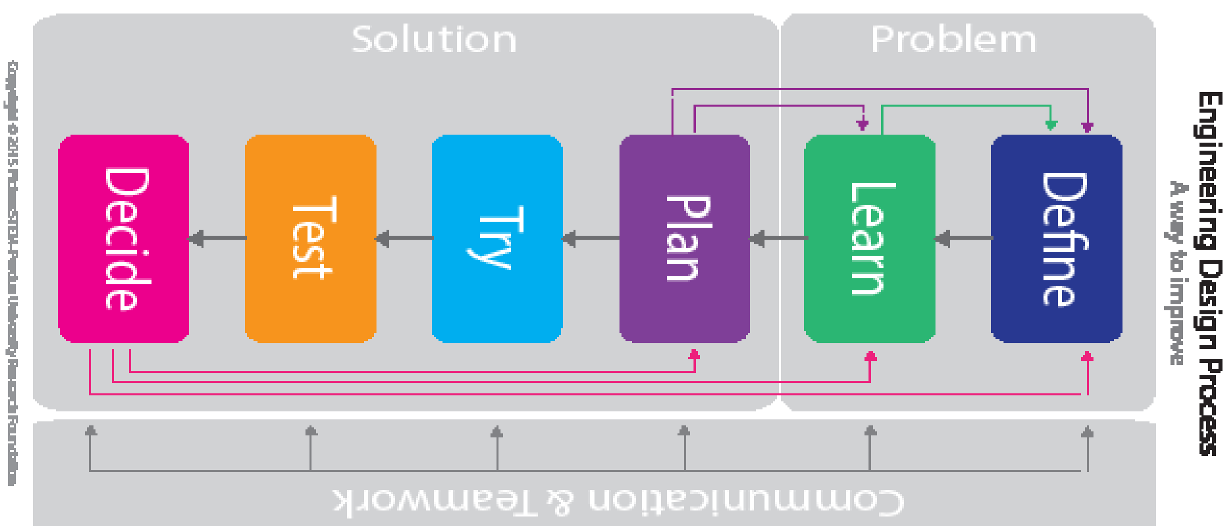
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A way to improve
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Unit Overview

Grade Levels: High School: Integrated Chemistry and Physics

Approximate Time Needed to Complete Unit: Three weeks

Unit Summary

In this unit students will use the engineering design process to develop an understanding of the fundamentals of electrical circuits and microelectronics. In a partnership with Security Everyone Can Use to Resist Espionage (SECURE) Inc. student teams have been asked to design a deterrent device that can be added as a modification to one of their existing carrying cases. Through the lessons students will learn about the engineering design process, what is electricity, types of circuits, the elements of a circuit, sensors, and microcontroller. They will also learn how to communicate technical information to an audience by presenting their design ideas to their peers.

Subject Connections

Science Connections	Technology and Engineering Connections	Mathematics Connections
Chemistry, Physics	Engineering Design Process, Microelectronics	Algebraic expression

Standards

2023 Indiana Academic Standards for Science: Integrated Chemistry and Physics

HS-ICP3-1: Quantitatively analyze various scenarios to describe how the change of energy in one component in a system responds to the change in energy of the other components and flow of energy into and out of the system are known.

HS-ICP3-2: Essential Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles objects).

HS-ICP3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-ICP3-4: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-ICP3-5: Gather data to build a model to describe and explain the flow of current through series and parallel electric circuits.

HS-ICP4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves

2023 Indiana Academic Standards: Science and Engineering Practices

SEP.2: Developing and using models.

SEP.5: Using mathematics and computational thinking.

SEP.6: Constructing explanations (for science) and designing solutions (for engineering).

Lesson Summaries

Lesson 1: Understanding the Assignment In this lesson, students will be introduced to the engineering design process (EDP). They will walk through each step and the concepts of each step. Implementing the first step (Define), students will be introduced to an engineering design challenge that focus on exploring the fundamentals of electronic circuits.

Lesson 2: Making the Connection: How Electrons Flow In this lesson, students will gain a fundamental understanding of the flow of electrical energy in a circuit. Through demonstration, students will review the concept of ions and charged atoms and see how they function to generate electrical energy.

Lesson 3A: Variables of the Flow: Ohm's Law and Series Circuits In this lesson, students will gain knowledge of basic circuitry by building and manipulating different types of series circuits. Building upon this understanding, students will sue this analyze their relations in circuits through Ohm's Law.

Lesson 3B: Variables of the Flow: Ohm's Law and Parallel Circuits In this lesson, students will continue to gain knowledge of basic circuitry by building and manipulating different types of parallel circuits. Building upon this understanding, students will analyze Ohm's Law in parallel circuits. Putting it all together, students will model and build some complex circuits.

Lesson 4: The Invisible Signals: What We Can and Cannot See In this lesson, students will learn about the electromagnetic spectrum (EMS) and how higher wavelengths equate to higher energy and more waves. They will learn about the applications of the EMS, including microwaves, radios, and x-ray machines. Students will each construct their own spectroscope to see the different colors within the visible range of the EMS.

Lesson 5: Microelectronics and Sensors Students will investigate the sensors used in different alarm systems. Students will visit stations with physical devices that mimic or demonstrate the capabilities of different detection and communication capabilities using a microcontroller and accessories. For each station, some aspect of the physical science principles behind the operation of the device will be displayed via a video and/ or graphic. Students experiment with the device to discover the constraints around operating such devices.

Depending on the class, more or less emphasis can be given to coding.

Lesson 6: Working Toward a Solution In this lesson, students will use their knowledge of electrical circuits and senor to design an electrical deterrent device for those trying to enter a secure carrying case. Students will work through the solution section of the engineering design process to plan, design, and test their design and utilize evidence-based reasoning to justify design decisions.

Lesson 7: Final Design Review In this lesson, students will evaluate their final design. They will develop a presentation to communicate their final product to the client. They will justify each choice for their design and they will share their prototypes with their classmates.

Unit Planner

Lesson	Time Needed	Objectives Students will be able to...	Duplication Master
1. Understanding the Assignment	One 50-minute lesson	• Describe the different stages in the Engineering Design Process (EDP). • Identify the engineering problem and the needs of the client.	• 1.A Content Pre-Assessment • 1.B Problem Scoping • 1.C Problem Scoping Solutions • 1.D Client Memo 1
2. Making the Connection: How Electrons Flow	One 50-minute lesson	• Understand how energy flows in an electrical circuit.	• 2.A Circuits through Electrochemistry • 2.B What is happening in the demonstration • 2.C Flow of Electrons in a Circuit
3A. Variables of the Flow: Ohm's Law and Series Circuits	Three 50-minute lessons	• Build a series circuit. • Sketch and explain a schematic diagrams for a series circuit. • Explain properties of a circuit in terms of voltage, current, and resistance. • Manipulate Ohm's Law to solve for voltage, current, and resistance. • (Optional) Apply Ohm's Law to the elements of a series circuit to analysis the circuit.	• 3A.A Series Circuits and Ohm's Law Engineering Notebook • 3A.B Ohm's Law • 3A.C Ohm's Law Answer Key • 3A.D Images for Lesson • 3A.E Voltage and Resistance Example
3B. Variables of the Flow: Ohm's Law and Parallel Circuits	Two 50-minute lessons	• Build a parallel circuit. • Sketch and explain schematic diagrams for a parallel circuit. • (Optional) Apply Ohm's Law to the elements of a parallel circuit to analyze the circuit.	• 3B.A Parallel Circuit and Ohm's Law Engineering Notebook • 3B.B Images for Lesson
4. The Invisible Signals: What We Can and Cannot See	One 50-minute lesson	• Identify the different wavelengths within the electromagnetic spectrum. • Identify how different waves within the spectrum affect their daily routine. • Associate visible light as part of the electromagnetic spectrum and that white light is composed of different wavelengths consisting of the different colors of the rainbow.	• 4.A Electromagnetic Spectrum • 4.B Spectroscope Instructions

Lesson	Time Needed	Objectives Students will be able to…	Duplication Master
5. Microelectronics and Sensors	Two 50-minute lessons	• Identify Microelectronics (ME), microcontrollers, and Sensors • Explore sensors through Sensor Stations • Relating ME sensors to the electromagnetic spectrum	• 5.A Station 1: Accelerometer Sensor • 5.B Station 2: Light Sensor • 5.C Station 3: Capacitive Touch Station • 5.D Station 4: Code Station, Option 1: Simple Code Puzzle Station • 5.E Station 4: Code Sheet • 5.F Station 5: Ultrasonic Proximity Sensor • 5.G Station 6: Bluetooth Simulation Station • 5.H Stations 7: Magnetometer Stations
6. Working Toward a Solution	Two-three 50-minute lessons	• Work toward the solution of a problem using engineering. • Develop and evaluate a plan acting as an engineer. • Describe the trade-offs of an engineered design. • Justify why their solution is appropriate.	• 6.A Client Memo 2 • 6.B Generating Ideas • 6.C Evidence-Based Reasoning Graphic • 6.D EBR Instructions • 6.E EBR Example • 6.F Collaborative Planning • 6.G Coding Components • 6.H Testing Procedure • 6.I Testing Reflection • 6.J Redesign
7. Final Design Review	Two 50-minute lessons	• Explain why their secure device solve the engineering design problem. • Communicate mastery of physics concepts and engineering ideas verbally to peers.	• 7.A Client Communication Guidelines for the Final Design Review • 7.B Presentation Rubric • 7.C Content Post-Assessment • 7.D Content Post-Assessment Key

Master Material List

	Unit Material List	Lessons Where Material is Used
Per Class	EDP Poster	1, 2, 3A, 3B, 4, 5, 6, 7
	White incandescent light bulb	4
	Red LED light	4
	Yellow LED light	4
	Green LED light	4
	Blue LED light	4
	(8) micro:bits with battery backs and batteries	5
	(2) ELECFREAKS IIC OLED Module	5
	(2) ELECFREAKS iot:bit for micro:bit	5
	ELECFREAKS Octopus Sonar:bit (Distance Sensor Ultrasonic)	5
	ELECFREAKS Octopus Light Sensor	5
	(2) EMF blocking Fabric Pieces ~.25 yards each	5
	(2) Ruler/tape measure	5
	8.5 X 11 piece of cardboard (approximate size)	5
	Flashlight	5
	Dark/heavy cloth	5
	Light colored/light cloth	5
	Paper cup	5
	Dark plastic cup	5
	Magnet	5
	Cellphone stand (optional)	5
	Multiple types of magnets (optional)	5

Master Material List

	Unit Material List	Lessons Where Material is Used
Per Group (assume two students per group)	600mL Deionized water 20g of sodium chloride (table salt) 20g of sucrose (sugar) 200mL of Vinegar Conductivity tester 15-watt, 110-120 V light bulb Support Stand (4) 400mL beakers (2) plastic spoons or glass stirring rods (2) beakers for 150mL of salt and sugar Paper towels Circuit Kit (2) AA batteries (2) AAA Batteries Exacto knife latex/nitrile gloves (2 pairs) fabric gloves (1 pair) micro:bit (8) alligator clips box (represents L series carrying case) Electrical Tape Clear Tape AAA battery holder magnet LED Light	2 2 2 2 2 2 2 2 2 2 2 3A, 3B 3A, 3B 3A, 3B, 6 4 5 5 6 6 6 6 6 6 6 6
Per Student	Engineering notebook EDP Slider and paperclip Laptop or equivalent device Scissors Black cardboard tube for crafts CD (or quarter/sixth of a CD) Black cardstock paper 65lb or greater Black electrical tape Clear tape	1, 2, 3A, 3B, 4, 5, 6, 7 1, 2, 3A, 3B, 4, 5, 6, 7 1, 3A, 3B, 5, 6, 7 4 4 4 4 4 4

LESSON ONE:

Lesson Objectives
Students will be able to:
- Describe the different stages in the Engineering Design Process (EDP).
- Identify the engineering problem and the needs of the client.

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Engineering notebook

Standards Addressed
IAS Science and Engineering Practices
- SEP.1, SEP.2, SEP.3

Key Terms
engineering design process, constraints, criteria

Lesson Summary

In this lesson, students will be introduced to the engineering design process (EDP). They will walk through each step and the concepts of each step. Implementing the first step (Define), students will be introduced to an engineering design challenge that focus on exploring the fundamentals of electronic circuits.

Background

Teacher Background

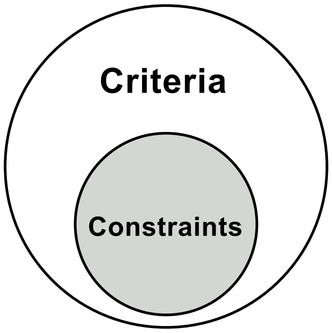
Teamwork: Students should be strategically assigned into groups. When forming student groups, consider academic, language, and social needs. In place of strategic grouping, a random grouping can be substituted. Students will work in these groups, or "teams" throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general; however, this unit does not provide specific support to develop those skills. If your students do not have experience with teamwork, it is highly recommended that you do some targeted team-building activities prior to beginning this unit.

Engineering Design Process: Students should have some familiarity with the engineering design process before beginning the unit. If they do not, the teacher will need to spend additional time explaining it, so this lesson may take more than one day. The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is not one scientific inquiry method. However, the various engineering design processes have similar components. *The **engineering design process** (EDP) is an iterative process that involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas.* Students will use an engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see the front matter section about it.

Some common misconceptions:
- Engineers do not have to learn anything new when they are working on a project. **In reality:** Engineers need to continually learn throughout their lives.

- The engineering design process is linear, and you never need to go back to previous phases. **In reality:** The EDP is a cyclical process that requires many iterations.
- Once engineers complete a project, they never think about it again. **In reality:** A project is never really "done," and engineers often continue to improve and make changes.

Criteria and Constraints: One difficulty students might have is distinguishing between criteria and constraints. ***Criteria*** *are the things required for a successful design, or goals of the designed solutions.* They help engineers decide whether the solution has solved the problem. Another way of thinking about criteria is that they are anything that the client and the engineers will use to judge the quality of a solution. ***Constraints*** *are a specific type of criteria; they are those criteria that limit design possibilities, or the ways that the problem can be solved.* If constraints are not met, the design solution is by default not a viable solution to the problem. The relationship between criteria and constraints is represented in the figure. It may be helpful to post the definitions with the figure somewhere in the classroom for future reference.



Cost is a common example of something that can be a criterion and a constraint. If the client requires engineers to stay within a specific budget, then this budget is a constraint. Any design solution that requires more money than the budget is automatically disqualified from being a quality solution. However, cost is also a relative criterion. Multiple design solutions that stay within the budget can be proposed. The costs of these solutions could be compared as one factor to determine which of the solutions is preferable.

Problem Scoping: In this lesson, students will be in the Problem Scoping section of the engineering design process, specifically on the define the problem step. Define the problem and learn about the problem combine to make Problem Scoping. In this stage, students will be first introduced to the engineering problem through a client letter and then be given a chance to ask questions to the client to receive more information about the problem. The problem statements given in the client memos purposefully do not provide all the information necessary to solve the problem. Students are tasked with generating questions about the problem to try to fill in

Assessments

Pre-Activity Assessment

Students will complete the 1.A Content Pre-Assessment.

Activity Embedded Assessment

Observe students' and teams' discussions and written responses to 1.B. Problem Scoping.

Duplication Masters

- 1.A Content Pre-Assessment
- 1.B Problem Scoping
- 1.D Client Memo 1

Educator Resources

- 1.C Problem Scoping Solutions
- EDP: https://www.youtube.com/watch?v=MAhpfFt_mWM

this missing information. Based on all information from the client, students will then define the problem in terms of: what the problem is and why it is important, who are the client and end users, what are the criteria and constraints, and what other information they may need to learn about in order to solve the problem. This process of generating ideas and questions for the client is an important skill on its own both in engineering and in other fields, but it also helps to ensure that the students fully understand the problem and their task in the engineering design challenge.

Solution Generation: The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration as a means to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints, and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering Notebook: Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook immediately in Lesson 1. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit. A number of worksheets are provided as duplication masters. If these worksheets are printed for students, they should be taped or stapled into their engineering notebooks so all of the unit information is stored within the notebooks.

Vocabulary: Students will be introduced to many new science and engineering vocabulary terms throughout the unit. It may be helpful to create a vocabulary section in their notebook with term definition and memory clue or picture. Additionally, the class could maintain a word wall.

Lesson 1 Vocabulary:

- **Engineering design process (EDP):** an iterative process that involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas.

- **Criteria:** the things required for a successful design, or goals of the designed solutions
- **Constraints:** a specific type of criteria; they are those criteria that limit design possibilities, or the ways that the problem can be solved.

Before the Activity

- Assemble the Engineering Design Process Sliders and post the EDP poster in the classroom (see the front matter for how to assemble them). If your students do not want to use the sliders, simply hanging the poster achieves the same result. Make sure you and your students can refer to the EDP sliders and/or poster throughout the unit.
- Determine student teams of two or four. These teams should be their teams throughout the rest of the unit.
- Download video so that it can be viewed and shared with students.
    - The Engineering Design Process: A Taco Party (3:37) https://www.youtube.com/watch?v=MAhpfFt_mWM
- Print and make copies (1 per student) of the following worksheets: 1.A Content Pre-Assessment, 1.B Problem Scoping, 1.D Client Memo 1

Classroom Instruction

Introduction

1. **Complete the pre-assessment activity.** Distribute copies of 1.A Content Pre-Assessment or prepare and have students respond to a digital version of the questions. Make sure to tell students that this is just to find out any prior knowledge they may have, so it is okay to not know the answers.
2. **Introduce the unit. Say:** *In this unit, we will be exploring the fundamentals of electronic circuits and the engineering design process by designing a device that will deter unwanted intruders using microelectronic devices.*
3. **Introduce the engineering notebooks. Say:** *As part of the design process, we will use an engineering notebook to document the design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the notebooks to take notes and what you are learning. In addition, there are questions that you'll be asked to answer. Sometimes you'll answer the questions first on your own, then in your teams. Each day, turn in your engineering notebooks before you leave class.*

NOTE: You can have your students write in their notebooks in two different colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This well help you assess the students' ideas as well as help them recognize their own contributions and ideas. You also may want to have students complete a Notebook Cover and start a Table of Contents page. You may choose to have students tape/glue copies of the notebook prompts and/or the duplication masters into their notebooks.

4. **Complete problem scoping section 1.**
   Have students individually answer the following prompts in Section 1 of the 1.B Problem Scoping handout in their notebooks prior to teaching them anything else about the unit or about engineering. **Say:** *Before we get started, you're going to respond to some prompts about engineers and what they do. It is okay if you do not know very much about engineers or engineering just answer the questions to the best of your ability.* Have them write their response in their engineering notebook, then discuss their answers with their neighbors. Have students share their responses with the class, and use students' responses to gauge their understanding of engineering and guide the following discussion. Encourage students to record new ideas in a different color in their notebooks.
5. **Form teams.** After students have finished responding to the prompts Say: We will start with a review of the engineering design process, and then look at a specific problem that will require the use of that process. Each of you will be working in small teams to solve a problem being brought to you by our client. Divide students into teams of 3 or 4.

Activity

6. **Introduce the Engineering Design Process.** Display the Engineering Design Process poster and pass out Engineering Design Process sliders to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. During this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.*
7. **Video on EDP. Say:** *To understand the engineering design process we will first watch a video on the engineering design process.* Play The Engineering Design Process: A Taco Party (3:37) https://www.youtube.com/watch?v=MAhpfFt_mWM
   NOTE: Video is from YouTube. Download video ahead of class

so that it can be viewed and shared with students.

8. **Briefly describe each step of the EDP.** See the front matter for explanations of the steps of the engineering design process. This can be carried out in different ways depending on students' knowledge of EDP and the needs of the students. Students could volunteer their ideas about the steps of the engineering design process and the teacher could guide the discussion, or the teacher could lead the discussion to explain the stages of the EDP.
9. **Introduce the client and the problem.** Hand out 1.D Client Memo 1. **Say:** *Now that we know about the engineering design process, we're going to see how this processes can be used to solve a real-world problem. Security Everyone Can Use to Resist Espionage (SECURE) Inc. is looking to partner with local high schools to help them engineer the design to their latest secure carrying case. To understand more about their problem, they provided us with a letter. While reading the client letter think about these questions: What problem are they asking us all to solve? What knowledge do we need to solve the problem?*

   NOTE: For ELL students or students who struggle with reading, a graphic organizer or other reading support strategy will be useful.

   NOTE: The community issue is context specific teachers can devise one or empower the students to devise their own. If students devise their own, a supplemental unit may be needed to help them do this.
10. **Complete problem scoping section 2.** After reading the letter, have students respond to the Section 2 prompt on the 1.B Problem Scoping worksheet. They can do this individually or in teams.
11. **Complete problem scoping section 3.** After students have completed the Section 2 prompt, direct students to Section 3 of 1.B Problem Scoping. Section 3 is structured to help students define the problem. The best way to implement is to have students first fill in the prompts individually, then discuss with their team and come to agreement. They may write their team response in a different color utensil to differentiate between how they answered on their own and how they answered as a team. **Say:** *You are going to fill out section 3 of the handout using the information you have acquired from the client letter. Remember that the client is the company who contacted us to do this work. The end users are the people who will use the product.*

Closure

12. **Identify where they are in the engineering design process. Ask:** *In relation to our design challenge, which phase of the engineering design process did we focus on today? Why is this important?* Have students move the paper clip on their Engineering Design Process slider to Define.
13. **Review problem scoping. Ask:** *What is the problem in our engineering challenge?*

Name______________________________________ Date______________ Period __________

1.A Content Pre-Assessment

1. **What is an electrical circuit?**

2. **What is the difference between strong and weak electrolytes?**

3. **What is Ohm's law?**

4. **Within the electromagnetic spectrum, what is the relationship between energy and wavelength?**

5. **What is a micro:bit?**

6. **What is a difference between a series and parallel circuit?**

Name____ Date_______________ Period __________

1.A Content Pre-Assessment

7. Sketch an example of a parallel circuit.

8. What does the term, "microelectronics" mean?

9. How are microelectronics used in the fields of chemistry and physics?

10. What jobs would you be interested in that use microelectronics?

11. Provide one example of how microelectronics is used in that job.

Name____ Date_______________ Period __________

1.B Problem Scoping

Section 1:

Directions: Please answer the following questions.

1. **What do engineers do?**

2. **How do engineers solve problems?**

Section 2:

Directions: Please answer this question after hearing about the engineering challenge.

1. **What questions do you want to ask the client?**

Section 3:

Directions: Please answer the following questions after you have been able to ask questions about the challenge.

First, on your own, complete each prompt. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

1. **The client is:**

2. **The client's problem is:**

Name____ Date_______________ Period __________

1.B Problem Scoping

3. The problem is important to solve because:

4. The end-users are:

5. An effective solution for the client will meet the following criteria:

6. The constraints (or the limits) of the solution are:

7. Think about the problem creating an electrical deterrent for the L series carrying case. In terms of circuit design and deterrent options, what are at least 2 things you need to learn in order to design an electrical modification to a carrying case that alarms when opened by an intruder? Make sure to consider all important aspects of the problem. Be specific.

1.C Problem Scoping Solutions

Section 1:

Directions: Please answer the following questions.

1. **What do engineers do?**

   Ex: Design products or processes to solve problems.

2. **How do engineers solve problems?**

   Ex: They use science and math knowledge, creativity, and the EDP.

Section 2:

Directions: Please answer this question after hearing about the engineering challenge.

1. **What questions do you want to ask the client?**

   Answers may vary.

Section 3:

Directions: Please answer the following questions after you have been able to ask questions about the challenge.

First, on your own, complete each prompt. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

1. **The client is: Security Everyone Can Use to Resist Espionage (SECURE) Inc.**

2. **The client's problem is: They would like to add additional security to the L series carrying case.**

1.C Problem Scoping Solutions

3. The problem is important to solve because: It would provide the customer with a way to know if anyone was trying to tamper with or got into their carrying case.

4. The end-users are: SECURE Inc customers interested in the carrying case with an alarm.

5. An effective solution for the client will meet the following criteria: Must be an electrical deterrent.

6. The constraints (or the limits) of the solution are: The electrical device must...
   - Fit into the L series model of the carrying case
   - Include one of the following deterrents (light, accelerometer, touch, or magnetometer alarm)
   - Include at least one parallel or series circuit
   - Include at least one load
   - Include at least one power supply
   - Work with a 3V power supply
   - Switch between an open and closed circuit

7. Think about the problem creating an electrical deterrent for the L series carrying case. In terms of circuit design and deterrent options, what are at least 2 things you need to learn in order to design an electrical modification to a carrying case that alarms when opened by an intruder? Make sure to consider all important aspects of the problem. Be specific.

   Answers may vary. Some potential questions may include:

   What are parallel and series circuits? Why do I need a 3V power supply? What is a load? How do these alarms work? How do I draw a schematic?

1.D Client Memo 1

Security Everyone Can Use to Resist Espionage (SECURE) Inc., Indiana Office
1500 Vault Way
Crane, Indiana

Hello Partners,

Security Everyone Can Use to Resist Espionage (SECURE) Inc. is a leader in the field of secure devices. We have two main sectors of the market. The first is our cybersecurity division that works on protecting important and vulnerable information stored on the networks of our customers. We actively monitor and prevent both internal and external threats. Our other sector is was what made SECURE Inc., it is what we were founded on, providing high quality secure carrying cases. Our durable cases are used to protect your most valuable possession, your cell phone and other small electronics to our nation's most valuable possessions. We design an array of carrying cases that can be customized to fit the needs of our customers.

This year, we are looking to add another product to our product line, and would like to partner with our local schools to bringing innovation to one of our carrying cases for small electronics. We would like your teams to help us design a carrying case that alarms when an intruder breaks into it. This carrying case will be a modification of our L series model. For this design modification, we have decided to add an electrical circuit to power a deterrent that is tripped the moment there has been a breach of the carrying case or an attempted breach. This modification will add an electrical system to this carrying case and that is why we would like to work with you. We know that your class is taking the curriculum needed to gain the electrical understanding to pull something like this off.

Using your knowledge of electrical systems, we would like for your team to develop a system that can meet the following design requirements:

The modification shall:
- Include one of the following deterrents (light, accelerometer, touch, or magnetometer alarm)
- Include least one parallel or series circuit
- Include at least one load
- Include at least one power supply
- Work with a 3V power supply
- Switch between an open and closed circuit.

In addition, we also need the following specification for your design.
- Evidence based documentation justifying your design decision
- The resistance in the circuit
- The current in the circuit
- A schematic of your circuit highlighting all of the components of your circuit

Once the design has been tested and all of the requirements have been met there will be design review where your team's modifications will be shared with the other groups in your class.

Sincerely,

India Scale

India Scale
R&D Design Lead
SECURE Inc.

LESSON TWO:

Lesson Objectives
Students will be able to:
- Understand how energy flows in an electrical circuit.

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster

Per group
- Deionized water
- Table Salt
- Sugar
- Vinegar
- Conductivity tester w/ light bulb
- Support Stand
- (4) 400 mL beakers
- (2) beakers for 150 mL of salt and sugar
- (2) plastic spoons or glass stirring rods

Per student
- EDP slider and paperclip
- Engineering notebook

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-1, HS-ICP3-2, HS-ICP3-3, HS-ICP3-4, HS-ICP3-5

Key Terms
circuits, current, resistance, voltage, energy, electrolytes (weak electrolytes and non-electrolytes), ions, energy transfer, conservation of energy, power, battery

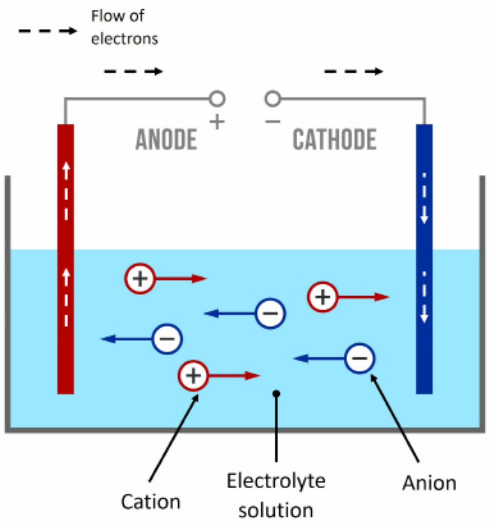
Lesson Summary
In this lesson, students will gain a fundamental understanding of the flow of electrical energy in a circuit. Through demonstration, students will review the concept of ions and charged atoms and see how they function to generate electrical energy.

Background
Teacher Background
Ions:
- In this lesson ions are a review subject. If your students do not have a fundamental understanding of this subject additional lessons may be needed prior to beginning this lesson.
- For review, ions are electrically charged atoms or molecules caused by an imbalance of electrons and protons. They can either be anions, negatively charged (more electrons than protons) or cations positively charged (more protons than electrons). They are created when there are free electrons in an atom's outer shell that move around until the electron's outer shells around an atom is balanced.
- In this lesson four solutions will be tested. Based on the level on conductivity of the solution, students will be able to determine if the solution is an electrolyte and determine its level. Is it a strong, weak, or a non-electrolyte.
    - Watch this video: https://www.youtube.com/watch?v=Pxegf2KKiuc&t=63s
    - Resource on conductivity of salt, vinegar, and sugar in aqueous solutions:
        - https://techiescientist.com/does-sugar-solution-conduct-electricity/
        - http://guweb2.gonzaga.edu/faculty/cronk/CHEM101pub/electrolyte.html
        - https://lecturedemos.chem.umass.edu/chemReactions4_6.html
    - Deionized water: H_2O
        - Does not have any ions
        - Non-electrolyte
    - Sodium chloride (salt) dissolved in water
        - Strong electrolyte
        - Salt is an ionic bond that breaks down in water creating positive and negative charges particles within the solution.
        - $NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$

Sodium Chloride Sodium ion Chlorine ion

- Vinegar (4-6% acetic acid dissolved in water):
  - Weak electrolyte
  - Ions are partially formed.
  - $HC_2H_3O_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2^-(aq)$
    Acetic acid Water hydronium ion acetate ion
- Sucrose (sugar) dissolved in water:
  - Covalent bond
  - Non-electrolyte
  - $C_{12}H_{22}O_{11}(s) \xrightarrow{H_2O} C_{12}H_{22}O_{11}(aq)$
    Sucrose Sucrose

Circuits:
The electrolyte lab introduces to the concept of an electrical circuits based on previous knowledge that the students have about ions. The electrolyte solution, a conductive solution due to its positive and negatively charged particles, creates an electrical circuit with the rest of the tester. It serves as the conductive connection between the electrodes, light bulb, and power supply. Students can visibly see the strength of the conductivity of the electrolyte because of the brightness of the light bulb. In this demonstration the light bulb is an electrical load in the circuit because electrical energy from the power supply is being transferred to thermal energy in the form of heat emitting light. Charged electrons are supplied to the circuit through the power supply. In this lab the power supply is the electrical socket, but it can also be a battery. Looking at the flow of electrons in the image below, electrons are moving from the power supply to the cathode to connect with the anions in the solution and the electrons from the cations in the solution are moving through the anode to the positive terminal of the power supply.

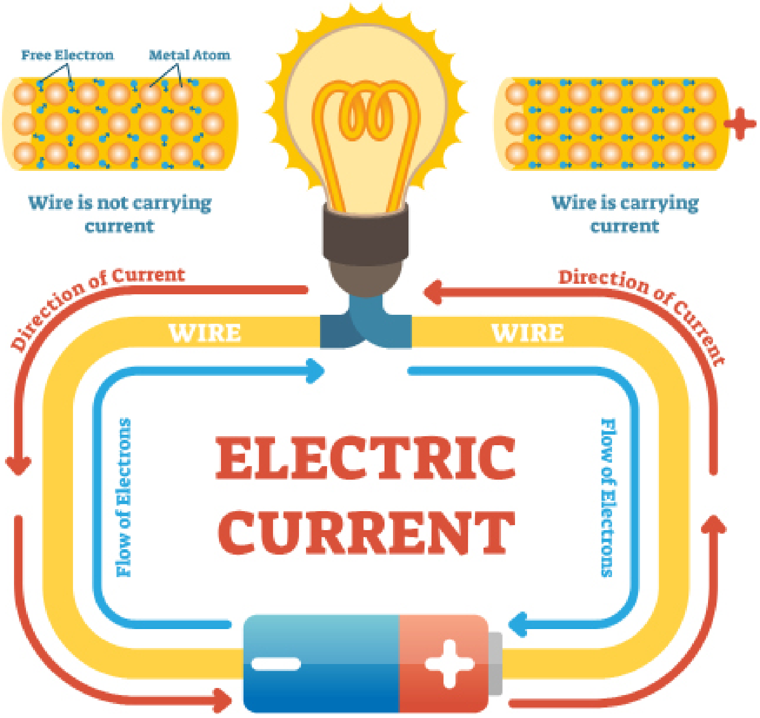


Assessments
Activity Embedded Assessment
Listen to group discussions as they work through 2.A Circuits through Electrochemistry.

Duplication Masters
- 2.A Circuits through Electrochemistry
- 2.B What is happening in the demonstration
- 2.C Flow of Electrons in a Circuit

Educator Resources
- https://www.youtube.com/watch?v=Pxegf2KKiuc&t=63s
- https://techiescientist.com/does-sugar-solution-conduct-electricity/
- http://guweb2.gonzaga.edu/faculty/cronk/CHEM101pub/electrolyte.html
- https://lecturedemos.chem.umass.edu/chemReactions4_6.html

Electrons in a Circuit:
Similar to the cations and anion in an electrolyte solution the free electrons in conductive material behave the same way. When an electrical charge is present the free electrons in the ions move from high potential to low potential creating electricity.



Vocabulary:

- **Circuit:** a closed path where electrons can flow due to a change in voltage potential creating electricity
- **Load:** a circuit device or component which converts electrical energy into another form (e.g., light)
- **Energy:** kinetic energy associated with electric charge
- **Ions:** electrically charged atoms or molecules
- **Strong electrolytes:** substances that dissolve in water completely or almost completely, forming ions. They are good conductors of electricity. Ionic compounds (including strong bases) and strong acids are strong electrolytes.
- **Weak electrolytes:** substances that dissolve in water, but do not completely ionize and therefore only weakly conduct electricity in solution
- **Non-electrolytes:** substances that dissolve in water, but have no ionized particles (except for impurities) and therefore have nearly no electrical conduction

Before the Activity

- Set up each lab space with conductivity tester on stand, 4 beakers, and stirring rods or plastic spoons.
- Have DI water, salt, and sugar available for the students to measure off of.
- Make copies of the duplication masters in the following amount:
  - 2.A Circuits through Electrochemistry (1 per student)
  - 2.B What is happening in the demonstration (1 per student)
  - 2.C Flow of Electrons in a Circuit (1 per student)

Classroom Instruction

Introduction

1. **Review the engineering challenge. Ask:** *What is our engineering design problem?* Students may need to revisit the original client letter to remind themselves of the engineering design challenge.
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the “Problem” block on the engineering design process and have students look at their Engineering Design Process sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.
3. **Identify what students need to learn about. Say:** *In the previous lesson, you brainstormed what we need to learn about.* **Ask:** *What were some of those concepts that we need to learn?* Remind students to refer to their notes from the previous lesson.

Activity

4. **Bridge knowledge activity. Say:** *In this class we have learned about ionic bonds and covalent bonds during our chemistry unit.* **Ask:** *As a review, what is an ionic bond and what is a covalent bond? Specifically what happens to the electrons in the atom of those bonds?*
   a. This activity uses prior knowledge that students have about covalent and ionic bonds to introduce electrical circuits. (If students do not have this background, additional class periods many be needed if you would like to do this lab as part of this lesson)
   b. Through discussion, the definition of an ionic bond and a covalent bond should be shared.

5. **Introduction to circuits using electrochemistry. Say:** *Knowing what you know about ionic bonds we are now going to look at how ions are connected to circuits.*
   a. Break students up in groups and complete the lab using the 2.A Circuits through Electrochemistry handout
   b. Give students 20 mins to complete lab
6. **Connect knowledge (electrolytes to conductive surfaces). Say:** *In this lab we learned about electrolytes, how they are formed, and how ions, positive and negatively charged particles, loose within an aqueous solution, create electrical circuits. Let's dig deeper into what is happening.* Review Handout 2.B What is happening in the demonstration.
   a. Say: *Taking a step back. Electrons in the outer shell of an atom move freely between atoms. Ions are created when electrons within an atom move to another atom balancing its outer shell creating a positively or negatively charged atom due to the uneven count of protons (+) and electrons (-) with an atom.*
   b. Say: *Within an aqueous solution, the ions break apart into positively and negatively charged atoms. These atoms then interact with the positive and negative charged probe creating a chemical reaction as electron flow through the solution.*
   c. Say: *This reaction caused distilled water, a non-conductive solution, to become as conductive as most metal wire.*
7. **Connect knowledge (the whole circuit). Say:** *Now that we know what is going on within the electrolyte, let's look at the rest of the circuit.* Hand out or have each student draw in their engineering notebooks the 2.C Flow of Electrons in a Circuit image.
   a. Say: *In an electrical circuit, which is a closed loop for electrons to flow, electrons from a power supply, the voltage source (battery, power outlet, etc.), are transferred into the conductive body due to a change in potential within the circuit which caused electrons in that area to flow creating electricity.*
   b. Say: *This movement creates kinetic electrical energy. This energy can be used by the light bulb, the electrical load in this lab, to emit heat, causing light.*
   c. Say: *An electrical load is a circuit device or component that converts electrical energy into another form of energy*
   d. Ask: *In the lab the light bulb was an example of an electrical load what are some other examples of electrical load in a circuit?*

Closure

8. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us with the design challenge given to us from our partners, SECURE Safe? Why is it important that we know about electrical circuits?* **Say:** *As we add more to our understanding of electrical circuits, we will continue in the Learn stage next class.*

Name______________________________________ Date______________ Period __________

2.A Circuits through Electrochemistry

Review Terms

- **Ionic Bond:** a bond that forms when the valence (outermost) electrons of one atom move to another atom. The atom that loses the electrons becomes a positively charged ion (cation), while the one that gains an electron becomes a negatively charged ion (anion).
- **Covalent Bond:** a bond that forms when valence electrons are shared between two atoms.

Vocabulary

- **Strong electrolytes:** substances that dissolve in water completely or almost completely, forming ions. They are good conductors of electricity. Ionic compounds (including strong bases) and strong acids are strong electrolytes.
- **Weak electrolytes:** substances that dissolve in water, but do not completely ionize and therefore only weakly conduct electricity in solution
- **Non-electrolytes:** substances that dissolve in water, but have no ionized particles (except for impurities) and therefore have nearly no electrical conduction

Materials

- conductivity tester
- 15 watt, 110-120 V light bulb
- support stand for conductivity tester
- (4) 400 mL beakers
- (2) beakers for 150 mL of salt and sugar
- 600 mL deionized water
- 20 g of sodium chloride (salt) about 150 mL in a beaker
- 20 g of sucrose (sugar) about 150 mL in a beaker
- 200 mL vinegar
- (2) plastic spoons or glass stirring rods
- paper towels

Safety:

Be sure not to touch the electrodes of the conductivity apparatus while plugged in.

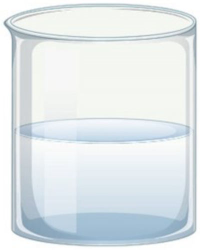
Procedure

1. Setup conductivity meter (power outlets required). Attach conductivity meter to support stand and plug it in to outlet. Conductivity tester should be able to move up and down support stand.
2. Prepare solution in beakers and add labels.
   A. 200 mL deionized (DI) water
   B. 20 g of sodium chloride (salt) + 200 mL DI water
   C. 20 g sucrose (sugar) + 200 mL DI water
   D. 200 mL vinegar (4-6% acetic acid dissolved in water)
3. Lower the electrodes of the conductivity tester into solution (A) deionized water.
4. Note the intensity of the light connected to the meter.
5. Remove the conductivity tester from the solution.
6. Turn off power to the tester or unplug it.
7. Identify what type of electrolyte the solution is.

Name______________________________________ Date_______________ Period __________

2.A Circuits through Electrochemistry

8. Dip the electrodes in the DI water to clean them.
9. Wipe down electrodes with paper towels.
10. Turn on conductivity tester.
11. Repeat steps 3-10 replacing solution (A) with (B), (C), and (D).
12. Once the lab is complete, turn off the conductivity tester.

A  B  C  D 

Brightness of light

__________________ __________________ __________________ __________________

Type of electrolyte

__________________ __________________ __________________ __________________

Discussion

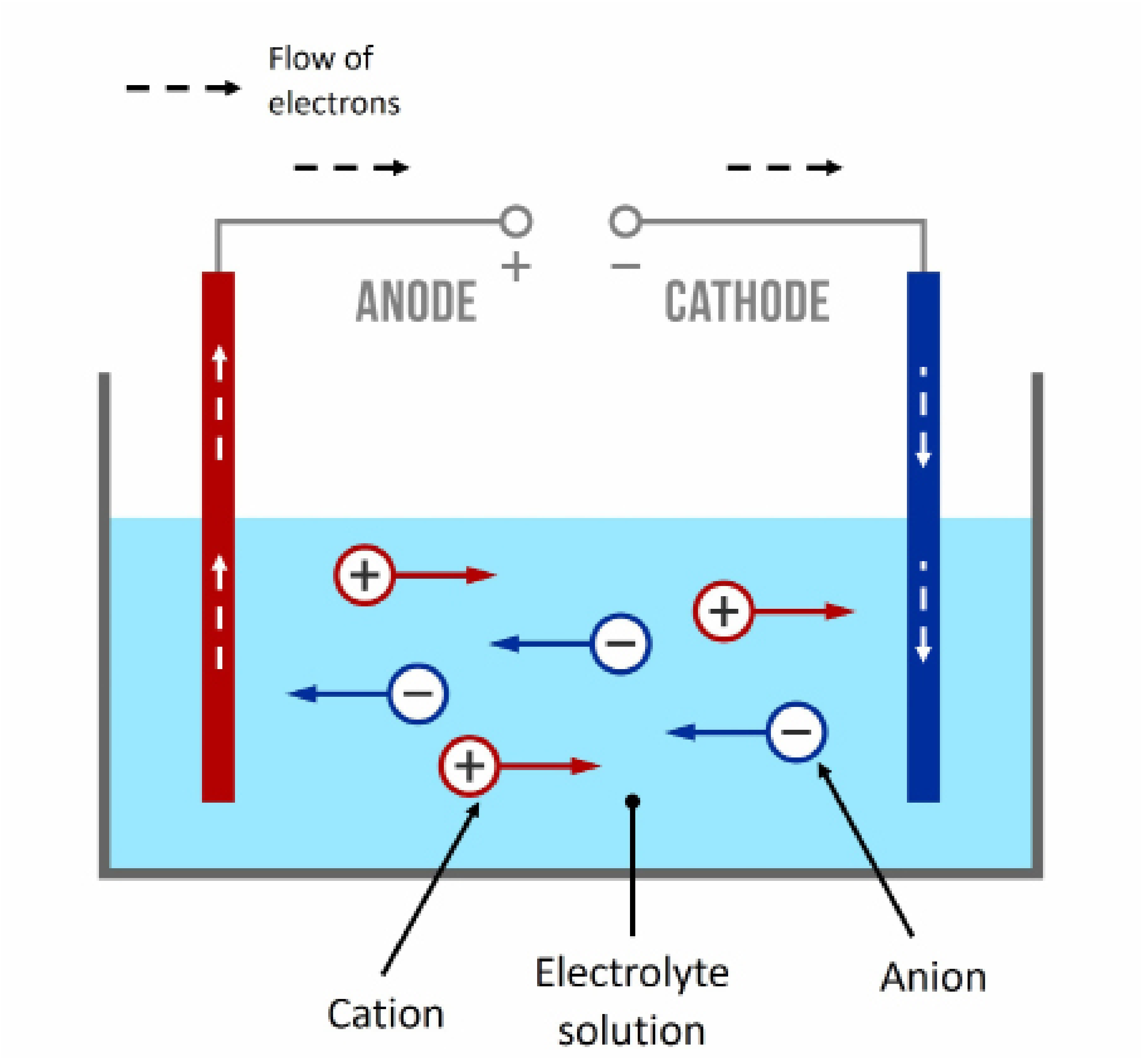
1. What were some of your observations?

References

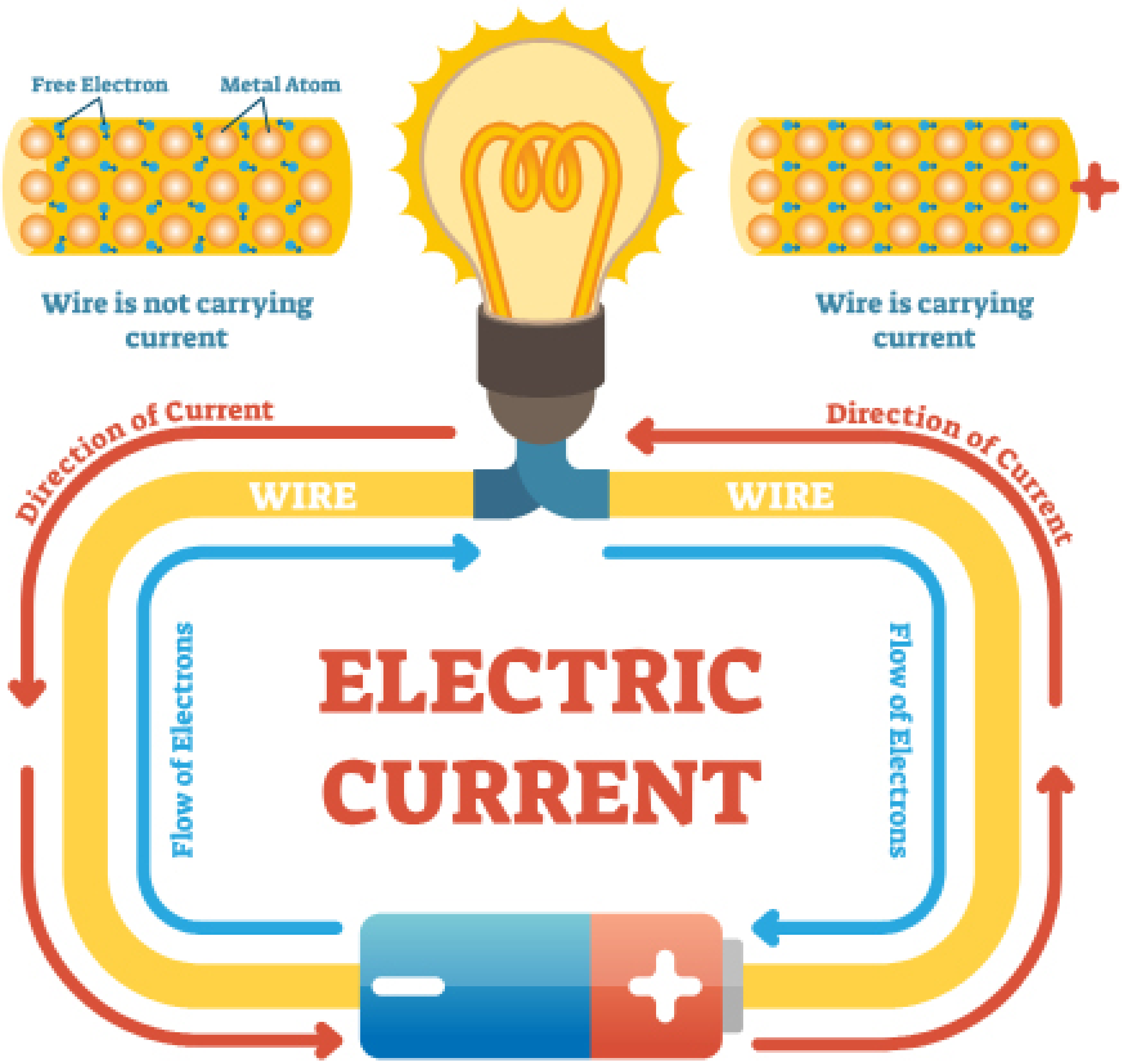
https://lecturedemos.chem.umass.edu/chemReactions4_6.html
https://cider.uoregon.edu/group/conductivity-testing-strong-electrolytes-and-non-electrolytes-presentation#

2.B What is happening in the demonstration

Electrical current is conducted through charged atoms called ions due to the movement of electrons. The ions can be positively or negatively charged due to an excess or a reduction of electrons in an atom.



2.C Flow of Electrons in a Circuit



LESSON THREE A:

Lesson Objectives
Students will be able to:
- Build a series circuit.
- Sketch and explain a schematic diagrams for a series circuit.
- Explain properties of a circuit in terms of voltage, current, and resistance.
- Manipulate Ohm's Law to solve for voltage, current, and resistance.
- (Optional) Apply Ohm's Law to the elements of a series circuit to analysis the circuit.

Time Required
Three 50-minute lessons

Materials
Per classroom
- EDP Poster

Per group
- 1 Circuit Kit (2 single AA battery holders, two light bulb holders, 1 switch, 6 cables, at least 2 light bulbs)
- 2 AA Batteries

Per student
- Engineering notebook
- Laptop or equivalent device

Key Terms
series circuit, limiting resistors, circuit schematic diagram, circuit schematic symbols, open circuit vs closed circuit, ohm's law, voltage, ampere, resistance

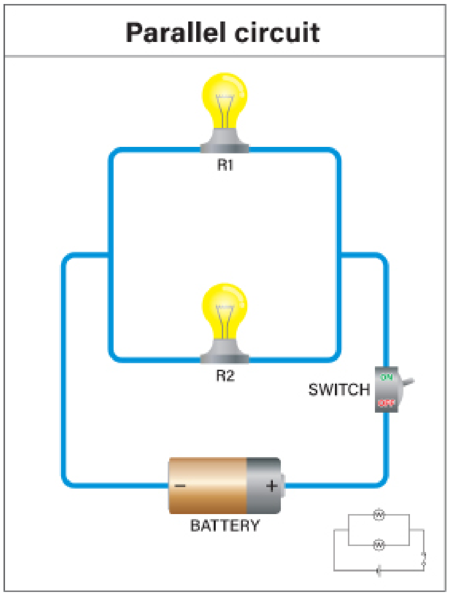
Lesson Summary

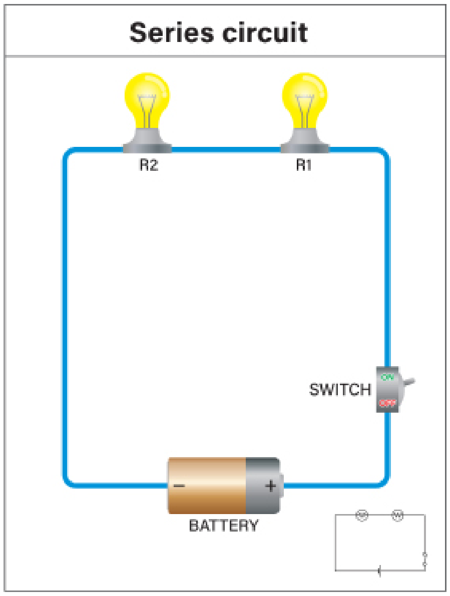
In this lesson, students will gain knowledge of basic circuitry by building and manipulating different types of series circuits. They will learn about the elements of a circuit, voltage, current, and resistance, and their relationship to each other through Ohm's Law. Building upon this understanding, students will analyze Ohm's Law in series circuits.

Background

Teacher Background

Circuits: In the last lesson we learned that a circuit was any complete path in which electrons can flow. Devices can be arranged in series or in parallel in a circuit. If they arranged in series that portion of the circuit is connected in a row and the current is the same through all devices. If they are arranged in parallel the devices are connected at two points and there is an alternative path for current to flow.





Series Circuit: A **series circuit** is a closed circuit in which the electrical charge flows in one single path, devices are arranged so that the charge flows through each sequentially. If the electrical flow is stopped in one part of the circuit, it will stop throughout the circuit.

This means that if any part of the circuit is disconnected the circuit is broken and the electrical flow stop.

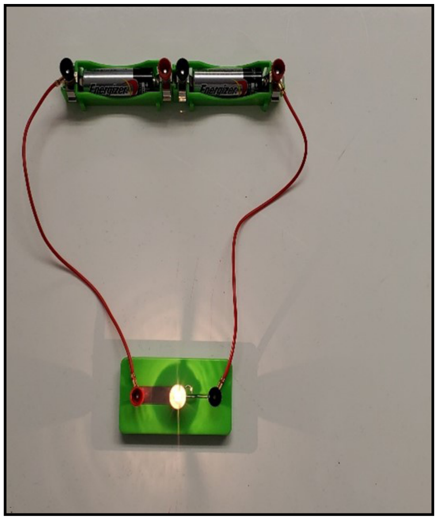
Examples of series circuits include light bulbs that go out when one light is bad and a flashlight.

Parallel Circuit: A **parallel circuit** is a closed circuit in which the current divides into two or more paths before recombining to complete the circuit. Each load connected in a separate path receives full voltage and the total circuit current is equal to the sum of the individual branch current.
Examples of parallel circuit include the power in a house and the electrical controls in a car.

Resistors and incandescent light bulbs: A resistor is something that slows down the electrical flow within a circuit, during this time electrical energy is transformed to heat energy. This is why a resistor heats up in a circuit. The same is true with a light bulb as the electrons flow through the filament of the light bulb, the electrons are slowed down transformed to heat energy and the heat emits light. In this lesson even though a light bulb is not a resistor it behaves like a resistor and can be treated like a resistor in calculations.

In this lesson:

Circuit 1 (2 AA batteries, 2 wire, and a light bulb): The light bulb is the only device in the circuit providing resistance. An assumption is that the wire does not have any resistance. In this case the light bulb will shine bright because there is no other resistance in the circuit making the current equivalent to the 3V provided by the light bulb and the resistance due to the light bulb.



Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-1, HS-ICP3-2, HS-ICP3-3, HS-ICP3-4, HS-ICP3-5

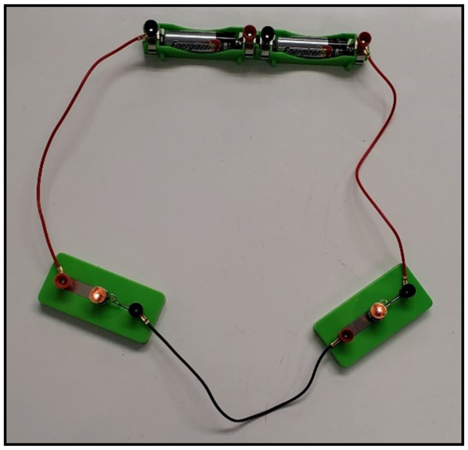
IAS Science and Engineering Practices
- SEP.5

Assessments
Activity Embedded Assessment
Listen to group discussions and look at student work as they work through and complete 3A.A Series Circuit and Ohm's Law Engineering Notebook, 3A.B Ohm's Law, and 3A.E Voltage and Resistance Examples. Ask students to share their responses with other groups and the class.

Duplication Masters
- 3A.A Series Circuits and Ohm's Law Engineering Notebook
- 3A.B Ohm's Law
- 3A.E Voltage and Resistance Example

Educator Resources
- 3A.C Ohm's Law Answer Key
- 3A.D Images for Lesson
- Circuit Elements: https://www.youtube.com/watch?v=m75jvmtVyVY
- Current: https://www.youtube.com/watch?v=HXOok3mfML Mwater

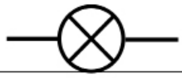
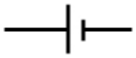
Circuit 2 (2 AA batteries, 3 wire, and 2 light bulbs): There are two light bulbs providing resistance in this circuit. In this case the light will be about half as bright because there is less current or electrons flowing through the circuit. The voltage stayed the same in the circuit, but the resistance was doubled (the light bulbs have the same resistance). Since the current remains the same in a series circuit across all devices as resistance increases the current decreases.



If a third light bulb was added to the circuit it would be even more dim because more resistance was added to the circuit reducing the current in each device.

Incandescent light bulbs and the LEDs: Light-emitting diodes (LEDs) are becoming more and more popular as sources of light. They are starting to replace incandescent light bulbs in a lot of areas due to their size and capability to not use as much power. This is the reason why incandescent light bulbs and LEDs cannot be compared and used in a circuit the same way. One acts like a resistor while the other is a diode. A diode controls the flow of electrons in a circuit so that they can only flow one way. Due to this LEDs do not follow the traditional assumptions when working with Ohm's Law.

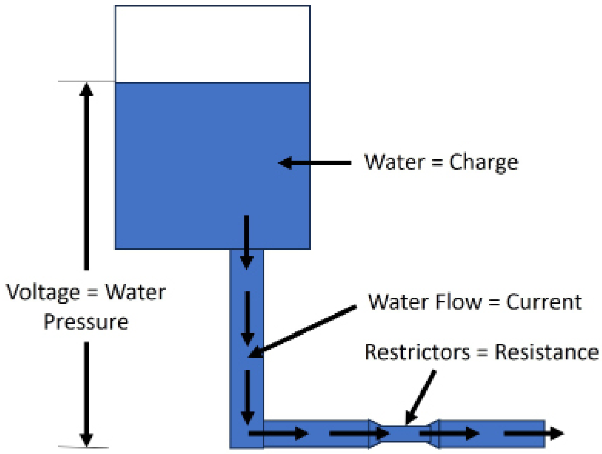
Schematic Circuit Diagram:

Component	Circuit Diagram Symbol
Wire	
Resistor	
Light Bulb	
Battery	
Switch	

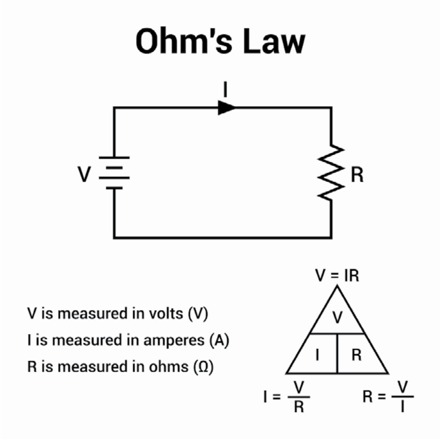
Elements of a Circuit

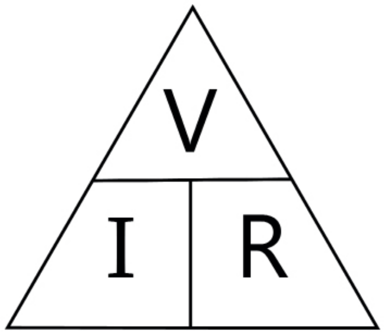
Voltage, Current, and Resistance:
Technical Video - The Basics: Voltage, Current, and Resistance (7:41): https://www.youtube.com/watch?v=m75jvmtVyVY
Application Video- Electric Current: Crash Course Physics #28 (8:22): https://www.youtube.com/watch?v=HXOok3mfMLMwater

Water Analogy: It is usually hard for students to understand what is happening within a circuit, this analogy is a good way for students to visually understand what is happening in a circuit. In this analogy an electrical circuit is compared to water flowing through a pipe from tank. Water is often compared to electrical charge, the electrons moving in a circuit. Voltage, electrical potential difference, is compared to the water pressure within system pushing the flow of water. The flow of water at any given time is compared to current and the reduction or resistance within a pipe is compared to resistors.



Ohm's Law: Voltage = Current X Resistance or V=IR





Vocabulary:
- **Series circuit:** a closed loop in which the electrical charge flows in one single path, devices are arranged so that the charge flows through each sequentially.
- **Schematic circuit diagram:** a pictorial representation of a circuit that shows the main features of a circuit using circuit symbols
- **Open circuit:** occurs when there is a break in the circuit preventing electrical flow (current) therefore stopping the flow of electrons.
- **Close circuit:** occurs when there is a complete path in the circuit allowing electrons to flow(current) through the entire circuit.
- **Voltage:** the amount of potential energy given to electrons in a circuit to do work
- **Electric Current:** the flow of electrons or electric charge at a given point
- **Resistance:** the restriction of flow of electrons or charge in a circuit

Before the Activity
- Ensure each team has a complete circuit kt that has at least 2 AA battery holders, two light bulbs, two light bulb holders, and 6 wires. Remove the instruction sheet provided with the kit because it also outlines how to create a series and parallel circuit, activities the students will be doing in this lesson.
- Check that websites can be shared and viewed by students.
- Make copies of the duplication masters for the following amount
    - 3A.A Series Circuits Engineering Notebook (1 per student)
    - 3A.B Ohm’s Law (1 per student)
    - 3A.E Voltage and Resistance Examples (1 per student)
- Create a PowerPoint or some visual to share graphic with class.

Classroom Instruction
Introduction
1. **Review introduction of circuits from last lesson. Say:** *Last class we covered the introduction to electrical circuits.* **Ask:** *What were some of the areas that we covered?*
2. **Tie in the engineering problem. Ask:** *Looking back over what we have been asked to do by SECURE Safe,*
    a. *What is the problem we are trying to solve?*
    b. *Why did we need to learn about electrical flow and the conservation of electrons?*

c. *What else do we need to learn to solve our problem?* Lead students to talk about understanding circuits better and then let them know the purpose of the day.

3. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem and started to learn about electrical circuits in order to be able to develop a good design.* Point out the "Learn" block on the engineering design process and have students look at their Engineering Design Process sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* Students should identify that they are still in the "Learn" phase.

Activity

4. **Hands-on activity.** Have the students break up into groups of two and provide each group with a circuit kit. For each group have them remove the two battery holders, two AA batteries, 2 wires and a light bulb from their electrical circuit kits. **Say:** *As we continue in the "Learn" phase, let explore more about electrical circuits.* Hand out worksheet 3A.A Series Circuit and Ohm's Law Engineering Notebook. **Say:** *Before we go into our lesson on circuits let's cover some electrical safety. We will be working with AA Alkaline Batteries and for all the labs completed with this kit, we will be working with the batteries in series. To do this safely and to prevent short circuiting the batteries, connect the red terminal of one of the battery holders to the black terminal of the other battery holder.* Show class Image A from 3A.D for reference. **Say:** *To start off, with the supplies provided to each team create a circuit that will light up the light bulb. As you come up with your design take into account what we have discussed so far. Once you have your light bulb lit, answer Question 1 in Part 1A of your worksheet either on the worksheet or in your engineering notebook.* Once students are done with this activity, take some time for students to share their answers.
5. **Introduction to series circuits. Say:** *Thank you for sharing how a circuit works. Let's take a closer look at what you all did. Everyone got the light bulb to light up, in doing so, you created the first of two types of circuits, a series circuit.* Refer to Image B in 3A.D **Say:** *A **series circuit** is a closed loop in which the electrical charge flows in one single path, devices are arranged so that the charge flows through each sequentially. If the electrical flow is stopped in one part of the circuit, it will stop throughout the circuit.*

6. **Circuit schematic. Say:** *Now that you have created a circuit let's look at how electrical engineers communicate their circuit designs to others. This is done by creating a circuit schematic and using symbols as representation of features in a circuit.* Refer to Image C on Handout 3A.D. Walk through the different symbols and have the students draw the schematic symbols as well as a schematic of Circuit 1 in their engineering design notebooks in Part 1B of the 3A.A Series Circuit and Ohm's Law Engineering Notebook.
7. **Build a series circuit. Say:** *Let's explore more on series circuits. In your teams work through Part 1C of the worksheet until to get to open and closed circuits.*
   a. Once the teams complete Part 1, have the teams pair up with a team close to them and share their responses with each other.
8. **Introduction to open and closed circuits. Say:** *For one of your circuits, I asked each group to disconnect one of the light bulbs* **Ask:** *What happened?* They should respond, the light bulb when out **Say:** *This happened because we created an open circuit. An open circuit occurs when there is a break in the circuit preventing electrical flow therefore stopping the flow of electrons. This is the opposite of a closed circuit, a **close circuit** is when there is a complete path within the circuit allowing electrons to flow, therefore, allowing the flow of electricity.* **Ask:** *In our everyday life, what do we use to do something similar?* They might mention using a light switch. **Say:** *Just like we see in switches that we have around our home, switches are an electrical component in a circuit that either allow electricity to flow or prevent electrical flow by creating a break in the circuit.*
9. **Introduction to voltage, current. Say:** *Now that you have an idea of what a circuit is, have an understanding of a series circuit, and how to communicate its design, let's take the time to look deeper and understand the fundamentals of what is happening in a circuit. In the first lesson we learned that electricity is caused by the flow of electrons. So, what caused electrons to flow? And what is that flow called? That would be voltage and current.*
10. **Introduction of vocabulary. Say:** *To understand what is going on in a circuit let's put a name to some of the terms we have been using these last couple of lessons.* Show Image D on Handout 3A.D as a visual. Point them to Part 2 of worksheet 3A.A Series Circuit and Ohm's Law Engineering Notebook to fill out during the discussion.

a. **Say:** *The first is voltage. Voltage is the amount of potential energy given to electrons in a circuit to do work across a circuit. It is what drives the movement of electrons. It is represented by the letter V and its units are Volts represented by the letter V.*
   i. *What are some examples of voltage sources?*

b. **Say:** *The second is electric current. Current is the flow of electrons at a given point through a circuit. It is represented by the letter I and its units are Amperes/Amps represented by the letter A.*

c. **Say:** *Resistance is a term we have not used much in our discussion, but it is the cause of something that we have seen in our circuit activity.* **Ask:** *Between Circuit 1 and Circuit 2 what happened?* They should answer that the light got dimmer when more light bulbs were added **Say:** *This was due to resistance which is the hindrance of the flow of charge in a circuit. It is represented by the letter R and its units are Ohms which is represented by the Greek letter Ω.*
   i. *Most electronic devices that use power create resistance in a circuit. In our activity the light bulb created resistance within the circuit. In a schematic instead of placing a light bulb there the resistance sign can also go in its place.*
   ii. *To regulate current within circuit electrical devices, call resistors are used to control the resistance with a circuit.* Refer to Image E on Handout 3A.D as a visual.

d. Once you have completed going over the three elements of a circuit show Image F on Handout 3A.D as a visual

11. **Circuit analogy. Ask:** *Let look at this using something that we are all familiar with?* Let’s look at water in a storage tank. Refer to Image G on Handout 3A.D
    a. **Say:** *In this example, an electrical circuit is compared to water flowing through a pipe from tank.*
    b. **Say:** *In this image, water represents the free electron within a circuit, the electrical charge.*
    c. **Say:** *While the voltage, electrical potential, is compared to the water pressure within system pushing the water throughout the system due to the change in elevation of the tank.*
    d. **Say:** *The flow of water at any given time is in the system is compared to the current in a circuit*
    e. **Say:** *And any reduction or resistance within the pipe is compared to resistance.*
    f. **Say:** *So, within our circuit, the battery is providing the*

electrical potential within the circuit, the wires are full of ions, free electrons, that enable electrical charge or current to flow, and the light bulb provides resistance because the electrons do work to light up the light bulb restricting/ slowing down the flow of electron through the circuit.

g. Complete Handout 3A.E Voltage and Resistance Examples

12. **Introduction to Ohm's Law. Say:** *To make use of the elements we need to know how they are related to each other and how they are calculated in a circuit. For this, we have Ohm's Law, Voltage = Current * Resistance or the electrical potential of charge = the flow of electrons at a given point * the hindrance of that flow.*
    - **a. Say:** *The equation for Ohms law is written V=IR*
    - **b. Say:** *Let's look at the equation using a formula triangle.* Refer class to Image H on Handout 3A.D and demonstrate how you get the equations using this method
        - i. Note: V=IR is a model of the quantities and in real life we will see minor difference, but this generally very good model for understanding what happen in a circuit when you add or take away things.
    - **c. Say:** *Let's look at a couple of examples.*
        1. 6V= I x 24Ω
        2. V= 4A x 3Ω
        3. 150V = 20A x R
13. **Ohm's Law worksheet.**
    - a. Hand out worksheet 3A.B Ohm's Law
    - b. This worksheet is to get additional practice with Ohm's Law. Work within your teams to complete the worksheet.
14. **(Optional) Connection to circuit. Note:** If the teams have disassembled their circuits that they created on day one, have them use their schematic diagrams to recreate their circuits. **Say:** *Let's look at the circuits that we have created and let's see how Ohm's Law apply to a series circuit.* Refer to Image I on Handout 3A.D when explaining Ohm's Law rules for Series Circuit.
    - a. Series Circuit Rules when looking at Ohm's Law
        - i. Total voltage drop in a circuit equals the sum of the voltage drop within the circuit

$$V_{total}=I_{total}R_{total}= I_1 R_1+ I_2 R_2+ I_3 R_3+ I_n R_n=I(R_1+R_2+R_3+ R_n)$$

        - ii. Current is the same through every resistor in the circuit

$$I_{total}= I_1=I_2=I_3= I_n$$

        - iii. Voltage drop across each resistor decreases as more resistors are added

iv. The total resistance in the sum of all of the resistors in a circuit

$$R_{total} = R_1 + R_2 + R_3 + R_n$$

b. Do two examples in class

Closure

15. Connect the activity to the engineering design challenge. **Ask:** *What did we learn today that will help us with the design challenge given to us from our partners, SECURE Safe? Why is it important to understand Ohm's Law?* **Say:** *As we add more to our understanding of electrical circuits, we will continue in the Learn stage next class.*

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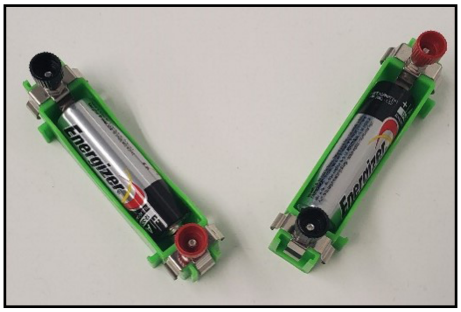
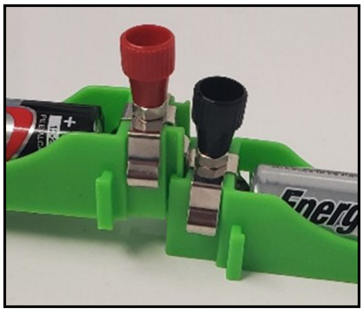
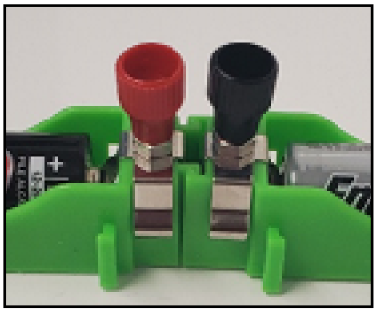
3A.A Series Circuits and Ohm's Law Engineering Notebook

Part 1. Series Circuit Activity

Material List
- **2 AA batteries,**
- **2 AA battery holder**
- **2 light bulbs**
- **1 switch**
- **6 wires**

Electrical safety
Place batteries in series for all circuit designs.

Proper setup to prevent short circuiting the batteries, connect the red terminal of one battery holders to the black terminal of the other battery holder.

A.

Question 1 Describe how the circuit works, label your voltage source, wires, and load in the circuit.	
Key words definition **Series Circuit** **Schematic Diagram**	

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3A.A Series Circuits and Ohm's Law Engineering Notebook

B.

Schematic Symbols	Draw Circuit Schematic Symbol
Wire	
Resistor	
Light Bulb	
Battery	
Switch	

C.

Circuit 1 Using the batteries, wires, and one light bulb from the kit create a circuit that will turn on the light bulb	**Draw Circuit Schematic**
Circuit 2 Using the batteries, wires, and two light bulbs, create a circuit that will turn on the light bulbs	**Draw Circuit Schematic**

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3A.A Series Circuits and Ohm's Law Engineering Notebook

Question 2 A. What did you observe between the circuits related to the brightness of the light bulbs? B. Why do you think this happened? C. What do you think will happen if a third light bulb was added?	
Circuit 3 Using the batteries, wires, and two light bulbs, add a switch to the circuit	**Draw Circuit Schematic**
Question 3 A. What happened to the circuit when you add and use a switch to the circuit? B. Does the location of the switch matter for it to work? Why?	
Question 4 A. Using the circuit you just created unscrew one of the light bulbs. What happened? B. What happens when you screw the light bulb back in?	
Key words definition **Open Circuit** **Close Circuit**	

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3A.A Series Circuits and Ohm’s Law Engineering Notebook

Part 2 Ohm’s Law

Key words with definition	Abbreviation	Unit of Measurement	Symbol
Voltage:			
Current:			
Resistance:			
Ohm’s Law **Voltage equation:** **Current equation:** **Resistance equation:**	**Notes:**		

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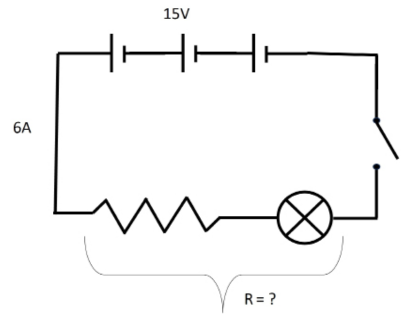
3A.B Ohm's Law

Ohm's Law Review

Part 1:

Do not solve the problems. For each question, list what variable you are solving for and the correct unit.

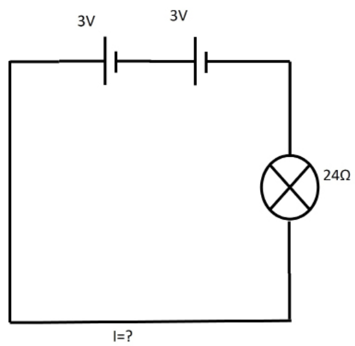
1. The voltage in a circuit is 15 V and the current flow is 6 Amps. Find the resistance of the circuit.



What are you solving for? ________________

What are the units? ________________

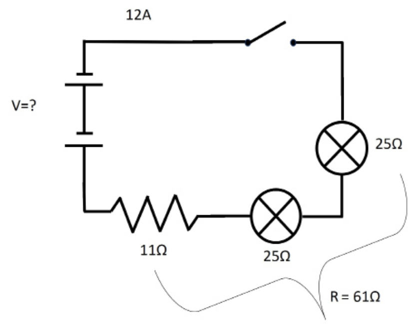
2. Find the current in a circuit that has a voltage of 6 Volts and a resistance of 24 Ohms.



What are you solving for? ________________

What are the units? ________________

3. The circuit has a current of 12 Amps and resistance of 61 Ohms. Find the voltage in the wire.



What are you solving for? ________________

What are the units? ________________

Part 2:

Visit website: https://phet.colorado.edu/sims/html/ohms-law/latest/ohms-law_all.html

This simulation shows what happens if the voltage or resistance is increased in a circuit. Using the simulation tool work through the following problems. For the resistance values try to get within + or - 5 ohms of the value that you are trying to get. Don't forget units.

Name_______________________________________ Date_______________ Period __________

3A.B Ohm's Law

Problem 1
Look at Circuit 1 and Circuit 2 from the Engineering Notebook worksheet on series circuits. If the resistance of the light bulb is 330 ohms what is the current in Circuit 1 and Circuit 2?

The total voltage =____________

The total resistance in Circuit 1 = _____________ The total resistance in Circuit 2 = ________________

What is the current in Circuit 1? ______________ What is the current in Circuit 2? ________________

Looking at these values explain why there was a difference in Circuit 1 and Circuit 2 brightness?

Problem 2
A video game controller needs 4 AA 1.5 Volts batteries to work. The total resistance in the video game controller is 500 Ohms. What is the current flowing in the controller?

The total voltage =____________

The total resistance from question = _____________ Resistance in simulation = ________________

What is the total current? ______________

Problem 3
You are using a micro:bit that runs on 3 Volts for a project. 187.5mA is the max current it can support before additional external power is needed. What is the maximum resistance the micro:bit can support?

The total voltage =____________

The max current? ______________

What is the max resistance? _____________

Part 3:

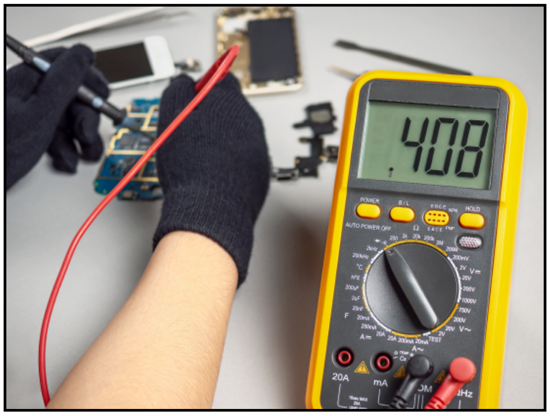
Visit website: https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html

Click on the Lab icon

This simulation allows you to build circuits virtually. Using tools like a voltmeter and ammeter this lab will allow you to use these measurement devices to find the voltage and current within the circuit.

Name____ Date________________ Period ___________

3A.B Ohm's Law



- Voltmeters are used to check the voltage across an electrical circuit
  - It is used by placing the probes, the red and black pointers, on either side of what you are trying to measure. If you want the voltage across the whole circuit you have to pick two points that include the whole circuit.
- Ammeter monitors the current through an electrical circuit
- Both are usually found together in a digital multimeter, a tool used to measure electrical properties with a circuit. (Shown in the image)

Problem 1
Using the simulation, create a circuit with two batteries, one light bulb, and a switch. Use the voltmeter to find the voltage in the circuit. Using the ammeter find the current in the circuit.

The total voltage =____________

Total current = _____________

Click on each battery and document the voltage of each battery.

Battery 1 = ______________ Volts

Battery 2 = ______________ Volts

Click on the light and document the resistance of the light bulb.

Light bulb = ______________ Ohms

Problem 2
Using the simulation, create a circuit with two batteries and one light bulb, and a resistor. Click on the battery to set each battery value to 12 Volts, the light bulb to set it to 10 Ohms, and the resistor to 15 Ohms. Use the voltmeter to find the voltage in the circuit. Using the ammeter find the current in the circuit.

The total voltage =____________

Total current = _____________

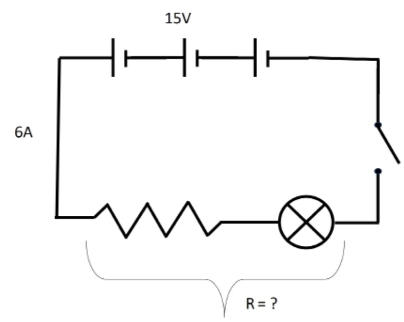
3A.C Ohm's Law Answer Key

Ohm's Law Review

Part 1:

Do not solve the problems. For each question, list what variable you are solving for and the correct unit.

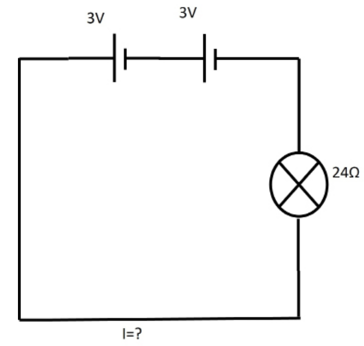
1. The voltage in a circuit is 15 V and the current flow is 6 Amps. Find the resistance of the circuit.



What are you solving for? Resistance

What are the units? Ohms

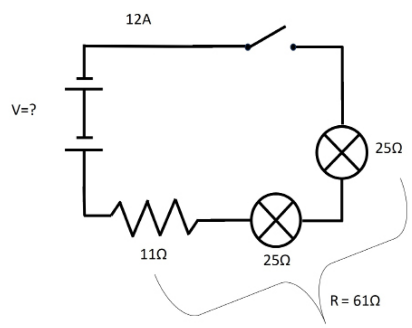
2. Find the current in a circuit that has a voltage of 6 Volts and a resistance of 24 Ohms.



What are you solving for? Current

What are the units? Amps

3. The circuit has a current of 12 Amps and resistance of 61 Ohms. Find the voltage in the wire.



What are you solving for? Voltage

What are the units? Volts

Part 2:

Visit website: https://phet.colorado.edu/sims/html/ohms-law/latest/ohms-law_all.html

This simulation shows what happens if the voltage or resistance is increased in a circuit. Using the simulation tool work through the following problems. For the resistance values try to get within + or - 5 ohms of the value that you are trying to get. Don't forget units.

3A.C Ohm's Law Answer Key

Problem 1
Look at Circuit 1 and Circuit 2 from the Engineering Notebook worksheet on series circuits. If the resistance of the light bulb is 330 ohms what is the current in Circuit 1 and Circuit 2?

The total voltage = 3V

The total resistance in Circuit 1 = 330Ω The total resistance in Circuit 2 = 660Ω

What is the current in Circuit 1? 9.1mA What is the current in Circuit 2? 4.6mA

Looking at these values explain why there was a difference in Circuit 1 and Circuit 2 brightness?

As more resistance is added to the circuit the current is reduced, decreasing the brightness of the light bulbs.

Problem 2
A video game controller needs 4 AA 1.5 Volts batteries to work. The total resistance in the video game controller is 500 Ohms. What is the current flowing in the controller?

The total voltage = 6V

The total resistance from question = 500Ω Resistance in simulation = 500Ω

What is the total current? 6mA

Problem 3
You are using a micro:bit that runs on 3 Volts for a project. 187.5mA is the max current it can support before additional external power is needed. What is the maximum resistance the micro:bit can support?

The total voltage = 3V

The max current? 187.5mA

What is the max resistance? Between 11 - 21mA

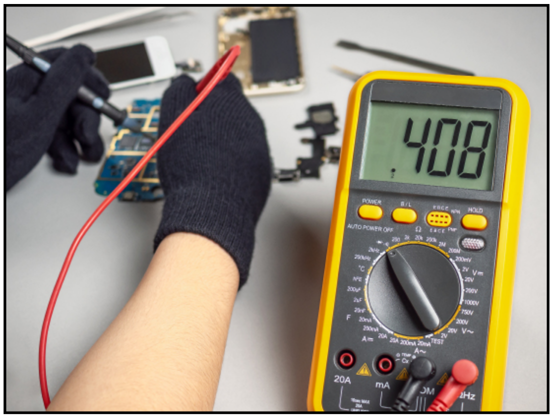
Part 3:

Visit website: https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html

Click on the Lab icon

This simulation allows you to build circuits virtually. Using tools like a voltmeter and ammeter this lab will allow you to use these measurement devices to find the voltage and current within the circuit.

3A.C Ohm's Law Answer Key



- Voltmeters are used to check the voltage across an electrical circuit
  - It is used by placing the probes, the red and black pointers, on either side of what you are trying to measure. If you want the voltage across the whole circuit you have to pick two points that include the whole circuit.
- Ammeter monitors the current through an electrical circuit
- Both are usually found together in a digital multimeter, a tool used to measure electrical properties with a circuit. (Shown in the image)

Problem 1
Using the simulation, create a circuit with two batteries, one light bulb, and a switch. Use the voltmeter to find the voltage in the circuit. Using the ammeter find the current in the circuit.

The total voltage = 18V

Total current = 1.80A

Click on each battery and document the voltage of each battery.

Battery 1 = 9 Volts

Battery 2 = 9 Volts

Click on the light and document the resistance of the light bulb.

Light bulb = 10 Ohms

Problem 2
Using the simulation, create a circuit with two batteries and one light bulb, and a resistor. Click on the battery to set each battery value to 12 Volts, the light bulb to set it to 10 Ohms, and the resistor to 15 Ohms. Use the voltmeter to find the voltage in the circuit. Using the ammeter find the current in the circuit.

The total voltage = 24V

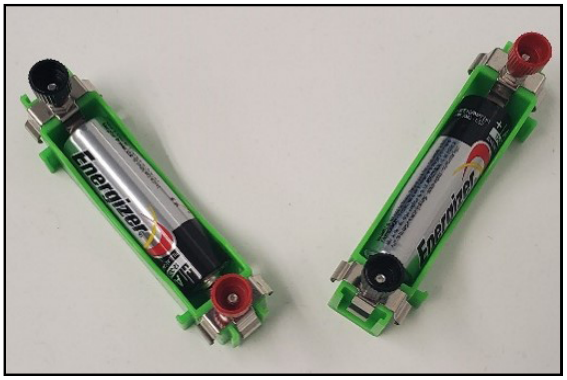
Total current = 0.96A

3A.D Images for Lesson

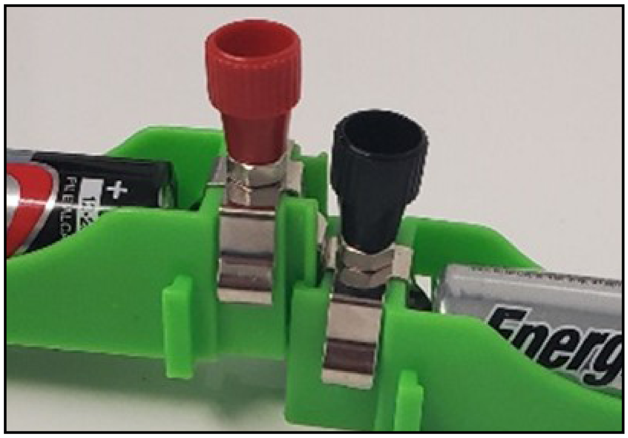
A. Electrical Safety

Connecting the Batteries in Series

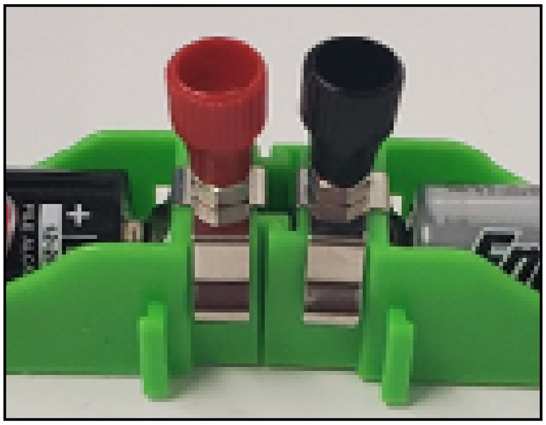
Step 1:



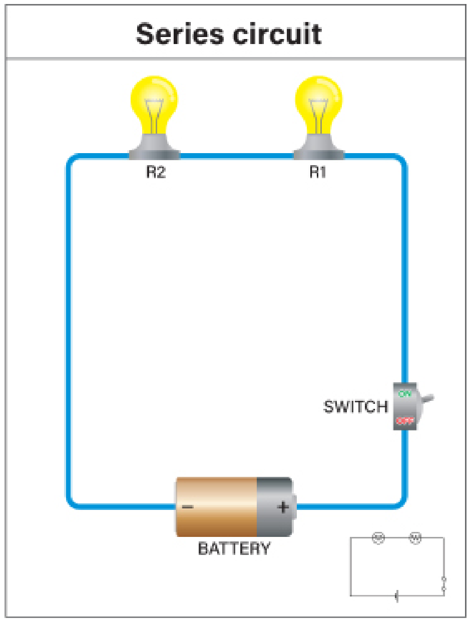
Step 2:



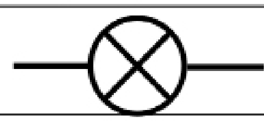
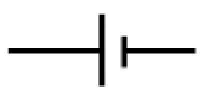
Step 3:



B. Series Circuit

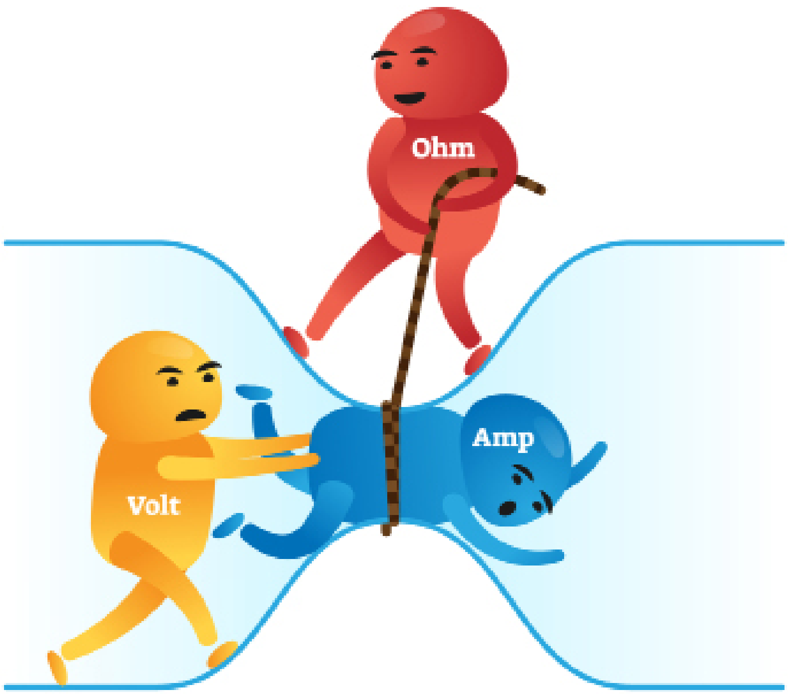


C. Circuit Diagram Symbols

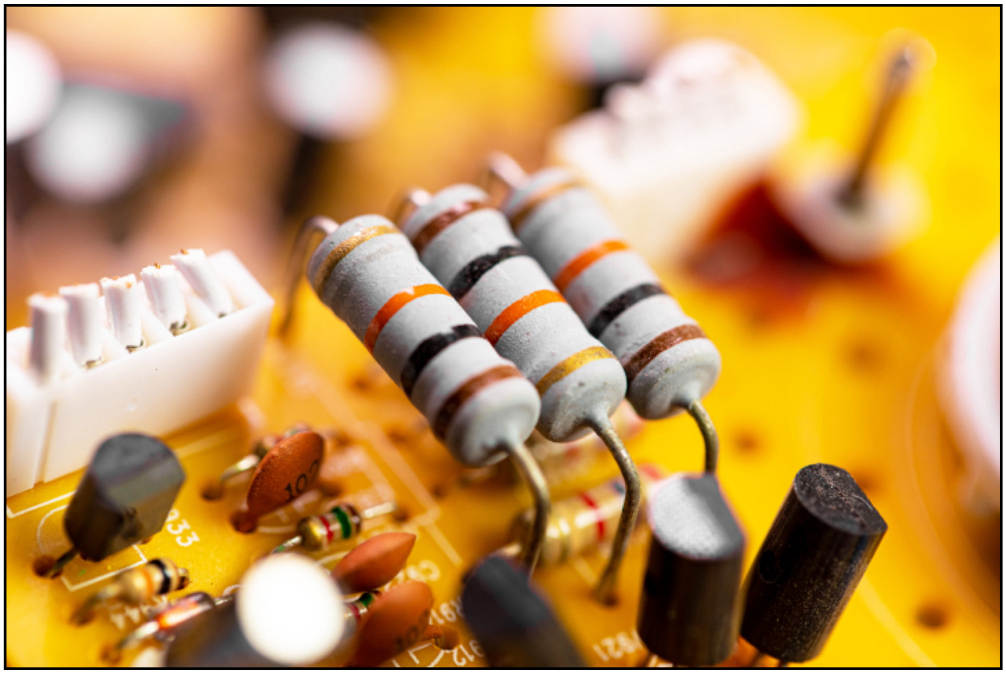
Component	Circuit Diagram Symbol
Wire	
Resistor	
Light Bulb	
Battery	
Switch	

3A.D Images for Lesson

D. Voltage, Current, and Resistance



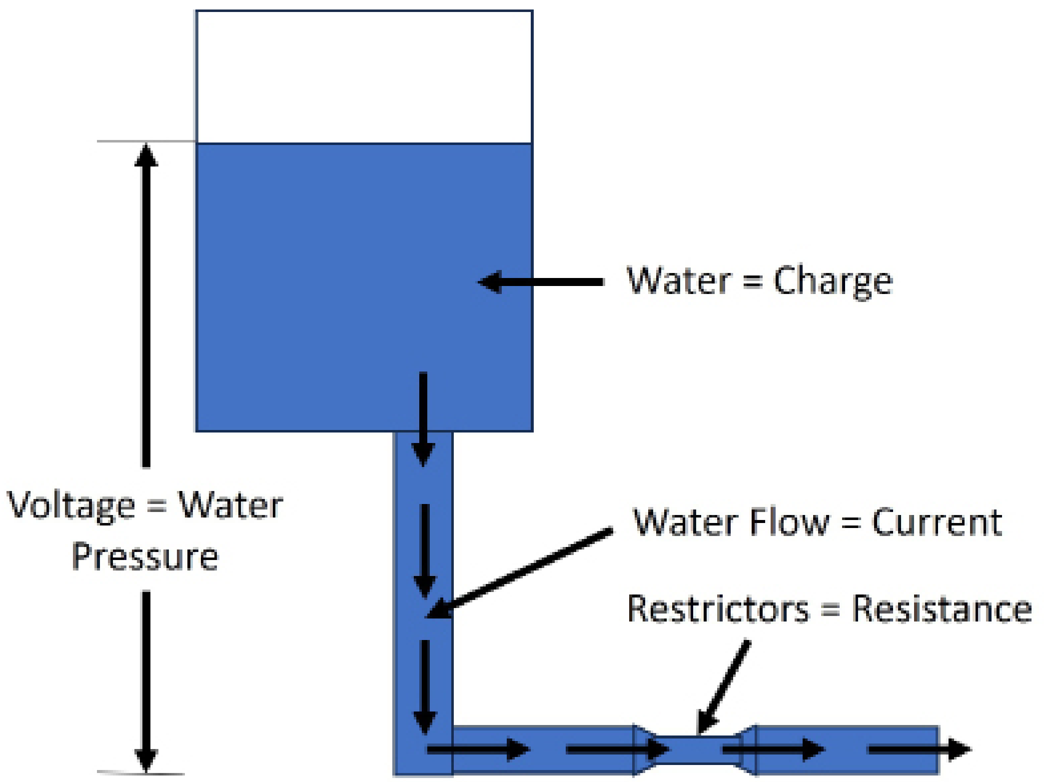
E. Resistor



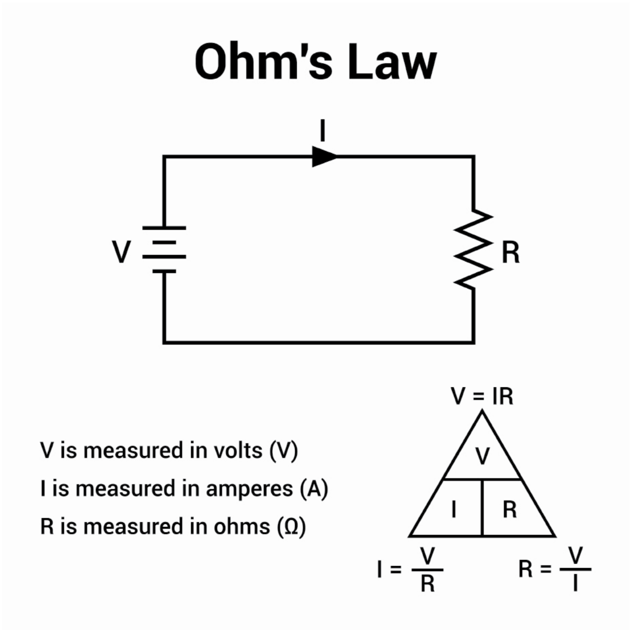
F. Units of measurement

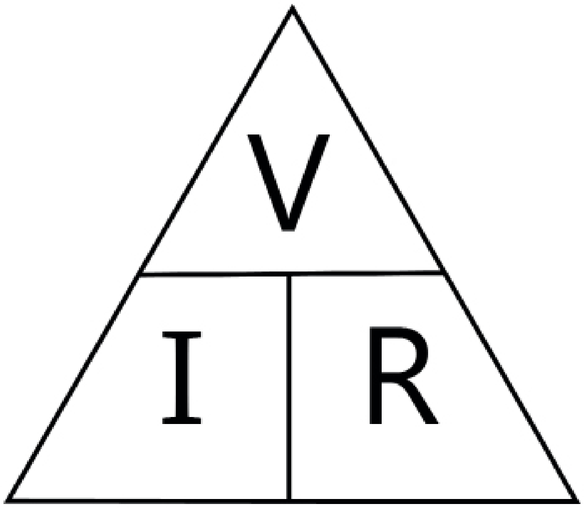
Name	Abbreviation	Unit of Measurement	Symbol
Voltage	V	Volt	V
Current	I	Ampere or Amps	A
Resistance	R	Ohm	Ω

G. Voltage Current and Resistance Analogy

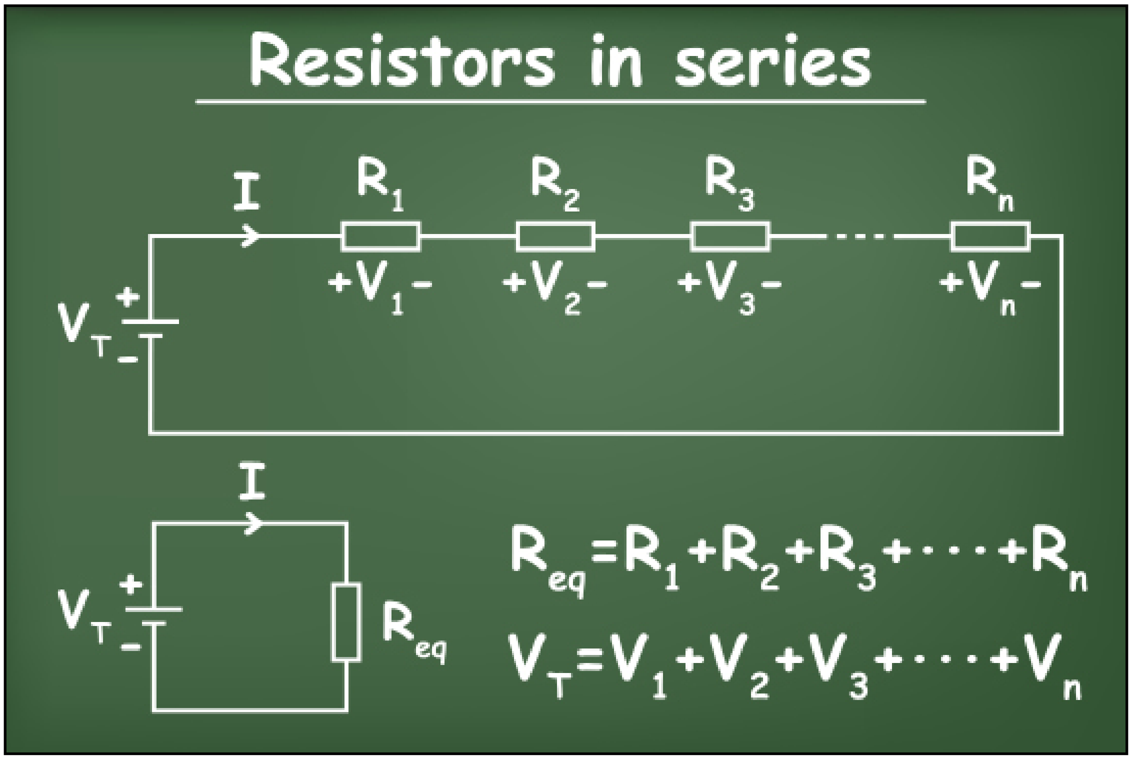


H. Ohm's Law





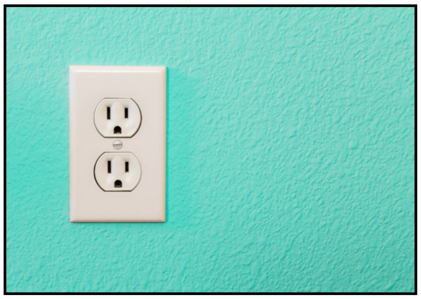
I. Resistor in Series

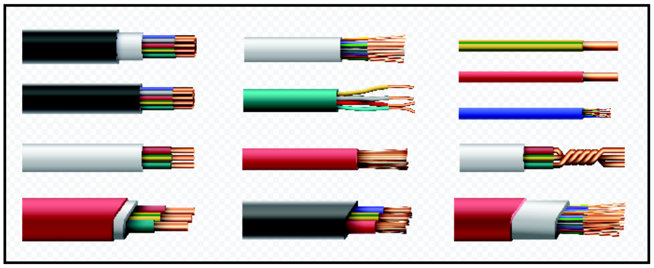


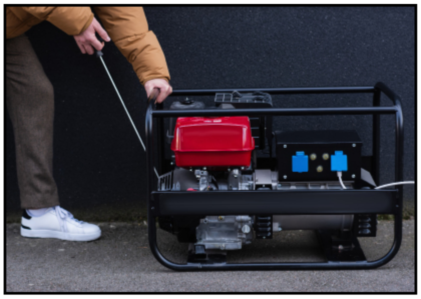
Name____ Date_______________ Period __________

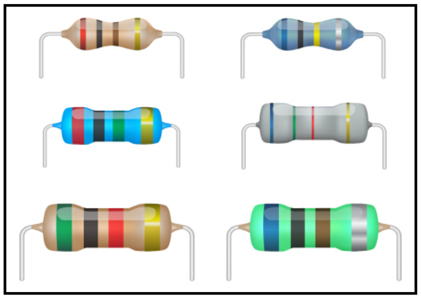
3A.E Voltage and Resistance Example

Directions: Place a "V" by items that are voltage sources, place a "R" on items that provide resistance, and place an "I" in items that carry current through a circuit.









LESSON THREE B:

Lesson Objectives
Students will be able to:
- Build a parallel circuit.
- Sketch and explain schematic diagrams for a parallel circuit.
- (Optional) Apply Ohm’s Law to the elements of a parallel circuit to analyze the circuit.

Time Required
Two 50-minute lessons

Materials
Per classroom
- EDP Poster

Per group
- 1 Circuit Kit (2 single AA battery holders, two light bulb holders, 1 switch, 6 cables, at least 2 light bulbs)

Per student
- EDP Slider and paperclip
- Engineering notebook
- Laptop or equivalent device

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-1, HS-ICP3-2, HS-ICP3-3, HS-ICP3-4, HS-ICP3-5

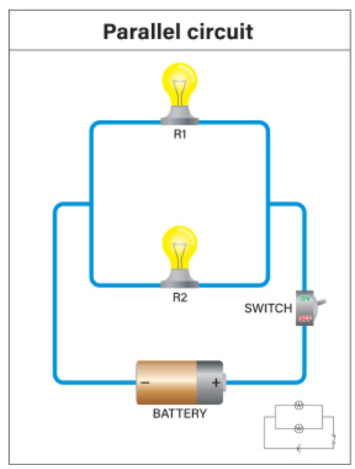
IAS Science and Engineering Practices
- SEP.5

Key Terms
parallel circuit

Lesson Summary
In this lesson, students will continue to gain knowledge of basic circuitry by building and manipulating different types of parallel circuits. Building upon this understanding, students will analyze Ohm’s Law in parallel circuits. Putting it all together, students will model and build some complex circuits.

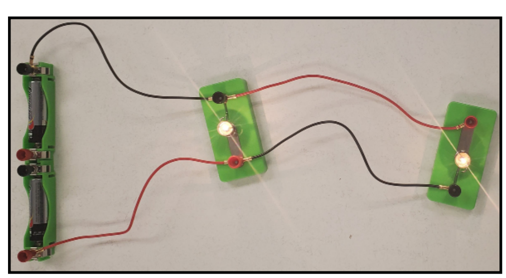
Background
Teacher Background
Refer to Teacher Background in **Lesson 3A Variables of the Flow: Ohm’s Law and Series Circuits** for review.

Parallel Circuit: A **parallel circuit** is a closed circuit in which the current divides into two or more paths before recombining to complete the circuit. Each load connected in a separate path receives full voltage and the total circuit current is equal to the sum of the individual branch current.



In this lesson:

Circuit 1 (2 AA batteries, 4 wires, and two light bulbs): In a parallel circuit the voltage across each of the branches is the same. If the resistance across each branch is different the current through each branch is different to make the voltage drop in each branch the same. Therefore, the brightness of the light bulbs will be equal to each other.



Circuit 2 (2 AA batteries, 4 wires, two light bulbs, and a switch): When a switch is added to a parallel circuit it matters where the switch is located. If the switch is located before or after all of the branches in a parallel circuit, it creates an open circuit that prevents current from flowing across the circuit because there is no conductive path between the cathode and anode, see Image 1. If the switch is connected anywhere else in a circuit, where the switch is connected and how the branches are connected determines what branches are affected. In this circuit, since there are only two branches, if the switch is connected to either of the branches the switch will control that branch but not the other one because a closed loop will still be in place even if one of the branches are open (see Image 2 and Image 3).

Image 1

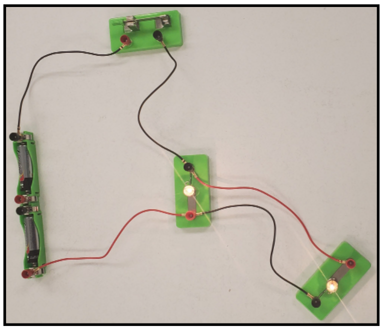


Image 2

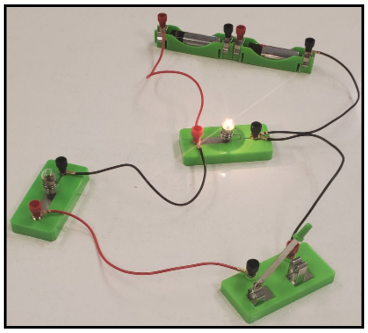
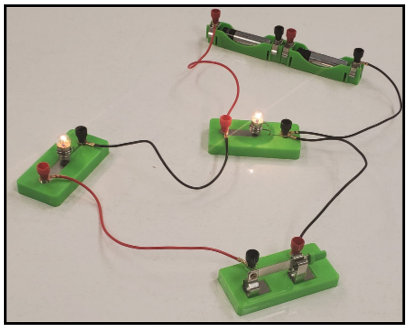


Image 3



Vocabulary:

- **Parallel circuit:** a closed circuit in which the current divides into two or more paths before recombining to complete the circuit.

Assessments

Activity Embedded Assessment

Listen to group discussions and look at student work as they work through and complete 3B.A Parallel Circuit and Ohm's Law Engineering Notebook. Ask students to share their responses with other groups and the class.

Duplication Masters

- 3B.A Parallel Circuit and Ohm's Law Engineering Notebook

Educator Resources

- 3B.B Images for Lesson

Before the Activity

- Ensure each team has a complete circuit kit that has at least 2 AA battery holders, two light bulbs, two light bulb holders, and 6 wires. Remove the instruction sheet provided with the kit because it also outlines how to create a series and parallel circuit, activities the students will be doing in this lesson.
- Check that websites can be shared and viewed by students.
- Make copies of the duplication masters for the following amount
  - 3B.A Parallel Circuit and Ohm's Law Engineering Notebook (1 per student)
- Create a PowerPoint or some visual to share graphics with class.

Classroom Instruction

Introduction

1. **Review series circuits. Say:** *In the last lesson we learned about series circuits, what were some concepts we learned about series circuits?*
2. **Review Ohms Law. Say:** *We then learned about voltage, current, and resistance. What are their roles within an electrical circuit?* **Say:** *In the last area that we covered was Ohm's Law. What is Ohm's Law?*
3. **Identify where they are in the engineering design process (Learn). Say:** *So far, we talked about series circuits and Ohm's Law.* Point out the "Learn" block on the engineering design process and have students look at their Engineering Design Process sliders. **Say:** *Before we can start designing solutions, we need additional information.* **Ask:** *What step of the engineering design process are we in?* Students should identify that they are still in the "Learn" phase.

Activity

4. **Hands-on activity.** Have the students break up into groups of two and provide each group with a circuit kit. For each group have them remove the two battery holders, two AA batteries, the wires, and two light bulb holder and bulbs from their electrical circuit kits. **Say:** *As we continue in the "Learn" phase, let explore more about electrical circuits.* Handout worksheet 3B.A Parallel Circuit and Ohm's Law Engineering Notebook **Say:** *Before we go into our lesson on circuits lets cover some electrical safety. We will be working with AA Alkaline Batteries and for all of the labs completed with this kit, we will be working with the batteries in series. To do this safely and to prevent*

short circuiting the batteries, connect the red terminal of one of the battery holders to the black terminal of the other battery holder. Show class Image A from 3B.B Images for Lesson for reference. **Say:** *To start off, with the supplies provided to each team create a circuit that will light up each light bulb independently (you can remove one and the other one still stays on). As you come up with your design take into account what we have discussed so far. Once you have your light bulb lit, answer Question 1 in Part 1 of the worksheet either on your worksheet or in your engineering.* Once students are done with this activity, take some time for students to share their answers.

5. **Introduction to parallel circuits. Say:** *Thank you for sharing how a circuit works. Let's take a closer look at what you all did. Everyone got the light bulbs to light up, in doing so, you created the second type of circuits, a parallel circuit.* Refer to Image B in handout 3B.B. **Say:** *A parallel circuit is a closed circuit in which the current divides into two or more paths before recombining to complete the circuit. Each load connected in a separate path receives full voltage and the total circuit current is equal to the sum of the individual branch current.*
6. **Build a parallel circuit. Say:** *Let's explore more parallel circuits. In your teams work through the rest of Part 1 of the worksheet.*
   a. Once the teams complete Part 1, have the teams pair up with a team close to them and share their responses with each other.
7. **Switch in a parallel circuit. Ask:** *For the last circuit on your worksheet, you added a switch to the circuit, what were some things that you noticed about the placement of the switch in a parallel circuit?* **Ask:** *What are some examples of parallel circuits that you see in your day to day?*
8. **Activity parallel and series together. Say:** *Now that we have learned about parallel and series circuits let built some complex circuits. Complex circuits are the combination of series and parallel circuits.*
   a. Have student teams pair up into groups of 4 and design various complex circuits.
   b. Have the students draw a schematic of their complex circuits in Part 2 (Complex Circuit Activity) of 3B.A Parallel Circuit and Ohm's Law Engineering Notebook.
9. **(Optional) Connection to circuit. Note:** If the teams have disassembled their circuits that they created on day on have them use their schematic diagrams to recreate their circuits. **Say:** *Let's look at the circuits that we have created and let's see*

how Ohm's Law applies to a parallel circuit. Refer to Image C on handout 3B.B when explaining Ohms's Law rules for Parallel Circuit.

a. Parallel Circuit Rules when looking at Ohm's Law
   i. Voltage does not change across each resistor

      $V_{total} = V_1 = V_2 = V_3 = V_n$

   ii. Total current equals the sum of the current on each branch of the circuit

      $I_{total} = I_1 + I_2 + I_3 + I_n$

   iii. The total resistance equals the sum of the inverse resistance across each branch of the circuit

      $\frac{1}{R_{total}} = (\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ... + \frac{1}{R_n})$

b. Do two examples in class.
c. Pass out worksheet with problems for class to work on.

Closure

10. Connect the activity to the engineering design challenge. **Ask:** *What did we learn today that will help us with the design challenge given to us from our partners, SECURE Safe? What are some benefits to a parallel circuit?* **Say:** *As we add more to our understanding on electrical circuits, we will continue in the Learn stage next class.*

Name_______________________________________ Date______________ Period __________

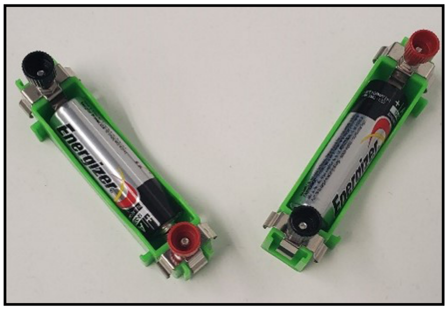
3B.A Parallel Circuits and Ohm's Law Engineering Notebook

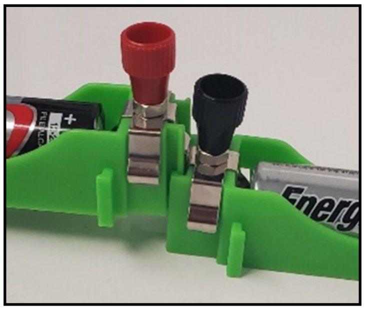
Material List

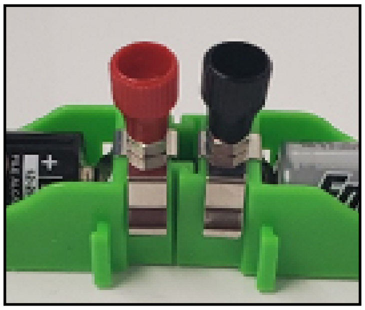
- **2 AA batteries,**
- **2 AA battery holder**
- **2 light bulbs**
- **1 switch**
- **6 wires**

Electrical Safety

Place batteries in series for all circuit designs. Proper setup to prevent short circuiting the batteries, connect the red terminal of one battery holder to the black terminal of the other battery holder.







Name______________________________________ Date______________ Period __________

3B.A Parallel Circuits and Ohm's Law Engineering Notebook

Part 1 Parallel Circuit Activity

Circuit 1 Using the batteries, wires, and two light bulbs, create a circuit that will light up each light bulb independently (you can remove one and the other one still stays on)	**Draw Circuit Schematic**
Question 1 Describe how the circuit works, label your voltage source, wires, and load in the circuit.	
Key words definition **Parallel Circuit**	
Circuit 2 Using the batteries, wires, and two light bulbs, add a switch to the circuit	**Draw Circuit Schematic**
Question 2 A. What happened to the circuit when you add and use a switch to the circuit? B. Does the location of the switch matter for it to work? Why?	

Name____ Date_______________ Period ___________

3B.A Parallel Circuits and Ohm's Law Engineering Notebook

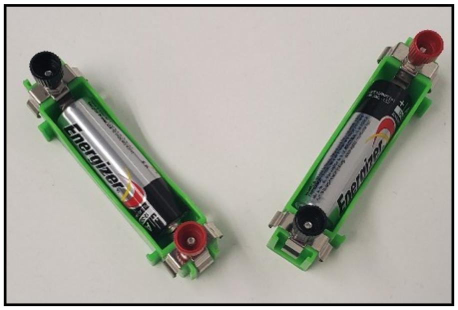
Part 2 Complex Circuit Activity

Complex Circuit	Draw Circuit Schematic
Circuit 1	
Circuit 2	
Circuit 3	
Circuit 4	

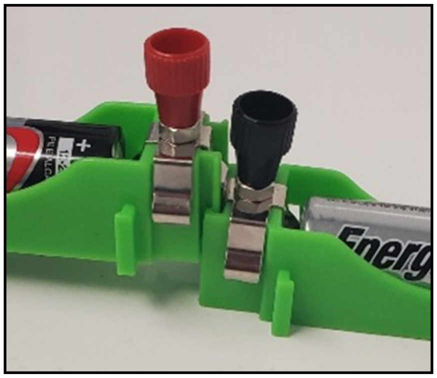
A. Electrical Safety

Connecting the Batteries in Series

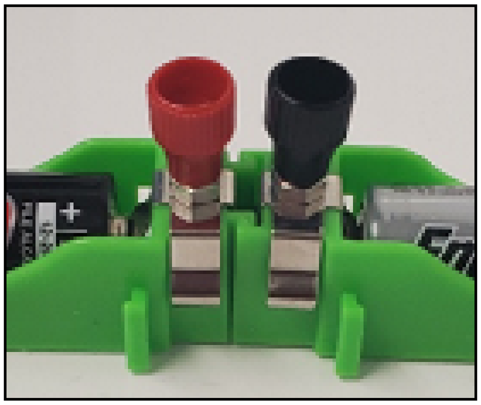
Step 1:



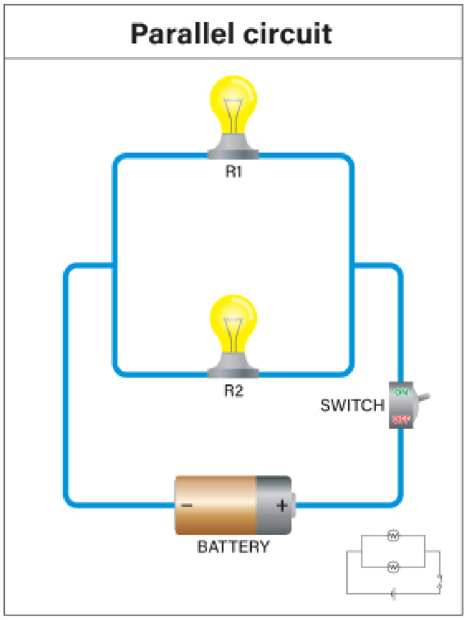
Step 2:



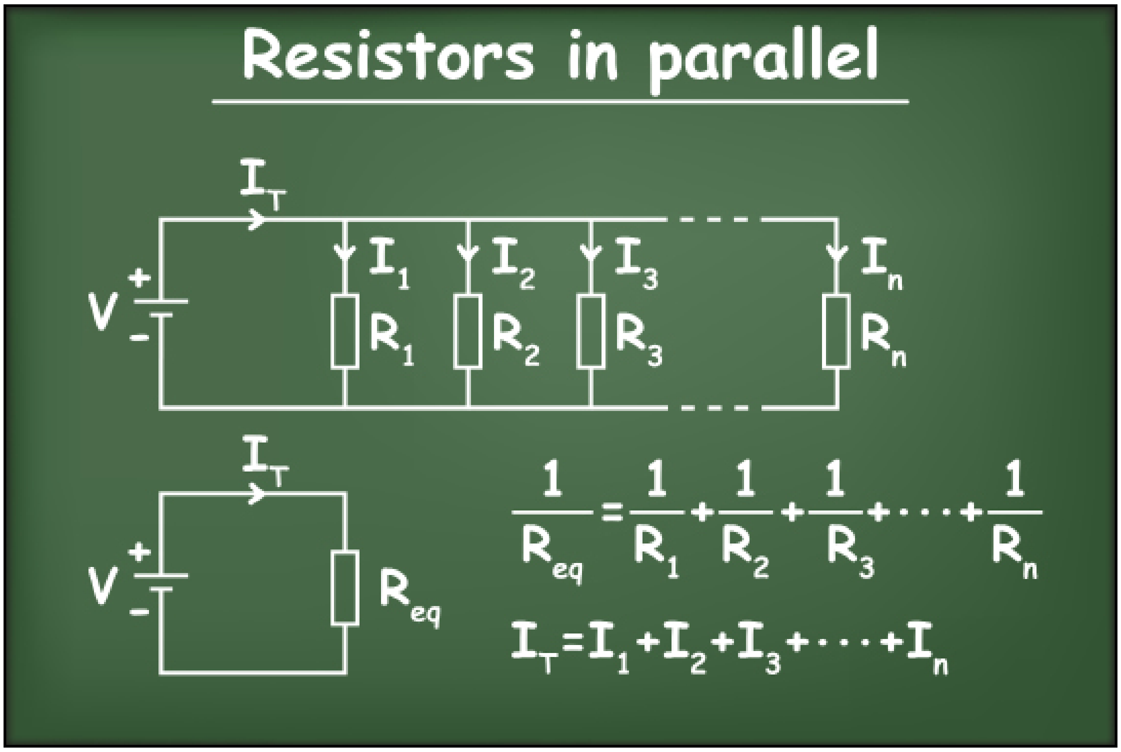
Step 3:



B. Parallel Circuit



C. Resistors in Parallel



LESSON FOUR:

Lesson Objectives
Students will be able to:
- Identify the different wavelengths within the electromagnetic spectrum.
- Identify how different waves within the spectrum affect their daily routine.
- Associate visible light as part of the electromagnetic spectrum and that white light is composed of different wavelengths consisting of the different colors of the rainbow.

Time Required
One 50-minute lesson

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP4-1

IAS Science and Engineering Practices
- SEP.5

Key Terms
wavelength, electromagnetic spectrum, spectroscope

Lesson Summary

In this lesson, students will learn about the electromagnetic spectrum (EMS) and how higher wavelengths equate to higher energy and more waves. They will learn about the applications of the EMS, including microwaves, radios, and x-ray machines. Students will each construct their own spectroscope to see the different colors within the visible range of the EMS.

Background

Teacher Background

The electromagnetic spectrum is the backbone behind science to a lot of the sensors and advancement in technology. This lesson gives students an introduction to the electromagnetic spectrum, providing a foundation for the students leading into Lesson 5 Lock It Up!: Micro:bit and Sensors.

Vocabulary:
- **Wavelength:** the distance for one point the corresponding point of a wave
- **Electromagnetic spectrum:** range of frequencies of electromagnetic radiation
- **Spectroscope:** breaks up light into its base colors of the visual spectrum

Before the Activity

- Set up supplies for activity for each student
    - Cut cardstock paper in half. Students do not need a full sheet of paper.
    - Cut CD into four pieces
- Decide which light option you want your class to observe and have those light sources available for students to view
- Make copies of the duplication masters for the following amount
    - 4.A Electromagnetic Spectrum (1 per student)
    - 4.B Spectroscope Instructions (1 per student)

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?* Students may need to revisit the original client letter to remind themselves of the engineering design challenge.
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have learned about circuits,*

electricity, and Ohm's Law. Point out the "Problem" block of the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need to learn more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

3. **Identify what students need to learn about. Say:** *Today we are going to learn about the electromagnetic spectrum, the foundation to what we can see and how information is shared all around us.*

Activity

4. **Introduce the concept of energy within electromagnetic spectrum. Ask:** *Why does someone get a sunburn?* Allow students to try and answer, and ask any necessary follow up questions: *The sun is very far away, so how does it harm us?* Facilitate a discussion about how the sun emits ultraviolet radiation in **waves** in the form of energy. **Ask:** *How does a microwave work?* Allow time for students to answer. **Ask:** *What allows our cell phones to send text messages back and forth while allowing you to sing and dance to your favorite song on the radio?* Continue discussing how each of these processes is a transfer of electromagnetic energy in a wave, radio waves to be specific.
5. **The electromagnetic spectrum. Say:** Let's take some time to learn more about the electromagnetic spectrum, these different waves we have been talking about.
   a. **Show Video:** Tour of the EMS 01 – Introduction (5:03): https://www.youtube.com/watch?v=lwfJPc-rSXw&t=1s
   b. **Say:** The electromagnetic spectrum or EM spectrum provides us with a lot of information and allows us to interact with the world around us in multiple ways. **Ask:** *To the naked eye thought there is only one part of the spectrum that we can analysis which part is that?* Visible light
6. **Introduce the spectroscope activity.** Hand out Duplication Master 5.A Electromagnetic Spectrum. **Say:** *The only part of the electromagnetic spectrum that we can physically see is the visible range. To see this, we are going to create a spectroscope which is a tool that splits into its unique colored spectrum.*
7. **Construct a spectroscope.** Hand out the materials for each student to build their own spectroscope. The teacher can either hand out Duplication Master 5.B Spectroscope Instructions, or lead the students through the activity step-by-step.

Materials

Per classroom
- EDP Poster
- White incandescent light bulb
- Red LED light
- Yellow LED light
- Green LED light
- Blue LED light

Per group
- Exacto knives

Per student
- EDP Slider and paperclip
- Engineering notebook
- Scissors
- Black cardboard tube for crafts
- CD (or quarter/sixth of a CD)
- Black cardstock paper (65 lb or greater)
- Black electrical tape
- Clear tape

Assessments

Activity Embedded Assessment

Listen to students' responses to the lesson questions on the electromagnetic spectrum.

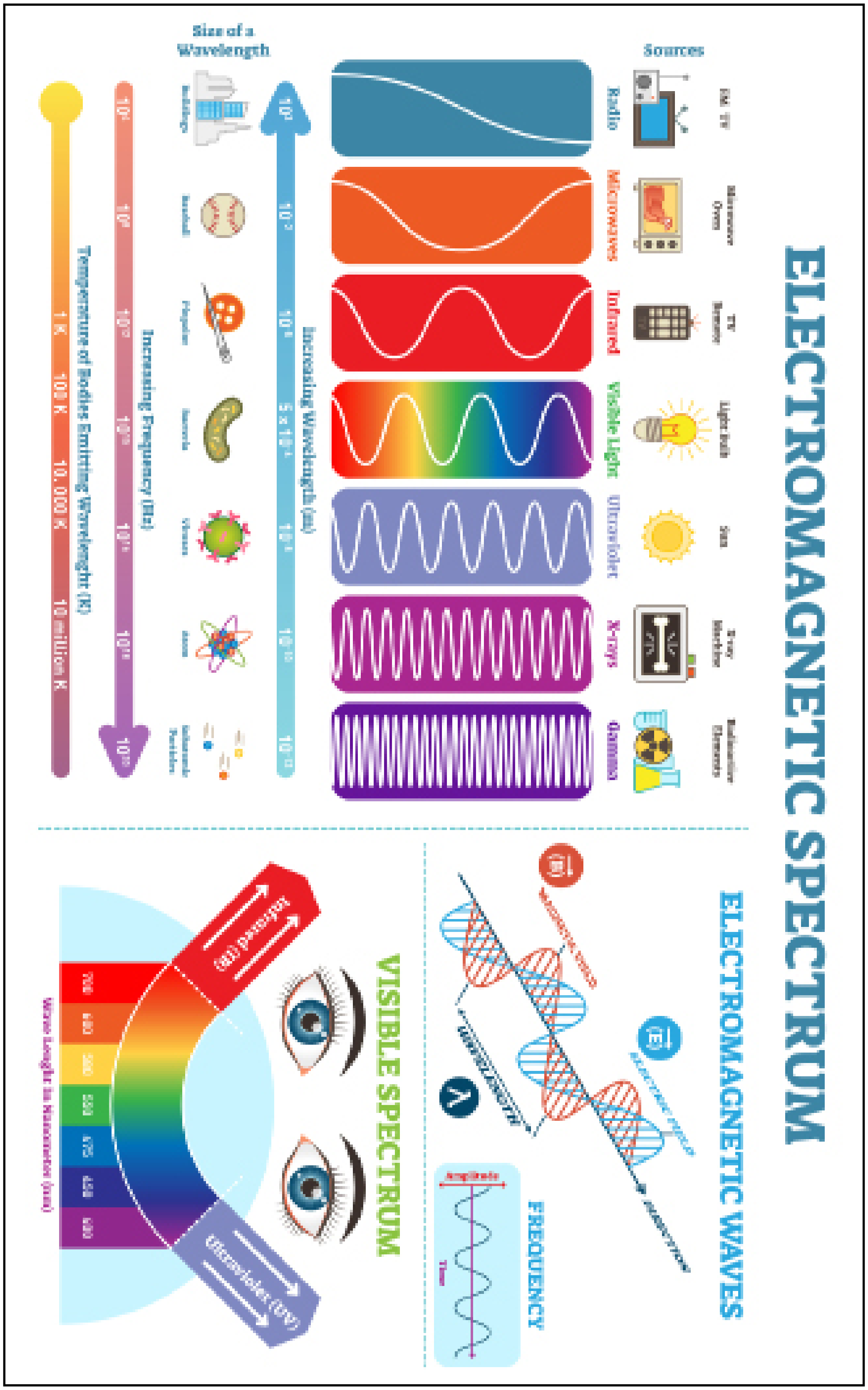
Duplication Masters
- 4.A Electromagnetic Spectrum
- 4.B Spectroscope Instructions

Educator Resources
- EMS: https://www.youtube.com/watch?v=lwfJPc-rSXw&t=1s

8. **Explore the colors.** When students are done with the activity, students can explore viewing visible colors that make up different light by looking at different light sources and colored lights.
   a. Set up stations where students can look at these different lights through their spectroscope. Some light sources can include white incandescent light bulbs, red, blue, green, and yellow-colored lights.

Closure

9. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us design a security box? How does learning about the electromagnetic spectrum help us with our designs?* **Say:** *We will continue in the Learn stage during our next class.*


ELECTROMAGNETIC SPECTRUM
Sources
Size of a Wavelength
Radio
Microwaves
Infrared
Visible Light
Ultraviolet
X-rays
Gamma
Increasing Wavelength (m)
Increasing Frequency (Hz)
Temperature of Bodies Emitting Wavelenght (K)
1 K
100 K
10,000 K
10 million K
ELECTROMAGNETIC WAVES
FREQUENCY
VISIBLE SPECTRUM
Infrared (IR)
Ultraviolet (UV)

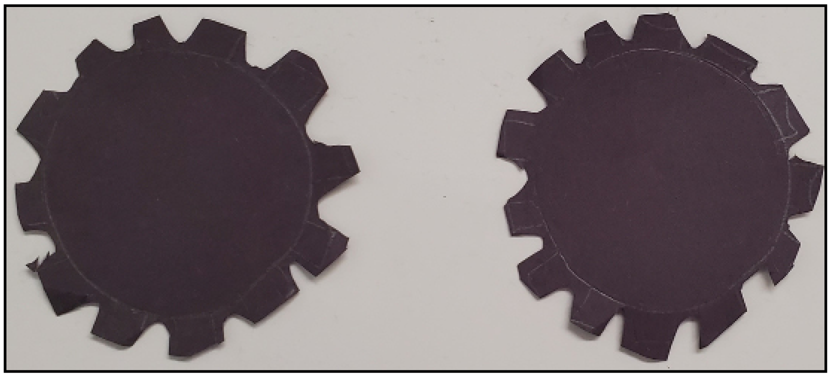
4.B Spectroscope Instructions

Materials

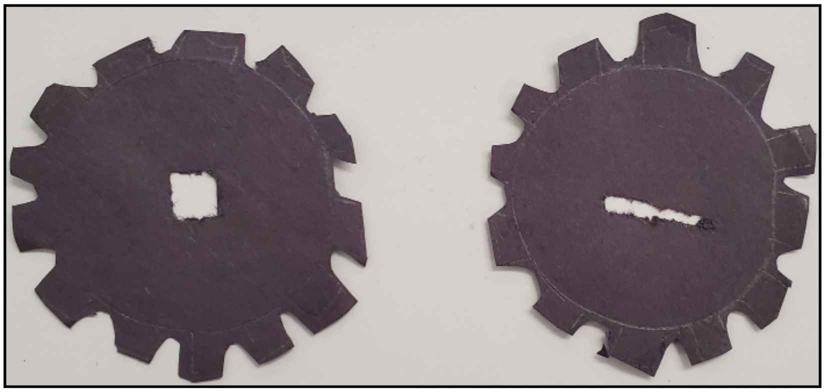
- Scissors
- Exacto knife
- Black cardboard tube for crafts (1.77 in-diameter, 10 in-length)
- CD-R blank (or quarter/sixth of a CD)
- Black cardstock paper (65 lb or greater)
- Black electrical tape
- Clear tape

Instructions

1. Take the black cardboard tube and trace two circles on the black cardstock paper leaving room between them.
2. Create tabs around the circle to be used to connect the circle to the end of each end of the tube. Cut out circles using scissors creating two end-caps.

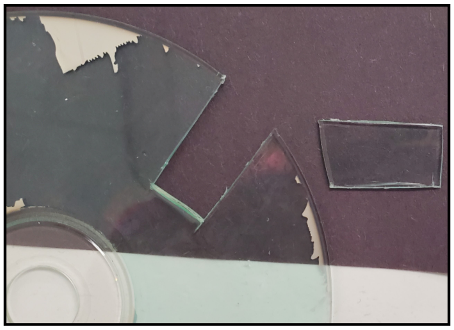


3. Using an exacto knife on one circle draw a small square about ¼ in length and width.
4. Using an exacto knife on the other circle draw a small slit about ¾ in long 1/16 in wide.

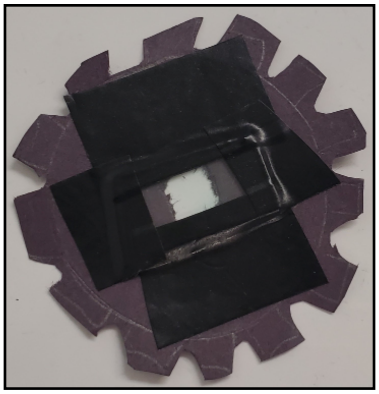


5. Set those aside and pick up the CD.
6. Remove the label off of the CD by first scraping at small section of the CD with a sharp edge removing some of the label.

7. Take clear tape and lay it over the section that was just scrapped off and pull up the tape. This should remove a large area of the film on the CD. Continue to do this until all of the label is removed.
8. Using scissors cut out a piece of the CD that can be used to cover the small square traced on one of the circles caps.



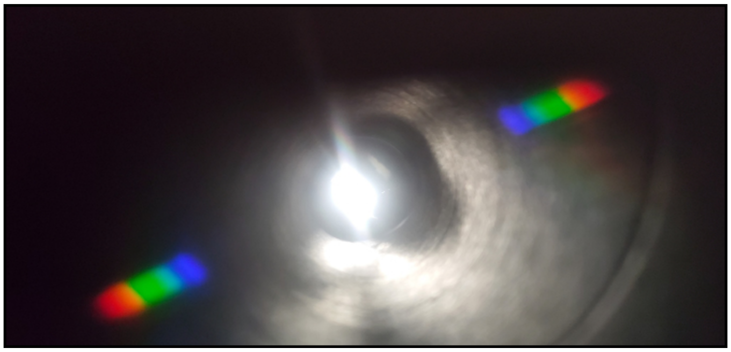
9. Using the black electrical tape, tape down the perimeter of the CD piece that you are securing to the end cap. Clean both sides of the CD by giving them both a quick dry wipe down.



10. Taking the end-cap with the square hole and attached lens, secure it to one end of the black cardboard tube using the black electrical tape.

    Note: It is good to first secure the end-cap with small pieces of tape to properly place the end-cap and then longer piece once the location is centered.

11. Prior to securing the slit end cap to the other end of the tube, it first has to be aligned to the lens on the square hole end-cap to get the best results. While looking through the lens on the square hole end cap looking at a light source (please do not look directly at the sun) rotate the slit end-cap until there is good visibility of a color spectrum along the wall of the tube.



12. At this point secure the slit end-cap to the other end of the tube.

Note: It is good to first secure the end-cap with small pieces of tape to properly place the end-cap and then longer piece once the location is centered.

13. Now it is time to explore different forms of visible light! What do you see when you look at the classroom light, the red, yellow, green, and blue light?

LESSON FIVE:

Lesson Objectives
Students will be able to:
- Identify microelectronics (ME), microcontrollers, and sensors
- Explore sensors through Sensor Stations
- Relate ME sensors to the electromagnetic spectrum

Time Required
Two 50-minute lessons

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-1, HS-ICP3-2, HS-ICP3-3, HS-ICP3-4, HS-ICP3-5

Key Terms
microelectronics, microcontroller, sensor

Lesson Summary

Students will investigate the sensors used in different alarm systems. Students will visit stations with physical devices that mimic or demonstrate the capabilities of different detection and communication capabilities using a microcontroller and accessories. For each station, some aspect of the physical science principles behind the operation of the device will be displayed via a video and/or graphic. Students experiment with the device to discover the constraints around operating such devices.

Depending on the class, more or less emphasis can be given to coding.

IAS 6-8 DL 3 Option 1: The simple coding puzzle station is included. For the other stations, teachers could also display the code (text or block) that was used to make the device work. Students will see that both a physical device and code which makes the physical device work are needed. However, students will not need to write code.

IAS 6-8 DL 3 Option 2: The online simple coding station is supplemental and not included. Students utilize Microsoft MakeCode (https://makecode.microbit.org) to experiment using the code template from Option 1. Students would use code blocks and a micro:bit emulator to experiment with the relationship between hardware and software. The same code blocks from Option 1 could be used and the experiments and code changes would be done online and in real-time – with results shown on the micro:bit emulator. This option could require significantly more time to implement, if unfamiliar students need to first familiarize themselves with Microsoft MakeCode. This lesson could also be extended to teach coding of the micro:bit and sensors such that students' prototypes are operational.

Background

Teacher Background

- **Sensors:** There are many different sensors used in security device. These components operate based on physical science principles.

Bluetooth and Wi-Fi	Electromagnetic (radio) waves
Fingerprint scanner	Ultrasonic waves or capacitance
Light sensors	Electromagnetic (light) waves
Proximity sensors	Light waves or sound waves
Accelerometer	Principles of velocity (v/t) and gravity
Magnetometer	Magnetic field and electricity

For example, with distance (proximity) sensors, the reflective properties of light or sound waves are used to measure the distance between the sensor and the object it is sensing. By knowing the speed of light (or sound), the sensor can calculate the distance between itself and the object based on how long it takes for the wave it sent out to return back. The following videos give a broad background of these sensors and the science behind them. Some of the deep science principles will be beyond the level of this class. Where appropriate, students can understand the scientific principles behind EM, light, and sound waves, magnetic fields, and electricity. Where the physics principles are beyond students, focus solely on understanding how the device works, in general, and on the constraints of the device.

View Videos

1. Sensors introduction: https://www.youtube.com/watch?v=R6Hf9TuWXjA
2. Sensors for detecting people: https://www.youtube.com/watch?v=LNeSz5hfTLI
3. Bluetooth/Wi-Fi overview: https://www.youtube.com/watch?v=mPMGRILsOVk
4. Magnetometer overview: https://www.youtube.com/watch?v=0kgw_P5q9_o & https://www.youtube.com/watch?v=3k_tnI1uGX8

Optional Videos for deeper background information:

- Bluetooth in-depth: https://www.youtube.com/watch?v=1I1vxu5qIUM
- Wi-Fi in-depth: https://www.youtube.com/watch?v=co4rLn9N8OU
- Accelerometer physics overview (high school level concept): https://www.youtube.com/watch?v=8E7C36wawqg

Materials

Per classroom

- EDP Poster
- (8) micro:bits with battery packs and batteries
- (2) ELECFREAKS IIC OLED Module
- (2) ELECFREAKS iot:bit for micro:bit
- ELECFREAKS Octopus Light Sensor
- ELECFREAKS Octopus Sonar:bit (Distance Sensor Ultrasonic)
- (2) EMF blocking fabric pieces ~0.25 yards each
- 8.5 X 11 piece of cardboard (approximate size)
- flashlight
- dark/heavy cloth
- light colored/light cloth
- paper cup
- dark plastic cup
- magnet
- (optional) cell phone stand
- (optional) multiple types of magnets

Per group

- (2 pair) latex/nitrile gloves
- (1 pair) fabric gloves

Per student

- EDP slider and paperclip
- Engineering notebook
- Laptop or equivalent device

Assessments
Activity Embedded Assessment
Listen to group discussions as teams walk through each station 5.A Station 1: Accelerometer Sensor, 5.B Station 2: Light Sensor, 5.C Station 3: Capacitive Touch Station, 5.D Station 4: Code Station, Option 1: Simple Code Puzzle, 5.F Station 5: Ultrasonic Proximity Sensor, 5.G Station 6: Bluetooth Simulation Station, 5.H Stations 7: Magnetometer Stations.

Post-Activity Assessment
Each station has reflection questions for students to answer. Review students' engineering notebooks to see how students relate lesson content to engineering design challenge and unit objectives.

NOTE: *For the Bluetooth Simulation Station:* Although the micro:bit does have Bluetooth capabilities, we are simulating Bluetooth communication using the micro:bit radio feature. Both protocols operate at 2.4Ghz, however the radio communication is much easier to demonstrate for the lesson as it does not require pairing.

Before the Activity

- Code the micro:bits and sensors for the stations using the supplementary instructor materials. Each configuration should be operational before the activities begin.
- Create the Posters/graphics that represent the science or general properties behind the associated stations.
    - 5.A Station 1: Accelerometer Sensor
    - 5.B Station 2: Light Sensor
    - 5.C Station 3: Capacitive Touch Station
    - 5.D Station 4: Code Station, Option 1: Simple Code Puzzle
    - 5.F Station 5: Ultrasonic Proximity Sensor
    - 5.G Station 6: Bluetooth Simulation Station
    - 5.H Stations 7: Magnetometer Stations
- Print out 5.E Station 4: Code Sheet to use for puzzle
- (Optional) For 6-8 DL.3 Options 1 & 2 - Create the Posters/graphics that show the code for each station using the hex files opened in MakeCode.
- Set up the stations at various locations in the classroom. The station will include the working device the science/properties poster and the code poster (for coding extensions).

Supplementary Instructor Materials

Software Download Instructions
Details for downloading code to the micro:bits. The compiled code (.hex files) for the micro:bits is located at https://nanohub.org/projects/scalek12curricu/files/browse?subdir=LockITUp.

1. Download the files in this repository to your local machine.
2. Connect a micro:bit to your computer via the USB cord provided with the device. Your computer will register the micro:bit as a supplemental drive.
3. Open the file explorer on your computer and locate the downloaded .hex files.
4. Drag one .hex file from the computer to the micro:bit drive to upload code to the micro:bit. You should see a flashing yellow light on the micro:bit, which indicates that the micro:bit is being “flashed” with the code.

5. Test the micro:bit functionality as described by the station that the code corresponds to.
6. Disconnect the USB cord connected to the computer from your micro:bit.
7. Repeat steps 2-7 to download the remaining code on to the micro:bits for each station.
8. When the stations are set-up for class, you will power them with a battery pack provided in the micro:bit kits.
9. Keep extra batteries on hand, especially for the Bluetooth section, which can use more power than the other stations.

Station Configuration

Station 1: Accelerometer Sensor
Material:
- micro:bit
- AAA Power Supply (came with micro:bit and had the connection that goes into the back of the micro:bit)
- (2) AAA batteries

Setup:
1. Complete steps 1-4 of the software download instructions to download the "Accelerometer" software.
2. Complete step 5 of the software download instructions to test micro:bit. For this station as the micro:bit is rotated arrows should point in the direction that it is being moved.
3. Complete step 6 of the software download instructions.

Station 2: Light Sensor
Material:
- micro:bit
- AAA Power Supply (came with micro:bit and had the connection that goes into the back of the micro:bit)
- (2) AAA batteries
- ELECFREAKS IIC OLED Module
- ELECFREAKS iot:bit for micro:bit
- ELECFREAKS Octopus Light Sensor
- Cup
- Dark/heavy cloth
- Light colored/light cloth
- Flashlight

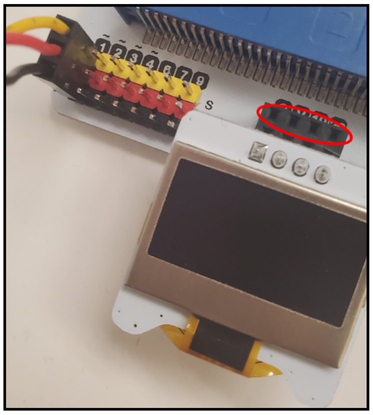
Duplication Masters
- 5.A Station 1: Accelerometer Sensor
- 5.B Station 2: Light Sensor
- 5.C Station 3: Capacitive Tough Station
- 5.D Station 4: Code Station, Option 1: Simple Code Puzzle
- 5.E Station 4: Code Sheet
- 5.F Station 5: Ultrasonic Proximity Sensor
- 5.G Station 6: Bluetooth Simulation Station
- 5.H Stations 7: Magnetometer Stations

Educator Resources
- Sensors: https://www.youtube.com/watch?v=R6Hf9TuWXjA
- Sensors for detection: https://www.youtube.com/watch?v=LNeSz5hfTLI
- Bluetooth/Wi-Fi: https://youtube.com/watch?v=mPMGRILsOVk
- Magnetometer: https://www.youtube.com/watch?v=0kgw_P5q9_o & https://www.youtube.com/watch?v=3k_tnI1uGX8
- Code: https://nanohub.org/projects/scalek12curricu/files/browse?subdir=LockITUp
- Micro:bit image: https://microbit.org/get-started/features/overview/

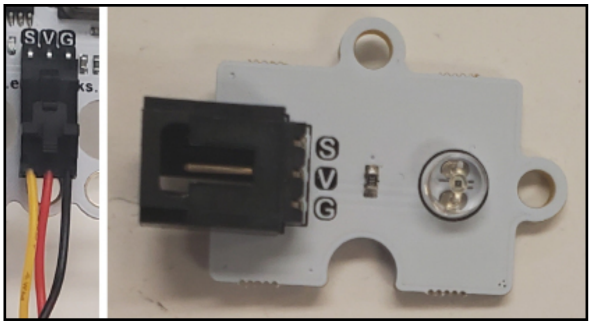
LESSON FIVE:

Setup:

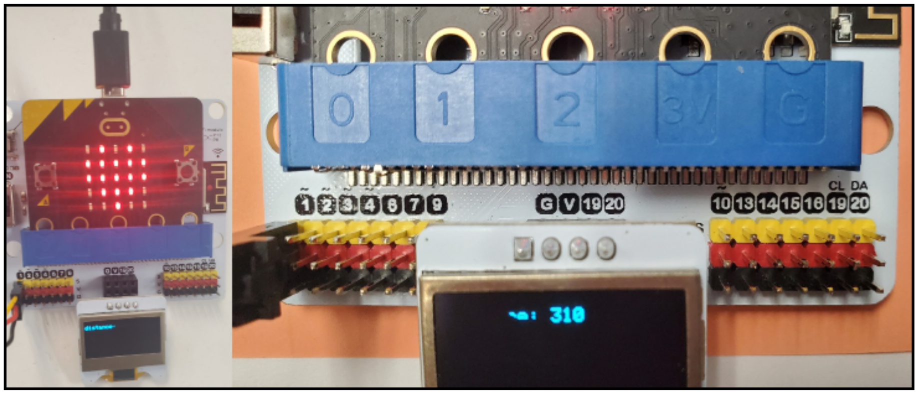
1. Connect an ELECFREAKS groove to octopus cable to the ELECFREAKS iot:bit for micro:bit at pin 1 matching the colors.
2. Plug in the in the ELECFREAKS IIC OLED Module to the top row of the ELECFREAKS iot:bit for micro:bit.



3. Connect the other side of the ELECFREAKS Grove to Octopus Cable to the ELECFREAKS Octopus Light Sensor. Align black to G, red to V, and yellow S.



4. Add micro:bit to the ELECFREAKS iot:bit, align the 0 with 0 on micro:bit, 1 to the 1, 2 to the 2, 3V with 3V, and G to G.



5. With the hardware connected complete steps 1-4 of the software download instructions to download the “microbit-IoT_Light_SensorBit” software.
6. Complete step 5 of the software download instructions to test micro:bit. For this station the ELECFREAKS IIC OLED Module will display “light” and then the light level intensity, similar to the display above. The higher the number the brighter the light. To test the sensor, cover the sensor with your hand and see if the number decreases.
7. Complete step 6 of the software download instructions.

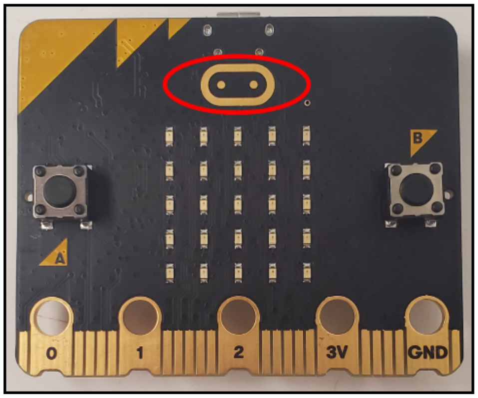
<u>Station 3: Capacitive Touch Station</u>

Material:

- micro:bit
- AAA Power Supply (came with micro:bit and had the connection that goes into the back of micro:bit)
- 2AAA batteries
- a latex/nitrile glove covered finger
- a fabric glove covered finger

Setup:

1. Complete steps 1-4 of the software download instructions to download the "microbit-CapacativeTouch" software.
2. Complete step 5 of the software download instructions to test the micro:bit. For this station to test the code place your finger on the touch sensor, a smiley face should show up because your body is electrically conductive. Try out the latex glove and fabric glove.



3. Complete step 6 of the software download instructions.

Station 4: Simple Code Puzzle Station

Material:

- Code Sheet for station 4

Setup:

1. Print out code sheet.
2. Cut out code blocks so that students can manipulate the code like a puzzle.

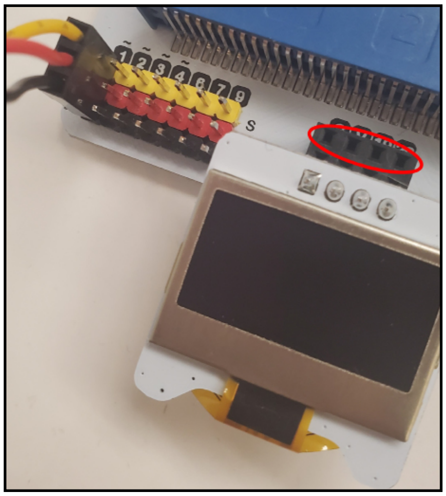
Station 5: Ultrasonic Proximity Sensor

Material:

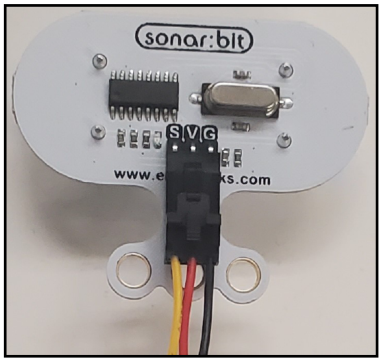
- micro:bit
- AAA Power Supply (came with micro bit and had the connection that goes into the back of micro:bit)
- 2AAA batteries
- ELECFREAKS IIC OLED Module
- ELECFREAKS iot:bit for micro:bit
- ELECFREAKS Grove to Octopus Cable
- ELECFREAKS Octopus Sonar:bit (Distance Sensor Ultrasonic)
- Tape measure
- Cardboard

Setup:

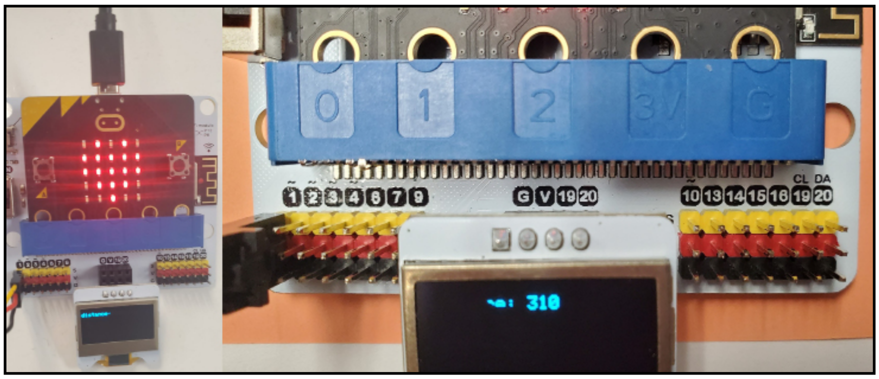
1. Connect an ELECFREAKS groove to octopus cable to the ELECFREAKS iot:bit for micro:bit at pin 1 matching the colors.
2. Plug in the in the ELECFREAKS IIC OLED Module to the top row of the ELECFREAKS iot:bit for micro:bit.



3. Connect the other side of the ELECFREAKS Grove to Octopus Cable to the ELECFREAKS Octopus Sonar:bit (Distance Sensor Ultrasonic). Align black to G, red to V, and yellow to S.



4. Add micro:bit to the ELECFREAKS iot:bit, align the 0 with 0 on micro:bit, 1 to the 1, 2 to the 2, 3V with 3V, and G to G.



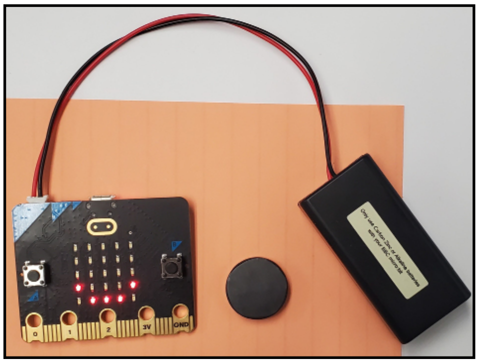
5. With the hardware connected complete steps 1-4 of the software download instructions to download the “microbit-DistanceSensor_SensorBit” software.
6. Complete step 5 of the software download instructions to test the micro:bit. For this station the ELECFREAKS IIC OLED Module will display “distance” and then the distance in centimeters, similar to the display above. The sensor measures relative distance to close objects in centimeters. It is set to go off if it detects something 30 cm or less across it. To help prop up the sensor a cell phone stand can be used. To test the sensor, move an object within the range of the sensor and see if it detects it, it should make a noise.
7. Complete step 6 of the software download instructions.

<u>Station 6: Bluetooth Simulation Station</u>
Material:
- micro:bit
- AAA Power Supply (came with micro bit and had the connection that goes into the back of micro:bit)
- 2AAA batteries
- EMF blocking Fabric

Setup:
1. Complete steps 1-4 of the software download instructions to download the “BluetoothReciever” software on micro:bit 1, Bluetooth Receiver.
2. Complete steps 1-4 of the software download instructions to download the “BluetoothTransmitter” software on micro:bit 2, Bluetooth Transmitter.
3. With micro:bit 1 and micro:bit 2 complete step 5 of the software download instructions to test micro:bit. For this station to test the code, rotate the transmitter micro:bit, as that is being done the receiver micro:bit should display the direction in which the transmitter micro:bit was turned. The second test is to place the emf blocking fabric over the transmitter micro:bit. When this done the receiver should not display anything.
4. Complete step 6 of the software download instructions.

<u>Station 7: Magnetometer Stations</u>
Material:
- micro:bit
- AAA Power Supply (came with micro bit and had the connection that goes into the back of micro:bit)
- 2AAA batteries
- magnet

Setup:
1. Complete steps 1-4 of the software download instructions to download the “microbit-Magnetometer” software.
2. Complete step 5 of the software download instructions to test micro:bit. To test this station the micro:bit should alarm when plugged up. The alarm should turn off when the magnet is placed close to the right hand side of the micro:bit. To prevent the alarm from going off the micro:bit can be turned off when not in use.



3. Complete step 6 of the software download instructions.

Station Code

Stations	Hex File	Uncompiled Code Repository
1. Accelerometer	Accelerometer.hex	Accelerometer (Python)
2. Light Sensor	microbit-IoT_Light_ SensorBit.hex	LightSensor_ SensorBit(makecode)
3. Capacitive Touch	microbit- CapacativeTouch.hex	Capacitivetouch (makecode)
4. Simple Code	microbit- SimpleCodeStation.hex	Simplecodestation (makecode)
5. Ultrasonic Proximity	microbit-DistanceSensor_ SensorBit.hex	Distancesensor (makecode)
6. Bluetooth	BluetoothReciever.hex BluetoothTransmitter.hex	Bluetooth (Python)
7. Magnetometer	microbit-Magnetometer. hex	

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Say:** *Before we can start designing solutions, we need more information.* **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.
3. **Identify what students need to learn about. Say:** *In the previous lesson, you learned about how the electromagnetic spectrum and circuits.* **Ask:** *What other information will you need to know in order to solve the problem?*
4. **Show video. Say:** *Today, you will go around to different stations to experiment with some of the types of sensors and other components that are used in detection applications. We will watch this video about a few different sensors to get an idea of what is available to us for our deterrent system.* Show the video on the detection sensors (8 mins): https://www.youtube.com/watch?v=LNeSz5hfTLI

5. **Introduce the Component Stations. Say:** *For the rest of today, we are going to explore different sensors and components. At each station you will experiment with a simulation. The simulations use a micro:bit, which is a small computer that is programmed to tell the component what to do. This is similar to how devices like smart phones and game controllers have a small computer that is programmed to tell all its components what to do.* [Show the micro:bit diagram. New micro:bit with sound: https://microbit.org/get-started/features/overview/] *The micro:bit acts as the brain that sends information to and receives information from the sensor or component. [(Code option) The micro:bit must be programmed by a human using a programming language also called "code." At each station you will see the code that makes the micro:bit work for that station.] Each component you will explore has different capabilities and constraints that are important to know and record in your notebooks. As you investigate the components, think about how they can be used in a deterrent device. Play close attention to the stations that have a star on them.*
6. **Complete the Sensor Stations:** Have students rotate through the stations labeled in the classroom using the handouts 5.A-5.G. There should be no more than four students at each station. Spend 10-15 minutes at each station performing the activities indicated.

Day 1 Stations

Station 1: Accelerometer sensor
Summary: Use a micro:bit programmed to show an arrow that always points in the direction the micro:bit is tilted (left, right, up down) (X and Y axis.) Have students rotate the micro:bit to confirm. Have students lift the micro:bit in the air or hold the micro:bit close to the ground (Z axis.) Does the height of the micro:bit affect its ability to sense tilt in the X/Y axis?

Station 2: Light sensor
Summary: Use a micro:bit and an attached external light sensor on Pin 1. The micro:bit is programmed to display the level of light detected by the sensor. Students can experiment with shining a bright light on the sensor, covering the sensor with a dark cloth, covering it with a cup. Students can note what light levels are detected for each situation (extra materials: cup, dark cloth, flashlight). Students can note: light level sensitivity of the sensor.

Station 3: Capacitive touch station
Summary: Students watch a video. Use the touch sensor on the micro:bit. When touched, the LED will flash a symbol and the micro:bit will make a noise. Students experiment with touching using a bare finger, a latex/nitrile glove covered finger, a fabric glove covered finger, etc.

Station 4: Code Station
Students complete a code puzzle using printed out blocks of code.
Code option 2: MakeCode, online coding (not included)

Day 2 Stations

Station 5: Ultrasonic Proximity sensors
Summary: Use a micro:bit with an attached external ultrasonic distance sensor on Pin 1. The micro:bit is programmed to sound a buzzer when something comes within its scope of distance sensing. Students can experiment with how close objects have to be before they are sensed by the distance sensor. (extra materials: ruler or tape measure, medium sized piece of cardboard to use for more easily triggering the sensor). Students can note: distance constraints for triggering the sensor.

Stations 6: Bluetooth Simulation stations
Summary: Use two micro:bits programmed to communicate with each other using Bluetooth simulation via radio wave communication. This builds on the accelerometer station from Day 1. One "sender" micro:bit will perform the physical tilting but the other "receiver" micro:bit will show the arrow indicating which direction the sender is tilting. An Electromagnetic wave diagram will show different frequencies used for different things. Bluetooth operates in the 2.4 GHz band. Students experiment with distance between devices and interference. For distance, two people take devices and walk further away from each other. Students can use a piece of nickel-copper fabric (EMF blocking) to experiment with blocking signals for interference. Students can go outside of the classroom with the sender micro:bit. Students can note: Distance constraints and constraints about interference.

NOTE: For the Bluetooth Simulation Station:
Although the micro:bit does have Bluetooth capabilities, we are simulating Bluetooth communication using the micro:bit radio feature. Both protocols operate at 2.4Ghz, however the radio communication is much easier to demonstrate for the lesson as it does not require a pairing phase.

Station 7: Magnetometer Stations
Summary: Students watch a video on how magnetometers work. Using the compass (magnetometer) sensor on the micro:bit and a magnet students will see how this sensor is affected by a magnet. When the magnet is close to the micro:bit the micro:bit will not alarm but as soon as the magnetic field changes the magnet is removed the micro:bit alarms. Students can experiment with distance and the location of the magnet.

Closure

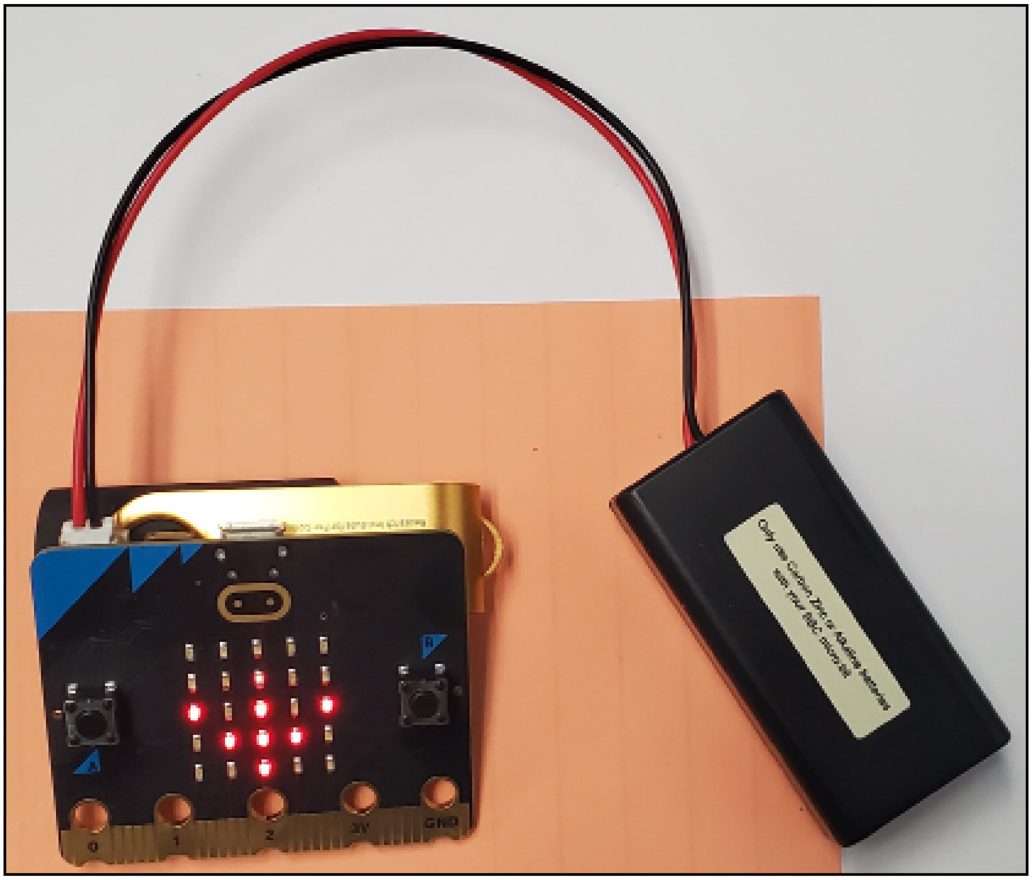
7. **Connect this activity to the Engineering Design Challenge (each day).** Ask students to discuss in their teams and report out:
   - How do the physical properties of electromagnetic or sound waves help some sensors to work?
   - What are some of the constraints of the simulated devices you've experimented with today?
   - How will your knowledge of the components you saw today contribute to your design?

5.A Station 1: Accelerometer Sensor ★

Learning Goal: Explain what the accelerometer sensor senses and one way that it is used. (Code option) Explain one relationship between the code and the operation of the sensor.

Instructions:

1. Watch the short video that gives examples of uses and briefly explains the science. https://www.youtube.com/watch?v=RLQGZI0IpjQ
2. Have the team experiment with the built-in accelerometer function of the micro:bit in the following ways and answer the questions in their notebooks:
   - Action: Rotate the micro:bit in several directions
     Observe: What happens on the micro:bit screen as you rotate the device?
   - Action: Try raising the micro:bit high in the air or placing it low to the ground and rotating it.
     Observe: Does raising or lowering the micro:bit change anything about how it operates?
   - Action: Look briefly at the code that makes this station work.
     Discuss: What do you think the command "display.show()" does?
   - Notebook: How does the accelerometer help a cell phone or car to function better?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?



5.B Station 2: Light Sensor ★

Learning goal: Explain that the ambient light level of the environment can be detected by a sensor.

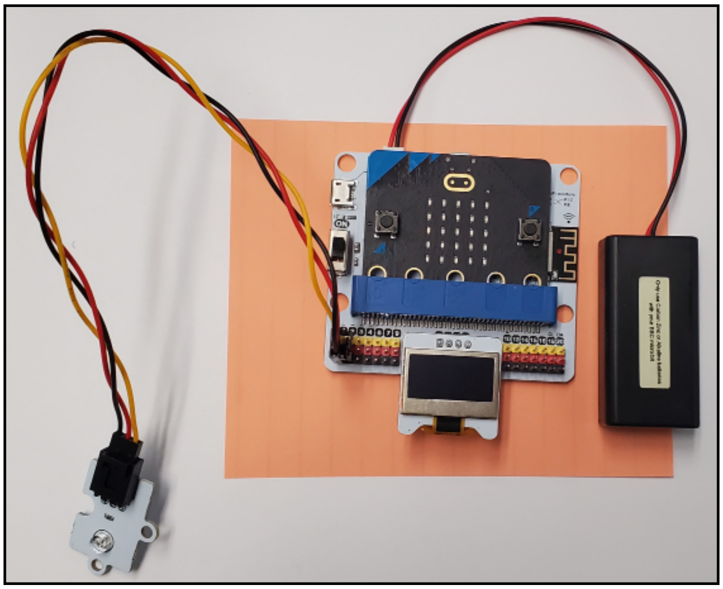
The light must be within the visible spectrum range of 38 nm to 700 nm. The sensor reading on the micro:bit is a relative, sensor specific reading that indicates the light level being sensed.

Instructions:

1. Watch the short video about light sensors: https://youtube.com/clip/UgkxvAtIXH6qQazY0UKP4sfCa0k6JnBghG-A
2. The LED screen shows the amount of light that the sensor is receiving. This measurement is in lux units. Have your team experiment with the external light sensor attached to the micro:bit.
3. You will experiment with placing different objects over the sensor to see how they affect the light readings.
   - Action: Place your hand over the light sensor
     Observe: What reading does the sensor give?
   - Action: Place different cups over the light sensor
     Observe: For each cup, how do readings from the sensor change?
   - Action: Place different pieces of fabric over the light sensor.
     Observe: For each type of fabric, what reading does the sensor give?
   - Action: Shine the flashlight on the sensor

Observe: What is the maximum reading you can get?

- Discuss: What did you notice about the light sensor readings for each type of object?
- Discuss: Do you think this code looks complicated or simple? Why?
- Notebook: How does being able to sense the level of light in the atmosphere help your cell phone to function better?
- Notebook: How might you use this sensor in your design?
- Notebook: What constraints do you need to consider if you use this sensor?

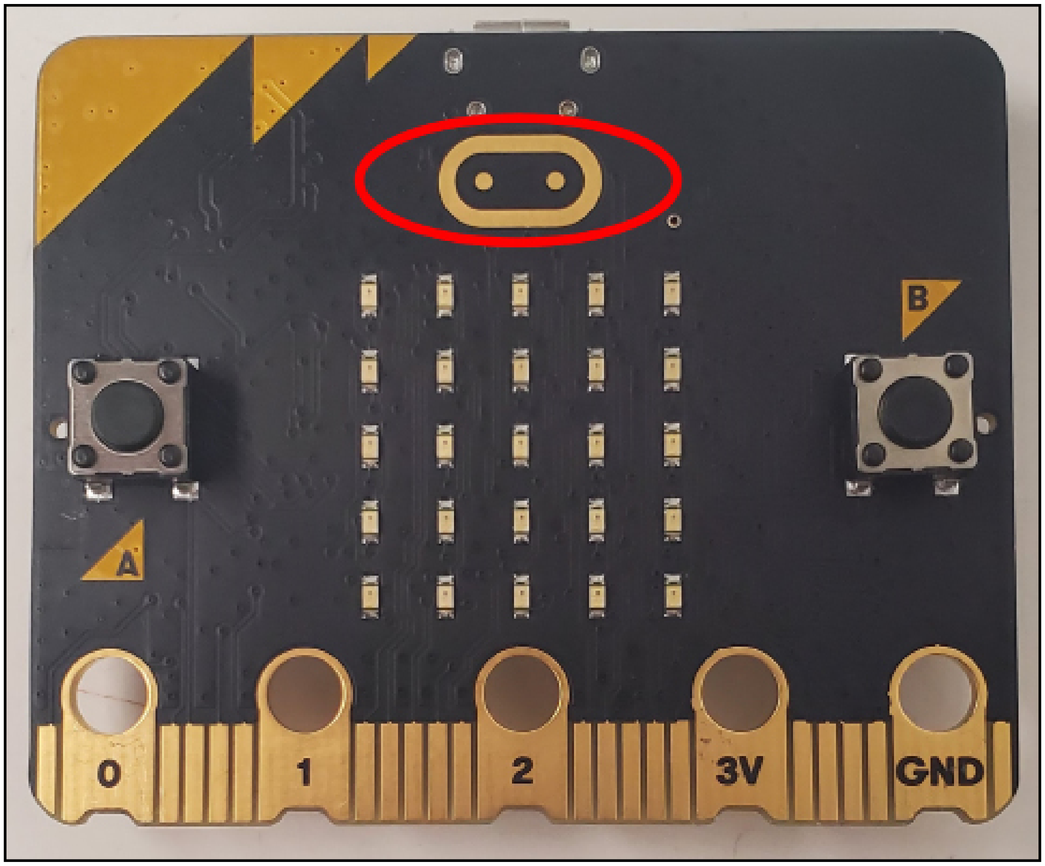


5.C Station 3: Capacitive Touch Station ★

Learning goal: The human body is a conductor of electricity.

Instructions:

1. Watch the short video about capacitive touch: https://www.youtube.com/watch?v=IdWXT391FJE
2. Experiment with what will register on the sensor.
   - Action: Touch the micro:bit logo with your finger.
     Observe: How long do you have to touch it before the buzzer sounds?
   - Action: Now experiment with touching the logo in various ways to see if the buzzer still sounds.
     Put on the rubber gloves
     Put on fabric gloves
     Touch with your fingernail
     Use a pencil or pen to touch it.
     Discuss: What experiments made the buzzer sound and which didn't.
   - Notebook: Why do you think that some of ways you tried did not make the buzzer sound?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?

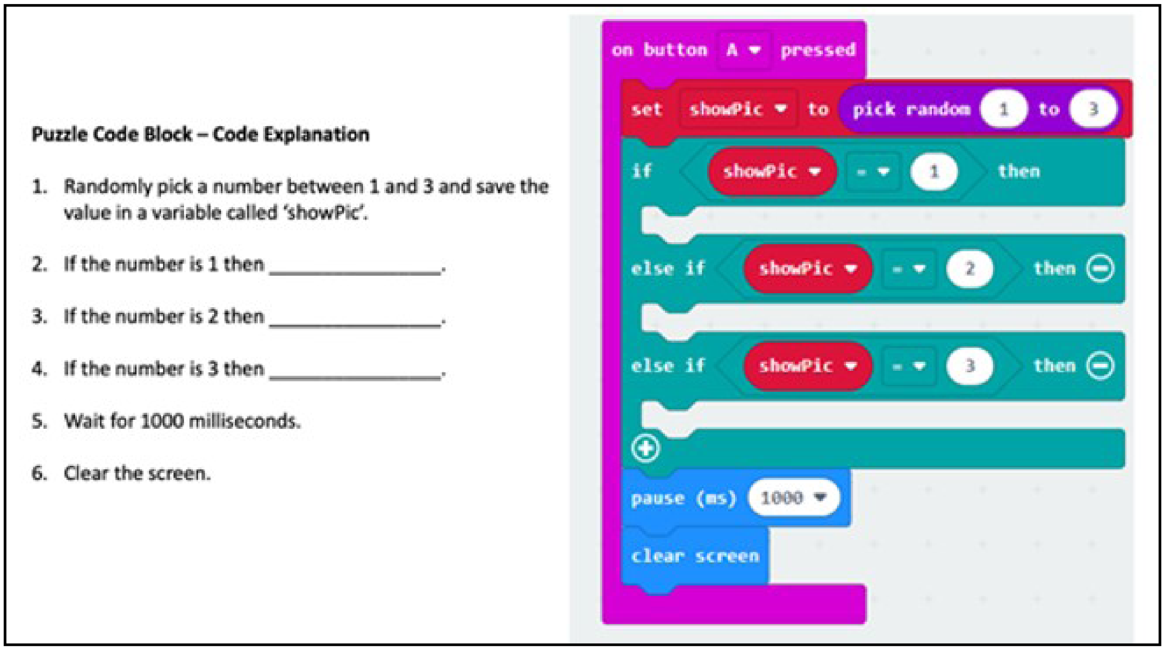


5.D Station 4: Code Station, Option 1: Simple Code Puzzle

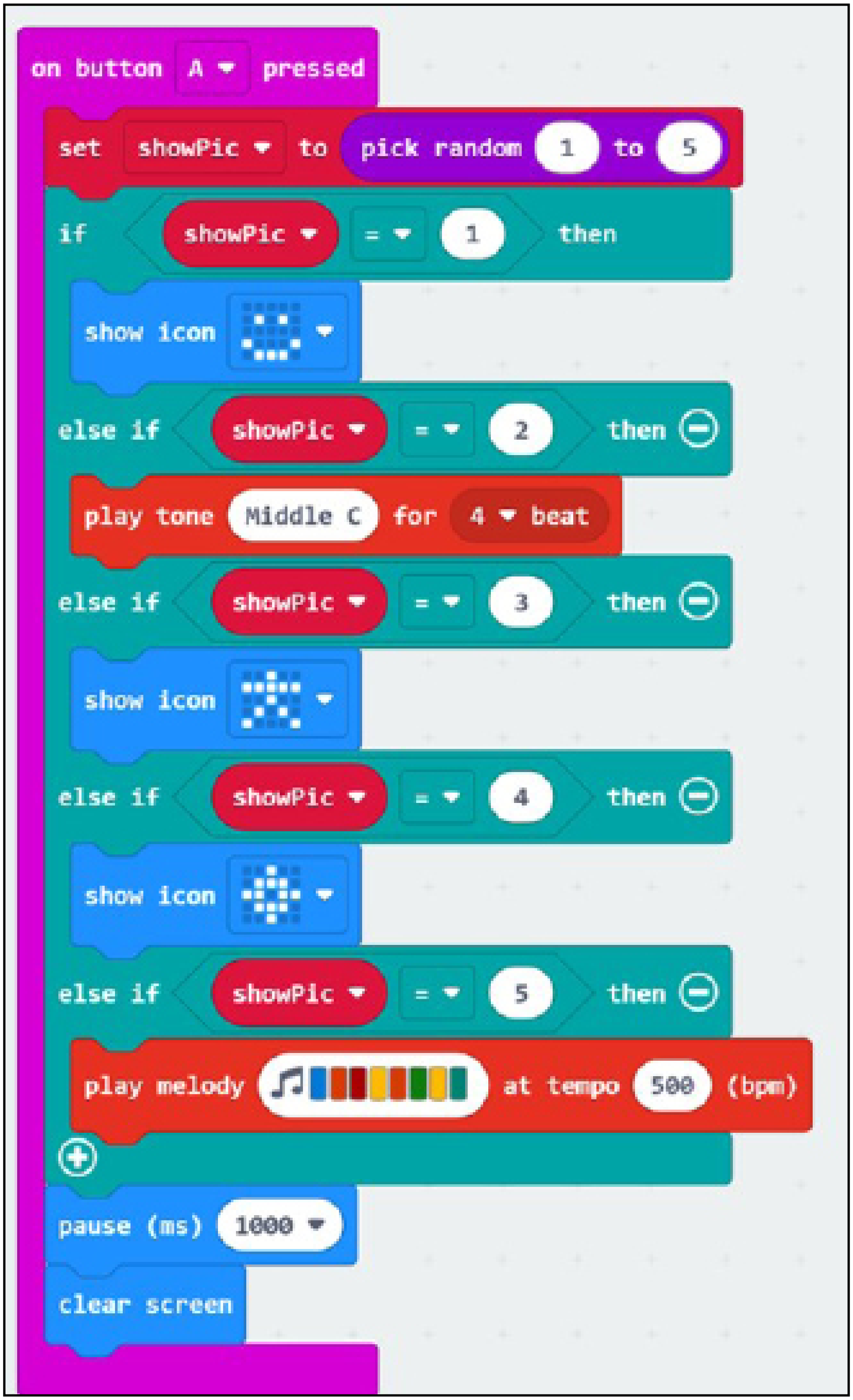
Learning goal: Microelectronic devices require coding to make them work.

Instructions:

1. Look at the Full code page. This type of code is called Block Coding because the code fragments are contained in visible, colorful blocks that can be assembled together to make a program.
2. This code corresponds to the micro:bit at this station. The micro:bit operates like this:
   a. When you press the 'A' button, it chooses a random number between 1 and 3
   b. Based on the number is chooses, the micro:bit will do 1 of three things.
      i. For #1, the micro:bit will show a smiley face
      ii. For #2 the micro:bit will play a short musical clip
      iii. For #3 the micro:bit will show a stick figure.
3. Look at the block code and see if you can correspond the code to the way the micro:bit functions. You will see a few "if" statements, and code that tell the micro:bit what to do for each number between 1 and 3.
4. Now, using the code puzzle, **<u>duplicate</u> the code that is show on the Full code page**.
5. Discuss: Once all team members agree that the code is correct, move to step 5.
6. Now think about if we wanted to **<u>change</u>** what the micro:bit shows for each number:
   a. For #1, the micro:bit will show a stick figure.
   b. For #2, the micro:bit will show a smiley face.
   c. For #3 the micro:bit will play a short musical clip.
7. Work with your team mates to **<u>change</u> the location of the puzzle pieces so that the code corresponds to the new scenario** in step 5.
8. Notebook: How did you change the code puzzle for step # 5 and 6? Draw the new order of the code blocks in your notebook.



5.E Station 4: Code Sheet

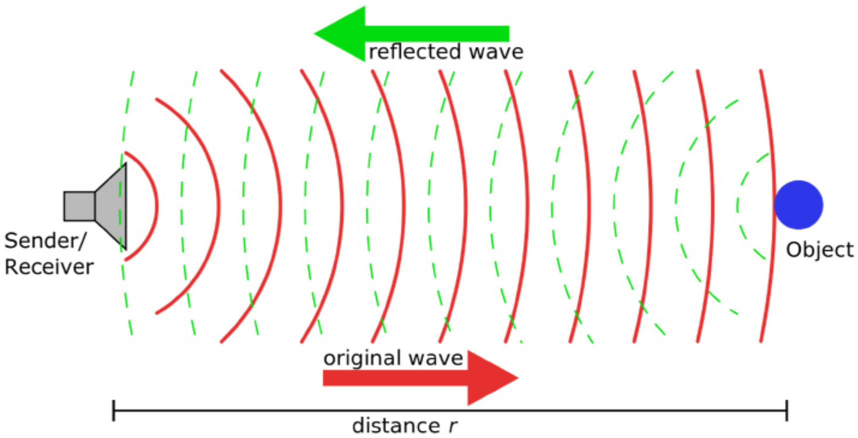


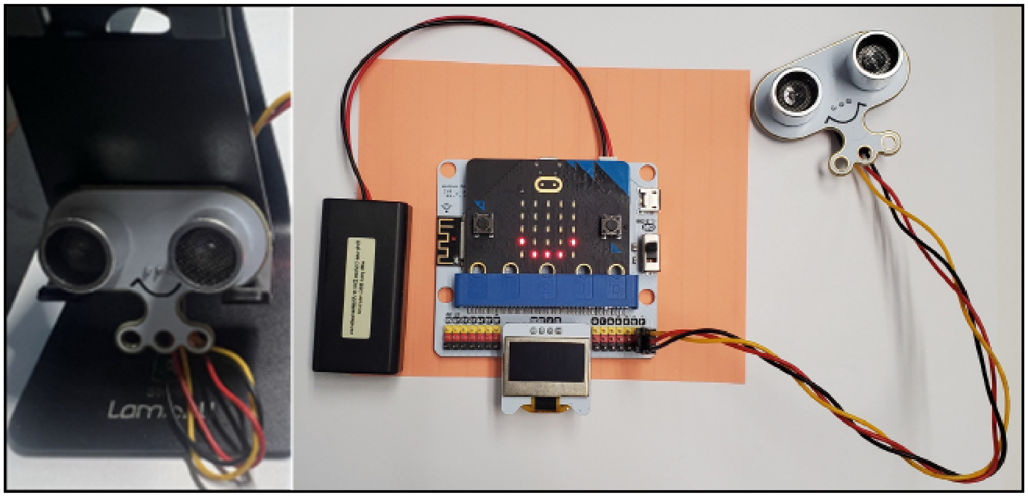
5.F Station 5: Ultrasonic Proximity Sensor

Learning Goal: Explain how sound wave properties play a part in sensing distance.

Instructions:

1. Complete the reading and look at the figure below as you view the video: https://www.youtube.com/embed/sYLMW7QhAJQ?start=1&end=79
2. You will determine how close you need to be to the sensor to set off the alarm.
   - Action: Use the piece of cardboard to experiment with the sensing range of the distance sensor. Hold the cardboard at the level of the sensor, directly in front of it, starting from 5 feet way. Slowly move the cardboard toward the sensor until you hear the alarm.
     Observe: Measure how close you need to be to the sensor before it reacts.
   - Action: Using the cardboard, try different angles of approach. For example, instead of coming directly in front of the sensor, come in from the left side of the sensor or the right, top or bottom sides.
     Observe: How does the angle of approach affect whether or not the sensor reacts?
   - Notebook: How do sound waves help the sensor to work?
   - Notebook: How might you use this sensor in your design?
   - Notebook: What constraints do you need to consider if you use this sensor?



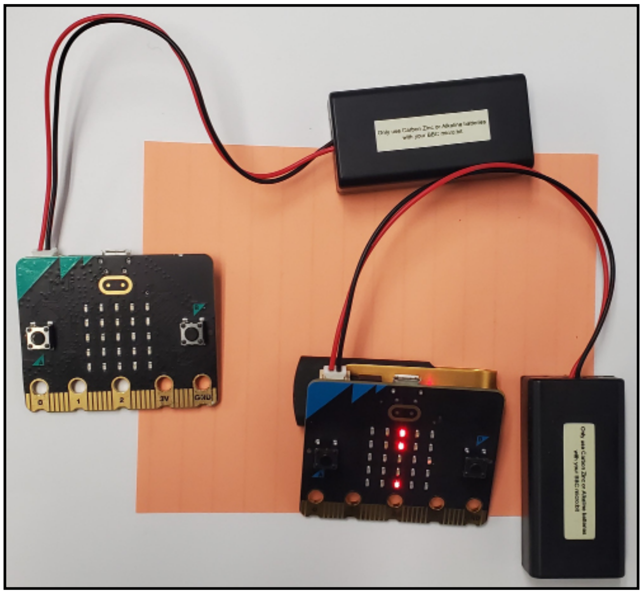


5.G Station 6: Bluetooth Simulation Station

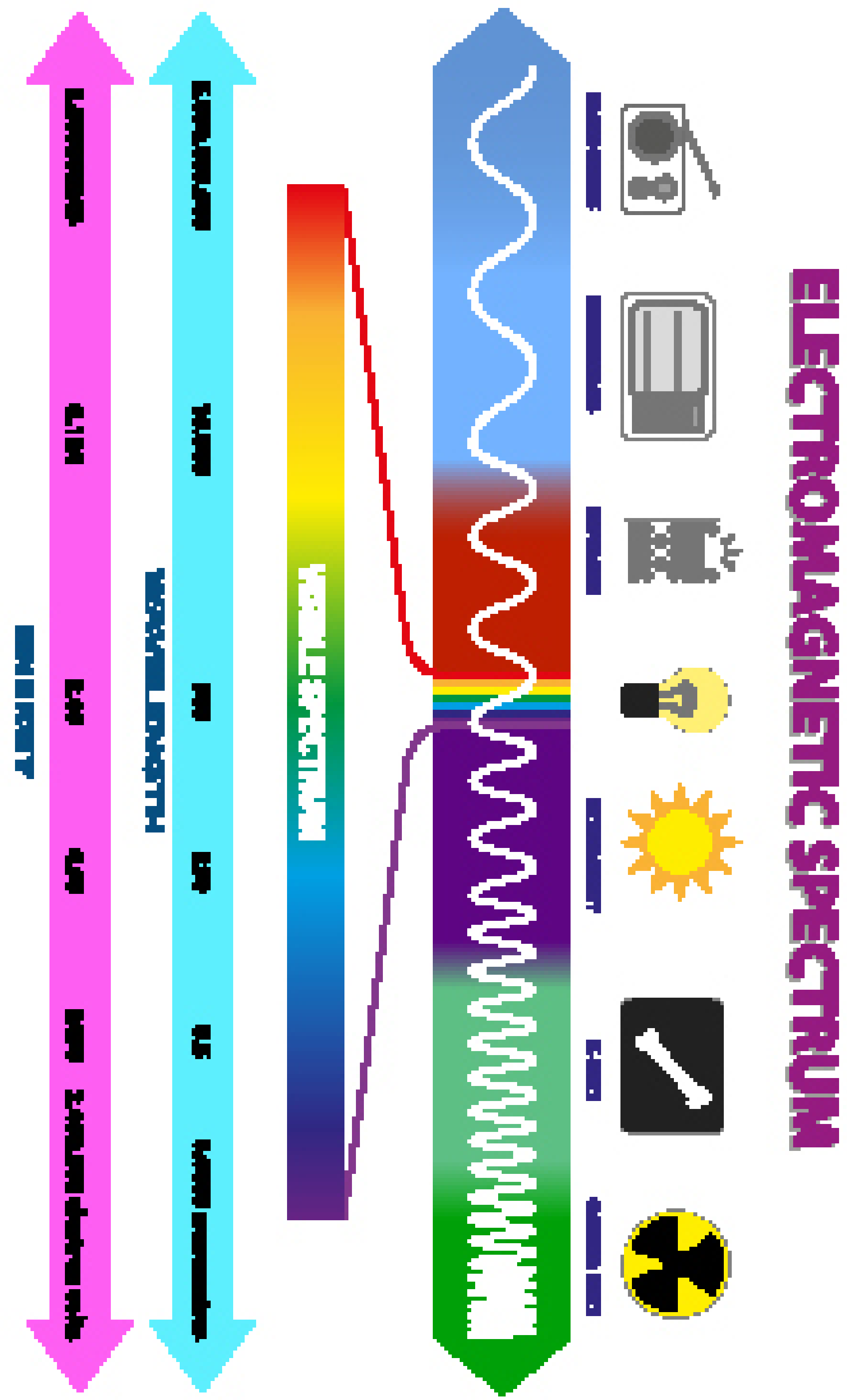
Learning goal: Explain how electromagnetic waves allow for communication between devices.

Instructions:

1. Watch the video for an overview of how Bluetooth works: https://www.youtube.com/embed/1I1vxu5qIUM?start=1&end=221
2. At this station, two micro:bits are set up to speak to each other. This station is somewhat like the Accelerometer station from last time. But, instead of the arrow on the micro:bit pointing in the direction you tilt it, a different micro:bit will control the direction the arrow points in. One micro:bit will act as a sender (like the cell phone in the video.) The other micro:bit is the receiver (like the earbuds in the video.) You will rotate the sender like you did at the Accelerometer station. However, the sender micro:bit will not display anything. The receiver micro:bit will display the direction that the sender micro:bit is rotated in. The two micro:bits are communicating with each other using electromagnetic waves, like Bluetooth.
   - Action: Rotate the sender micro:bit and observer the receiver micro:bit.
     Discuss: What do you notice about the relationship between the sender and receiver?
   - Action: Try moving the receiver far away from the sender, but remain in the same room.
     Discuss: How far away can the sender and receiver be and still communicate?
   - Action: Try moving the receiver beyond the same room so that there is a wall between it and the sender.
     Discuss: Can the sender and receive still communicate? How can you tell?
   - Action: Try covering the sender micro:bit with the electromagnetic signal blocking case.
     Discuss: Does this experiment block the signal? How can you tell?
   - Notebook: In what ways can you disrupt the electromagnetic wave signals between the two micro:bits?
   - Notebook: How might communication between two different or distant components be useful in your design?
   - Notebook: What constraints do you need to consider if you use Bluetooth communication?



5.G Station 6: Bluetooth Simulation Station

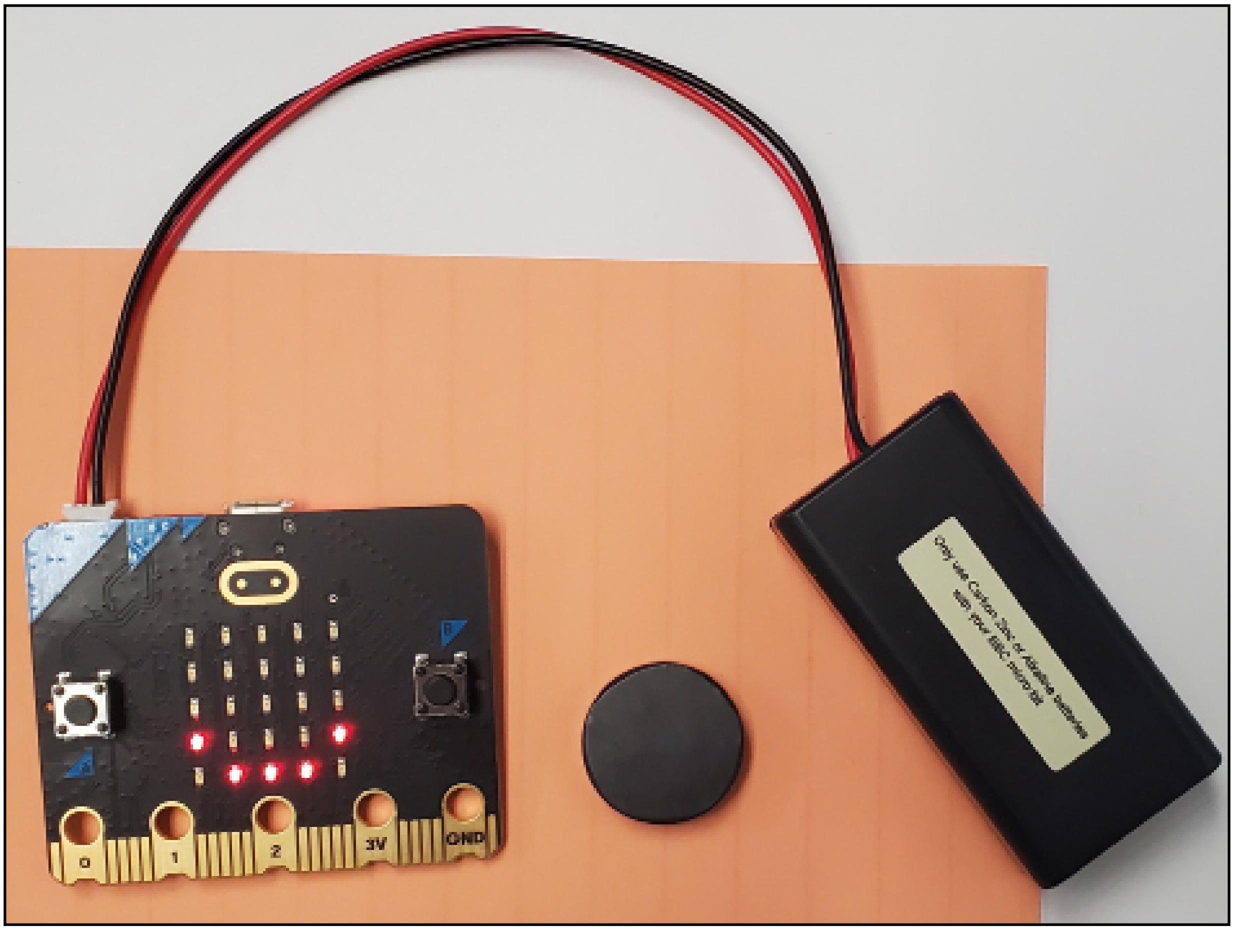


5.H Stations 7: Magnetometer Stations ★

Learning Goal: Explain how magnets' magnetic field can be used to create a switch in an electrical circuit.

Instructions:

1. Watch the two short videos about magnetometers:
2. Experiment with the sensor.
    - Action: Place magnet on the side of the micro:bit and rotate it around the micro:bit. Continue moving the micro:bit further away as you rotate it around the micro:bit in circles.
      Observe: See how far the magnet can be from the micro:bit before it starts to alarm. Take a ruler and measure the top distance, left distance, bottom distance, and right distance.
    - Action (optional): Try different magnets and see if there is a different response from the micro:bit.
    - Notebook: Why do you think the placement of the magnet made the buzzer go off?
    - Notebook: How might you use this sensor in your design?
    - Notebook: What constraints do you need to consider if you use this sensor?



LESSON SIX:

Lesson Objectives
The student will be able to:
- Work toward the solution of a problem using engineering.
- Develop and evaluate a plan acting as an engineer.
- Describe the trade-offs of an engineered design.
- Justify why their solution is appropriate.

Time Required
Two-three 50-minute lessons

Materials
Per classroom
- EDP Poster

Per group
- micro:bit
- LED light
- magnet
- (8) alligator clips
- box
- Clear tape
- Electrical tape
- AAA battery holder
- AAA Batteries

Per student
- Engineering notebook
- EDP Slider and paperclip

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-2, HS-ICP3-3, HS-ICP3-5

IAS Science and Engineering Practices
- SEP.2, SEP.5, SEP.6

Lesson Summary
In this lesson, students will use their knowledge of electrical circuits and sensors to design an electrical deterrent device for those trying to enter a secure carrying case. Students will work through the solution section of the engineering design process to plan, design, and test their design and utilize evidence-based reasoning to justify design decisions.

Background
Teacher Background
Evidence-based reasoning (EBR) refers to the engineering practice of providing rationale for design ideas and decisions. It is somewhat similar to scientific argumentation in the sense that it involves using evidence and explanations to support a statement, but it is ultimately different. In EBR, the statement being supported is an engineering design idea or decision, whereas in scientific argumentation it is a claim or conclusion about a natural phenomenon. EBR is used in the context of generating solutions for engineering problems; scientific argumentation is used to answer scientific questions about nature. Science and mathematical principles are important justifications for scientific argumentation and EBR. However, EBR often also includes justifications related to the context, criteria, and constraints of the engineering problem (e.g., cost, user needs, technical feasibility). In this lesson, students will use EBR to think deeply about their proposed design ideas and to justify them with information about the engineering problem and their science and mathematics knowledge.

It is important to provide evidence-based reasoning when proposing a solution to a problem. Without the ability to provide reasoning, the explanation will not be enough for the client to accept it. This is an essential component of good science and engineering practices. There must be logic and data-based explanations for a solution. At the completion of the challenge, the students will be asked to defend their decisions and designs using their knowledge and understanding of the science content standards, their evidence from data collection, and their experiences using the engineering design process.

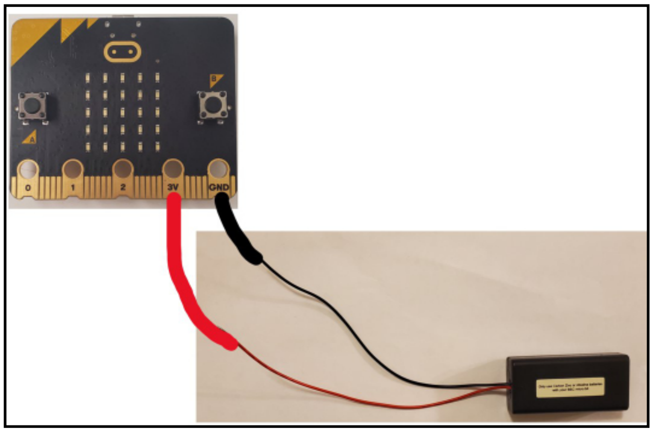
Electrical Safety
- Please visit the micro:bit website to go over the safety protocol they have for handling the micro:bit
  - https://microbit.org/get-started/user-guide/electrical-product-guidance/

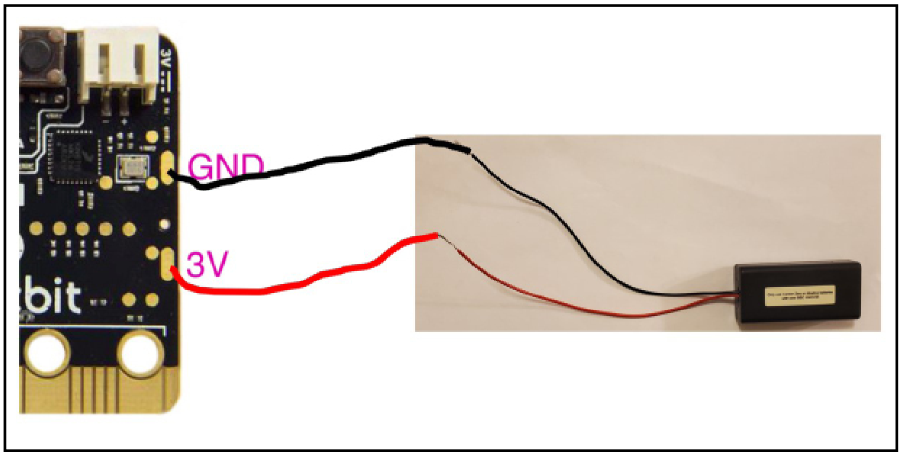
- NOTE: For this design will be using an external power supply that did not come with the micro:bit.

- The micro:bit is only rated for a 3V power supply
- LEDs will only work in a parallel circuit format since the voltage in each path stays the same. There is not enough voltage in a series circuit to power the micro:bit and an LED light bulb
- Use electrical tape to hold electrical components together at joints. Use the clear tape to hold down everything else.

Electrical Connections
Electrical connection of micro:bit to external power supply:
NOTE: This project does not use the power supply provided by micro:bit. An external power supply will be added using the edge connectors.

Below are two ways in which the power supply can be connected to the micro:bit
- The negative terminal is black and is connected to GND
- The positive terminal is red and is connected to 3V





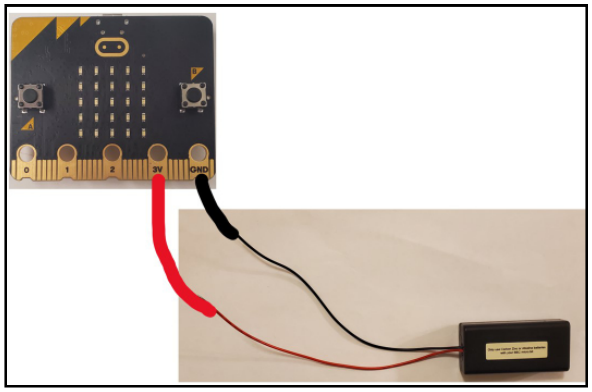
Key Terms
prototype, criteria, constraints

Assessments
Activity Embedded Assessment
Listen to group discussions as they work through their group brainstorming discussion, 6.C Evidence-Based Reasoning Graphic, 6.F Collaborative Planning, and 6.I Testing Reflection to assess their ability to work in teams, use the engineering design process, and justify their design decisions.

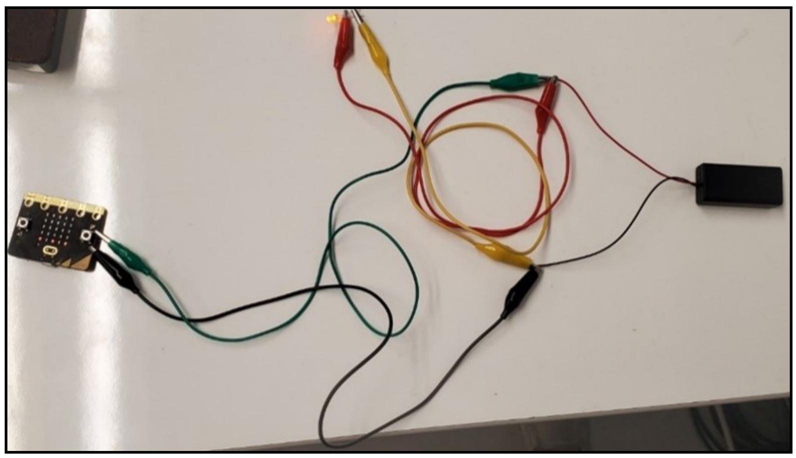
Duplication Masters:
- 6.A Client Memo
- 6.B Generating Ideas
- 6.C Evidence-Based Reasoning Graphic
- 6.F Collaborative Planning
- 6.G Coding Components
- 6.H Testing Procedure
- 6.I Testing Reflection
- 6.J Redesign

Educator Resources:
- 6.D EBR Instructions
- 6.E EBR Example
- Micro:bit safety: https://microbit.org/get-started/user-guide/electrical-product-guidance/
- Code: https://nanohub.org/projects/scalek12curricu/files/ browse?subdir=LockITUp

Example of Series Circuit



Example of Parallel Circuit



Sensors

Student will have access to four different codes for their alarms for their deterrent system:

1. Light sensor with alarm: when exposed to light above a specified level it will alarm.
   - The code will be written to 100. Your team may have to adjust the light level based on the lighting in the room.
2. Accelerometer sensor with alarm: when the box is shaken the alarm will go off.
   - This is a sensitive alarm and will go off before the box is opened
3. Tough sensor with alarm: when a spot on the carrying case is touched the alarm will go off.
   - This alarm will be limited to one location but in real life it can represent an area or perimeter.
4. Magnetometer sensor with alarm: when the magnetic strength between the sensor and magnet is reduced the alarm will go off.

- Depending on placement the alarm will go off as the case is being opened.
- The code will be written to 200. Your team may have to adjust the level based on how sensitive your team wants the alarm to be.

Deterrent Code
Codes are provided in two formats:
1. The MakeCode web link connects to the web-based Microsoft MakeCode studio. There users can see the block code for the program, make any edits to the code, and download the .hex file.
2. The .hex file format is already setup to be copied to the Micro:bit.

Sensor and Alarm	MakeCode Links	Hex Files
Light Alarm (Light sensor)	https://makecode.microbit.org/S56545-39560-12448-23666	https://nanohub.org/projects/scalek12curricu/files/browse?subdir=LockITUp
Tilt Alarm (Accelerometer sensor)	https://makecode.microbit.org/S82249-82896-06889-49262	
Touch Alarm (Touch sensor)	https://makecode.microbit.org/S80057-90004-18549-34670	
Magnet Alarm (Magnetometer sensor)	https://makecode.microbit.org/S03556-56933-83886-02953	

Instructions for downloading code:
- Micro:bit User Guide: Transfer code to micro:bit
  - Instructions for different devices: https://microbit.org/get-started/user-guide/transfer-code-to-the-microbit/
  - Video on moving .hex files to micro:bit: https://www.youtube.com/watch?v=iIxmk_OYiE0&t=32s
- Downloading from MakeCode: Coding with micro:bit - Part 2 - Connect & Code: https://www.youtube.com/watch?v=_cTHIQXwEO4&list=PLmqeu38gRdJVCMUhgmF8OrjOhYpYtoh9_U&index=2

Before the Activity
- On one poster-sized sheet of chart paper, draw an Evidence-Based Reasoning template (like worksheet 6.C) This will contain the explanations of the terms on the worksheets and what information goes in each section. You will fill out these explanations during the unit but make sure there is a way to continue to display the graphic so that students can refer to

these instructions when they fill out their team EBR graphics.

- Prepare all of the building materials: Group items can be placed in the box prior to class or items can be passes out as needed per group
- Make copies of the duplication masters for the following amounts:
  - 6.A Client Memo (1 per student)
  - 6.B Generating Ideas (1 per student)
  - 6.C Evidence-Based Reasoning Graphic (1 per student)
  - 6.F Collaborative Planning (1 per group)
  - 6.G Coding Components (1 per group)
  - 6.H Testing Procedure (1 per group)
  - 6.I Testing Reflection (1 per student)
  - 6.J Redesign (1 per student)

Classroom Instruction

Introduction

1. **Identify where they are in the engineering design process. (Plan)** Direct students' attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Say/Ask:** *As engineers, we have been using the engineering design process to guide us. What steps have we done so far?* Students should say that they have defined the problem and learned some science/background knowledge that will help them solve the problem. **Say:** *Now that we have defined our problem and learned background information about electrical circuits, we are ready to start planning our solution to the problem. We can always go back to define and learn (point to arrows on poster that show going back to previous steps) if we need to learn more about the problem or background information. For now, we will move on to the next step, which is to plan a solution.*
2. **Read the client memo. Say:** *The client would like to provide more information for us to solve this engineering challenge.* Handout 6.A Client Memo 2 from the client which gives students additional criteria and constraints for the engineering challenge.
3. **Review the criteria and constraints.** Discuss the criteria and constraints of the project, which can be found in 6.A Client Memo 2. **Ask:** *What criteria and constraints do you need to pay attention to when planning your solutions?* You can have students work in their teams to identify any new constraints now that they have all the information from the client.
4. **Establish a timeline.** Discuss their task for the day and what they need to accomplish by the end of the first class period.

This lesson should take two to three days so set a goal of completing the plan stage of their design with their team for day one, a goal of building (try) for day two, and a goal of testing and redesigning their design for day three.

Activity

5. **Brainstorm individually.** Explain that brainstorming is an important part of the engineering design process. To help with brainstorming the teacher could have a box of material available for the students to see. Students should not have their material kit yet because it can become a distraction. **Say:** *The goal of brainstorming is to develop many different ideas so you have many to choose from. Not all of the ideas will be perfect, but you will be able to combine and adapt your ideas with your teammates' ideas to develop a team design that meets the criteria and constraints the client put forth.* Hand out the 6.B Generating Ideas prompts. **Say:** *You are going to document your brainstorming ideas on this handout and answer the following questions. If you would like you can also write this information down in your notebook.* Give students time to sketch their individual brainstormed ideas in 6.B Generating Ideas. Encourage students to have more than one idea (at least 2) so that when they meet with their team, they will have a lot of ideas to pull from. Students should justify their choices based on what they learned in Lessons 2, 3, 4, 5, 6.
6. **Plan as a team.** Hand out the 6.F Collaborative Planning prompts. **Say:** *Now that you have thought of some ideas individually, you can work in your team and discuss the different design ideas using prior knowledge from the "Learn" lessons and the ideas list you created during your individual brainstorming time. As a team you will need to come up with at least two ideas.*
    a. Give the students time to work in their teams to brainstorm several ideas for solving the client's problem using the 6.F Collaborative Planning handout. Once they have considered all their design options, but before they make their final decision and answer questions 1 and 2 on 6.F Collaborative Planning, introduce evidence-based reasoning.
7. **Introduce evidence-based reasoning. Say:** *Each team now has at least two different options for their design strategy. As a team, you need to decide which design would best solve the client's problem. Scientists and engineers work hard to use evidence in making important decisions like this.* Project an 6.C

Evidence-Based Reasoning Graphic on the board or write on a piece of poster paper in front of the class. **Say:** *To help you with your planning, we are going to be using evidence-based reasoning. This means that you will need to support your design ideas with evidence and explanations. We will discuss each of the parts together.*

NOTE: To introduce the concepts needed for Evidence-Based Reasoning, you can fill out the projected version of the 6.C Evidence-Based Reasoning Graphic with explanations of what type of content fits in each section. Use the 6.D EBR Instructions as a reference to help as you provide general explanations and reminders of what kind of information should go in each section. This is different from what the students will write in their templates. They will fill out the sections with information specific to the engineering design problem and their teams' designs. If students are struggling with any of the sections, you can use the 6.E EBR Example to help prompt them.

8. **Review the engineering problem.** Direct students' attention to the "Problem including Criteria & Constraints" section of the 6.C Evidence-Based Reasoning Graphic. On the poster, write down a general definition of the term problem: "the engineering problem the client asked you to solve". Instruct students to write a summary of their engineering problem in this section, leaving room for criteria and constraints.
9. **Review the criteria and constraints of the problem. Ask:** *Can anyone remind me what the words "criteria" and "constraints" mean?* Criteria are the requirements, or goals, of the designed solutions. Constraints are things that limit design possibilities. Write these definitions on the EBR poster. Refer students back to their lists of criteria and constraints from their Define the Problem notes. **Ask:** *What are some of the criteria and constraints of our engineering problem?* Discuss the criteria and constraints of the problem, and have students write them in the "Problem including Criteria and Constraints" section of the 6.C Evidence-Based Reasoning Graphic.
10. **Introduce the concept of simplifying assumptions. Say:** *Engineers usually don't deal with every single aspect of a problem at once because that makes the problem too difficult to solve. Instead, they make a complex problem simpler, sometimes by ignoring some of the details of the problem and sometimes by pretending certain things are true about the problem when they actually aren't.* Write "ways to make a complex problem simpler" in the "Simplifying Assumptions (if

any)" section of the EBR poster. **Ask:** *What are some parts of our engineering problem that we can make simpler?* This may be a difficult concept for students, so provide an example or two if students struggle.

a. Simplifying assumptions (things to ignore): the external powerpack that comes with the micro:bit will not be used in out circuit an external supply as part of the circuit will be used to power the micro:bit

b. Simplifying assumptions (assume certain things are true when they aren't): materials used in classroom are similar to those the client has, the micro:bit will act as a resistor in our calculation even though the micro:bit is an electrical system made up of multiple circuits.

11. **Explain what information goes in each of the remaining sections.** Have students guess at what kind of information they think should go in the "Design Idea," "Data/Evidence," and "Justification" sections of the 6.C Evidence-Based Reasoning Graphic. Write down relevant student suggestions in the appropriate section of the EBR poster. This could include:
    - **Design Idea:** Description of the design idea; drawings of the design idea, possibly with different views (e.g., top view, side view); dimensions/sizes/angles; materials in the design idea labeled to show where they are used; interesting features of the design idea.
    - **Data/Evidence:** Observations and data that show why you think your design will work. Examples: data from the labs and simulations.
    - **Justification:** Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.
12. **Choose a design and justify it.** Have students return to their design ideas. Give teams the time to narrow down their designs to a final two options. Once they have their best two design ideas, direct students to fill in the remainder of the 6.C Evidence-Based Reasoning Graphic.
13. **Identify where they are in the engineering design process. (Try) Say:** *Now that we have our design decision and plan, we can start prototyping our design.* **Ask:** *What phases of the engineering design process have we used so far? What do you think we will be doing next?*
14. **Review safety. Say:** *Before we start working on our prototypes let's take the time to go over some additional electrical safety information.* For this project we will be using micro:bits as our sensors for our deterrent device. Please visit the micro:bit

website to go over the safety protocol they have for handling the micro:bit

a. https://microbit.org/get-started/user-guide/electrical-product-guidance/

NOTE: For this design students will be using an external power supply that did not come with the micro:bit.

b. The micro:bit is only rated for a 3V power supply

c. LEDs will only work in a parallel circuit since the voltage in each path stays the same. There is not enough voltage in a series circuit to power the micro:bit and light bulb

d. Use electrical tape to hold electrical components together at joints. Use the clear take to hold down everything else.

15. **Provide the building materials and coding instructions.**
16. **Begin building.** If teams finish planning before the end of class, you may choose to allow them to begin building and coding their prototype. If not, give students time in the next class to build their prototype. For this first design the students should build what they planned for. They may be tempted to change their design as they build based off of what they learn but encourage them to first build what they had originally planned. Allow 20-30 for this activity then introduce testing.
17. **Identify where they are in the engineering design process. (Test) Say:** *Now that some of you have completed your initial prototypes let's discuss the next phase of the engineering design process, the test phase.*
18. **Introduce the testing procedure.** Before students are ready to test their prototypes hand out 6.H Testing Procedure.
19. **Begin testing.** After students are finished building their prototypes, have them begin testing following the guidelines in the 6.H Testing Procedure.
20. **Reflecting on the testing process.** Have students complete both sections of 6.I Testing Reflection. This will help them reflect on their designs and begin thinking about how they want to redesign their solutions to better solve the engineering problem. **Say:** *It is important for engineers to improve their designs. Professional engineers know that the first idea is almost never the best one.*
21. **Planning to redesign.**
22. **Redesigning prototypes.**

Closure

23. **Connect to the EDP. Ask:** *Which phases of the engineering design process did we use today? What should we do next?*
24. **Review the design challenge.**

6.A Client Memo 2

Security Everyone Can Use to Resist Espionage (SECURE) Inc., Indiana Office
1500 Vault Way
Crane, Indiana

Dear Partners,

We thank you for your willingness to use your knowledge of electrical systems to engineer this design modification. As you begin to plan out and test your designs there are some additional requirements, we want to share with you.

To stay within critical weight requirements the follow materials can be used for the design modification:
- 1 micro bit
- 8 alligator clips
- 1 box (represents L series carrying case)
- Clear tape
- Electrical tape
- 1 battery holder
- 2 AAA Batteries
- 1 magnet
- 2 LED Lights
- 2 switches

Also, in addition to this team's work, the software team has developed and vetted code for some deterrent options. Below is the list of approved options that can be incorporated into your design. Reference the deterrent software specification sheet for code details.
- Light sensor with alarm
- Accelerometer sensor with alarm
- Touch sensor with alarm
- Magnetometer sensor with alarm

On top of these new requirements the modification must meet the requirements provided in memo one referenced below.

The modification shall:
- Include an approved method for deterring a breach
- Include at least one load
- Include at least one power supply
- Include at least one parallel or series circuit
- Work with a 3V power supply
- Switch between an open and closed circuit.

6.A Client Memo 2

In addition, we also need the following specification for your design.

- Evidence-based documentation justifying your design decision
- The resistance in the circuit (optional if using multimeter)
- The current in the circuit (optional if using multimeter)
- A schematic of your circuit highlighting all of the components of your circuit

Once your design has been tested, each team will present their design at a design review. A meeting with the product stakeholders walking through your design. Your team is responsible for putting together the evidence package and presentation to support this review.

Sincerely,

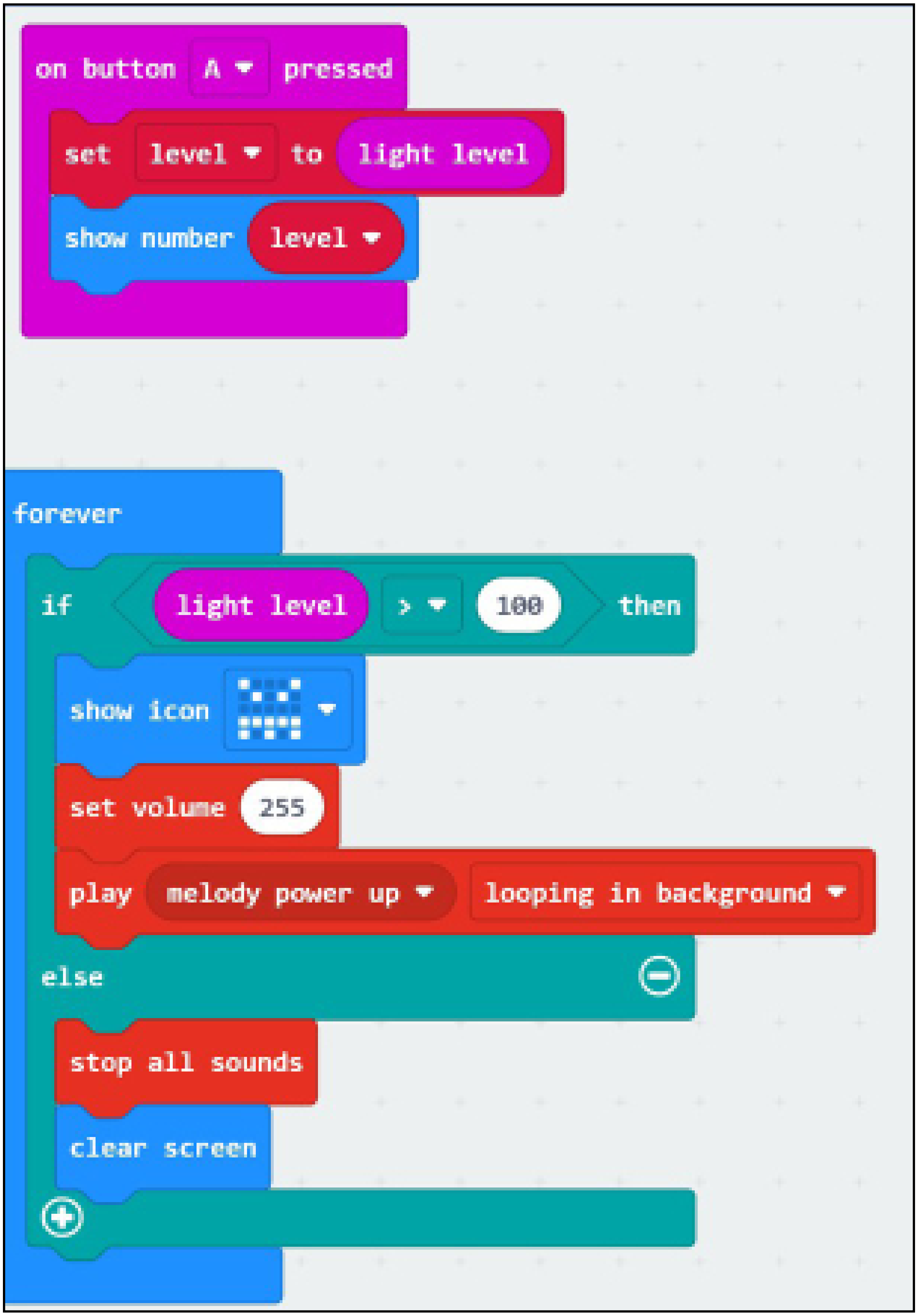
India Scale

India Scale
R&D Deign Lead
SECURE Inc

Deterrent Software Specification Sheet

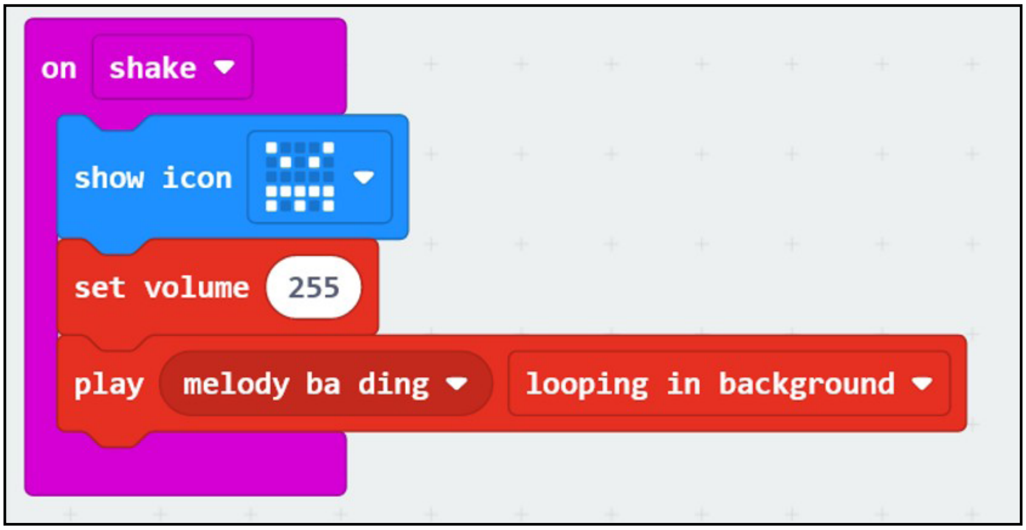
- Light sensor with alarm: when exposed to light above a specified level it will alarm.
    - The code will be written to 100. Your team may have to adjust the light level based on the lighting in the room.
- Accelerometer sensor with alarm: when the box is shaken the alarm will go off.
    - This is a sensitive alarm, it will go off before the box is opened.
- Touch Sensor with alarm: when a spot on the carrying case is touched the alarm will go off.
    - This alarm will be limited to one location but in real life it can represent an area or perimeter.
- Magnetometer sensor with alarm: when the magnetic strength between the sensor and the magnet is reduced the alarm will go off.
    - Depending on placement the alarm will go off as the case is being opened.
    - The code will be written to 200. Your team may have to adjust the level based on how sensitive your team wants the alarm to be.

Light Alarm Code

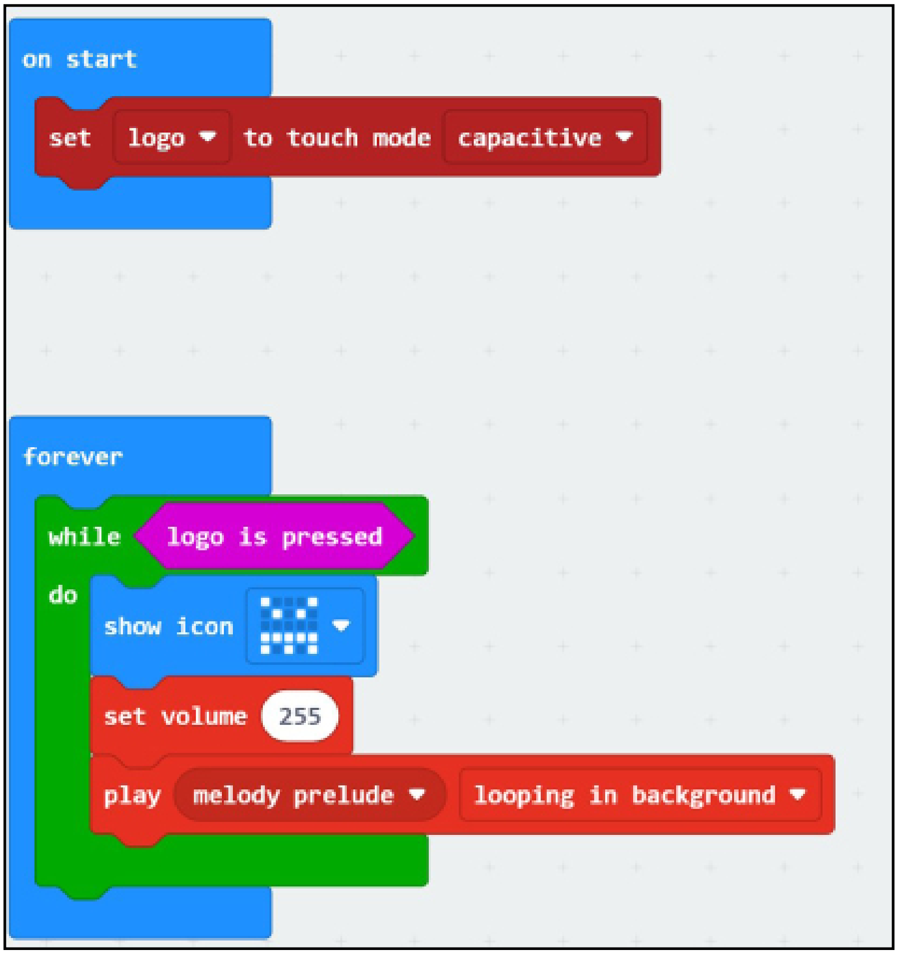


6.A Client Memo 2

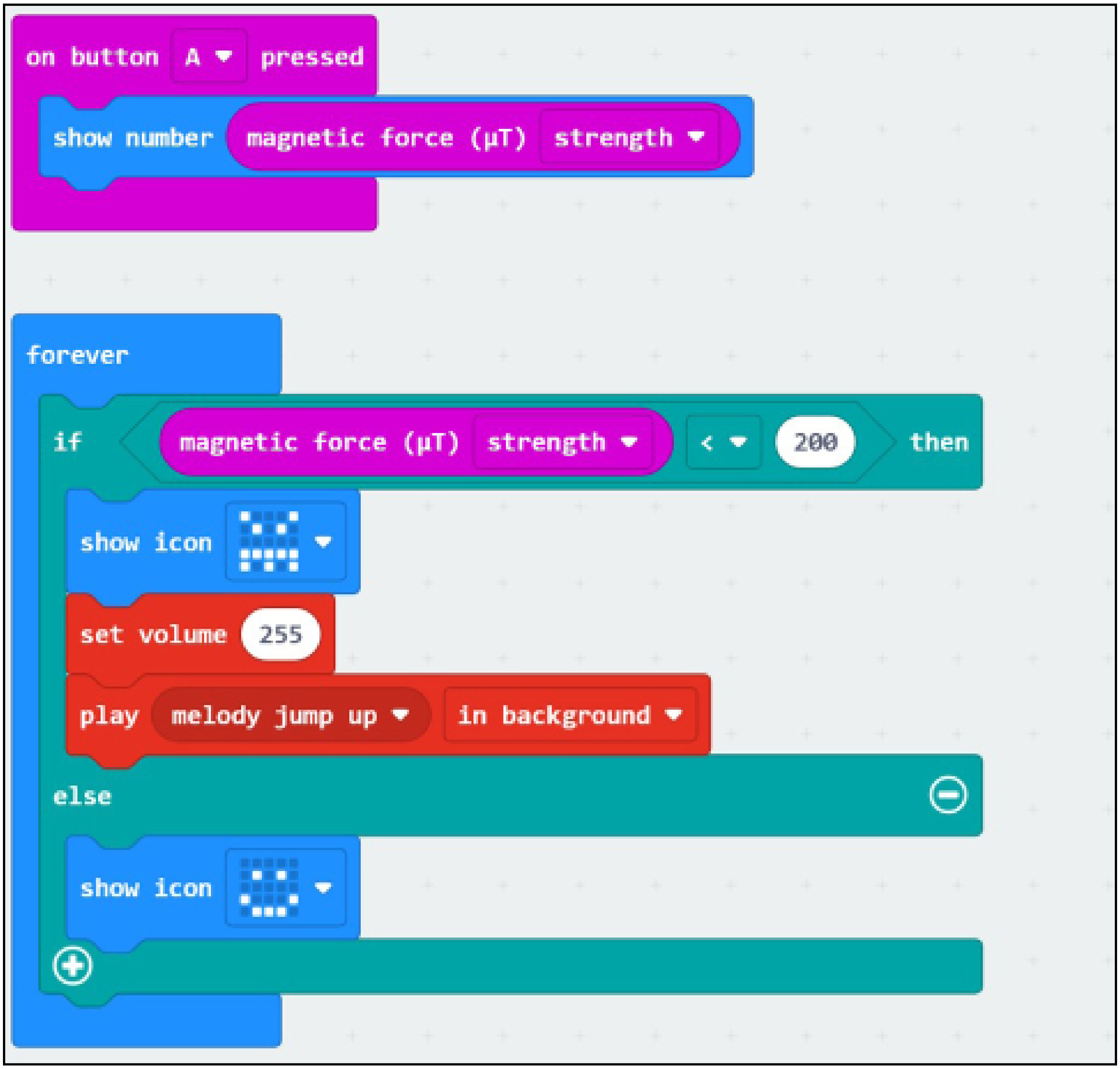
Tilt Alarm Code



Touch Alarm Code



Magnet Alarm Code



6.B Generating Ideas

Generate Ideas/Plan Lessons

Teacher Directions

Once students have generated a few solution ideas that they think could be potentially effective solutions, ask to students to individually complete Section 1- Pros and Cons. Then have them present their graphic from Section 1 to their team. The team needs to select ideas or integrate ideas from among their teams to get 2 ideas to flesh out. Have them complete Section 2 - Evidence-Based Reasoning (EBR) Idea Graphic for each of the ideas. You may want to divide this task among team members. In Section 3, students answer questions about these EBR graphics to make a decision about which idea(s) they should move forward with. Note: Curricula vary in terms of how many ideas students are expected to generate and how many ideas are tested. Use the EBR graphic and questions according to what your expectation is of students in terms of how many ideas they generate and how many prototypes are tested.

Section 1:

Analyzing Your Brainstormed Ideas

This question goes after individual brainstorming but before TEAM EBR Graphic.

Solution Ideas	Pros of idea	Cons of idea	Address Criteria?	Meet Constraints?	Rank ideas
Idea 1:			yes / no	yes / no	
Idea 2:			yes / no	yes / no	

Make changes based on analysis

6.C Evidence-Based Reasoning Graphic

Section 2:
Evidence-Based Reasoning Graphic

<table>
<tr><td>Problem including Criteria & Constraints
• Explain the client’s problem that needs a solution and why it is important to solve.
• List criteria and constraints you will use to decide if your solution is working.</td></tr>
<tr><td>Problem:
Criteria:
Constraints:</td></tr>
<tr><td>Simplifying Assumptions (if any)
• List things that might be important but you have decided not to worry about in order to focus the solution or simplify the analysis of the solution</td></tr>
<tr><td></td></tr>
</table>

<table>
<tr><td>Design Idea #1
• Plan including drawing, labels of materials used, and labels of what each part does.</td><td>Data/Evidence
• List science/mathematics learned and/or results of tests that support your design idea.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Justification - Why do you think this design idea will work?
• Explain how your data and evidence support your design idea in order to meet criteria/constraints.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

<table>
<tr><td>Design Idea #2
• Plan including drawing, labels of materials used, and labels of what each part does.</td><td>Data/Evidence
• List science/mathematics learned and/or results of tests that support your design idea.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Justification - Why do you think this design idea will work?
• Explain how your data and evidence support your design idea in order to meet criteria/constraints.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

6.D EBR Instructions

Evidence-Based Reasoning Graphic Instructions:

<table>
<tr><th colspan="2">Problem including Constraints & Criteria</th></tr>
<tr><td colspan="2">Problem: the engineering problem the client asked you to solve
Criteria: the requirements, or goals, of the designed solutions
Constraints: things that limit design possibilities</td></tr>
<tr><th colspan="2">Simplifying Assumptions (if any)</th></tr>
<tr><td colspan="2">Ways to make a complex problem simpler -
Things we ignore to focus the design or simplify analysis</td></tr>
<tr><th>Idea #_____</th><th>Data/Evidence</th></tr>
<tr><td>• Description of the design
• Drawings of the design, different views better
• Dimensions (sizes)
• Label materials in design (show where they are used)
• Interesting features</td><td>Observations and data that show why you think your design will work

Examples:
• Data from science or mathematics lessons/labs/experiments
• Total cost of design</td></tr>
<tr><th colspan="2">Explanation, Justification, Reasoning</th></tr>
<tr><td colspan="2">Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.</td></tr>
</table>

Evidence-Based Reasoning Graphic Example:

<table>
<tr><th colspan="2">Problem including Constraints & Criteria</th></tr>
<tr><td colspan="2">Problem: adding a deterrent modification to a L series carrying case
Criteria: must be an electrical deterrent
Constraints: fit into the L series model, include one of the following deterrents (light, accelerometer, touch, or magnetometer alarm), include least one parallel or series circuit, include at least one load, include at least one power supply, work with a 3V power supply, switch between an open and closed circuit, used approved material [1 micro:bit, 8 alligator clips, 1 box (represents L series carrying case), clear tape, electrical tape, 1 battery holder, 2 AAA Batteries, 1 magnet, 2 LED Lights</td></tr>
<tr><th colspan="2">Simplifying Assumptions (if any)</th></tr>
<tr><td colspan="2">The L series carrying case is the box provided by the instructor. The power source will be part of the circuit. We will not use the power supply provided for the micro:bit.</td></tr>
<tr><th>Design Idea #1</th><th>Data/Evidence</th></tr>
<tr><td>The circuit is made up of a parallel circuit. One circuit will have the micro:bit and the other circuit will have a light bulb. The light bulb will always be on to indicate something is in the box, the light bulb will be a load. The micro:bit will be a load and a switch in the circuit. The microprocessor will control the deterrent, an alarm that goes off when the light sensor detects light. The light sensor will be located at along the front of the box where the lid is first raised.</td><td>The light sensor detects the light when it hits it. From our sensor lesson the sensor detects different levels of light. The code is written for exposure greater than 100. We have a parallel circuit so the light bulb and the micro:bit can both work because they both have the same voltage across each branch and are independent of each other. Two batteries at 1.5 V in series equal 3V.</td></tr>
<tr><th colspan="2">Explanation, Justification, Reasoning</th></tr>
<tr><td colspan="2">This design will be successful because we have a closed circuit, so all of our components are getting power. The light bulb and micro:bit are on two different branches so both have enough voltage to power the load. The switch is on the branch with the light bulb so we can turn on and off the light. The micro:bit is placed at the bottom of the box so that it is exposed to the most light when the box is opened causing the alarm to go off. The power supply provides 3V of power because the batteries, 2 AAA 1.5 V batteries, are in series.</td></tr>
</table>

Section 3:

Analyzing Your Team Ideas

This question goes after TEAM EBR Graphic.

Directions: Analyze your team solutions and answer the final question. You may work as a team, but your answers for the table and the question are not required to be the same.

Solution Ideas	Pros of idea	Cons of idea	Address Criteria?	Meet Constraints?	Rank ideas
Idea 1			yes / no	yes / no	
Idea 2			yes / no	yes / no	

1. **Which solution did your team choose and why?**

2. **What changes do you need to make before you try to implement your solution?**

6.G Coding Components

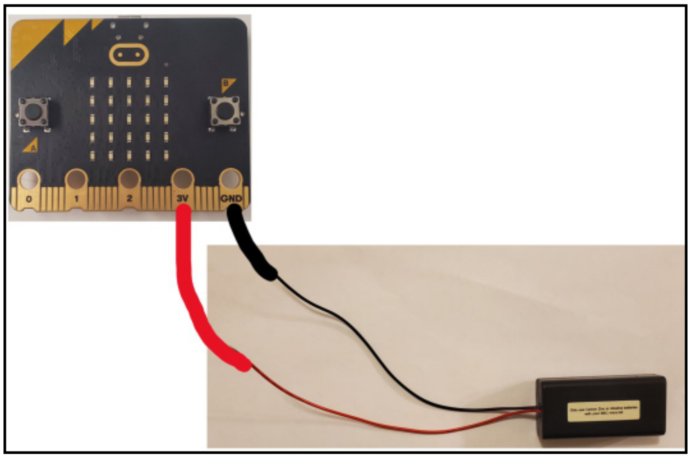
Electrical Safety

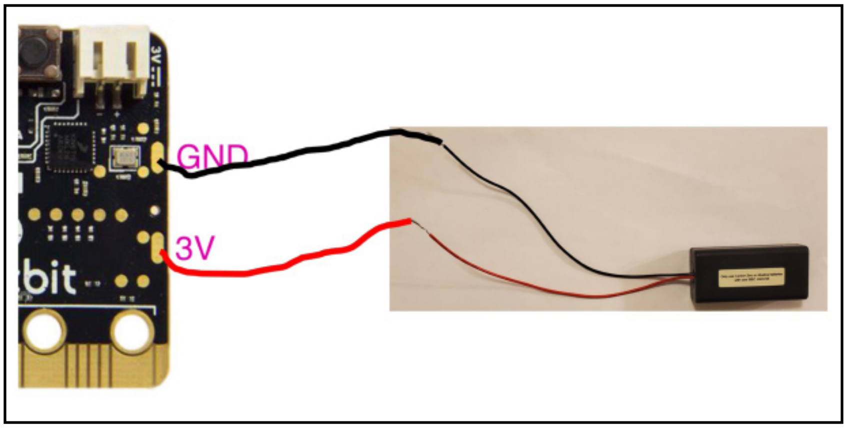
- Please visit the micro:bit website to go over the safety protocol they have for handling the micro:bit
  - https://microbit.org/get-started/user-guide/electrical-product-guidance/
  - NOTE: For this design will be using an external power supply that did not come with the micro:bit.
- The micro:bit is only rated for a 3V power supply
- LEDs will only work in a parallel circuit format since the voltage in each path stays the same. There is not enough voltage in a series circuit to power the micro:bit and a light bulb
- Use electrical tape to hold electrical components together at joints. Use the clear take to hold down everything else.

Electrical Connections

Electrical connection of micro:bit to external power supply:
NOTE: This project does not use the power supply provided by micro:bit. An external power supply will be added using the edge connectors.

Below are two ways in which the power supply can be connected to the micro:bit
- The negative terminal is black and is connected to GND
- The positive terminal is red and is connected to 3V





6.G Coding Components

Deterrent Code

Codes are provided in two formats:

1. The MakeCode web link connects to the web-based Microsoft MakeCode studio. There users can see the block code for the program, make any edits to the code, and download the .hex file.
2. The .hex file format is already setup to be copied to the Micro:bit.

Sensor and Alarm	MakeCode Links	Hex Files
Light Alarm (Light sensor)	https://makecode.microbit.org/S56545-39560-12448-23666	microbit-Light_Alarm.hex
Tilt Alarm (Accelerometer sensor)	https://makecode.microbit.org/S82249-82896-06889-49262	microbit-Tilt_Alarm.hex
Touch Alarm (Touch sensor)	https://makecode.microbit.org/S80057-90004-18549-34670	microbit-Touch_Alarm.hex
Magnet Alarm (Magnetometer sensor)	https://makecode.microbit.org/S03556-56933-83886-02953	microbit-Magnet_Alarm.hex

Instructions for downloading code:

- Micro:bit User Guide: Transfer code to micro:bit
  - Instructions for different devices: https://microbit.org/get-started/user-guide/transfer-code-to-the-microbit/
  - Video on moving .hex files to micro:bit: https://www.youtube.com/watch?v=iIxmk_OYiE0&t=32s
- Downloading from MakeCode: Coding with micro:bit - Part 2 - Connect & Code: https://www.youtube.com/watch?v=_cTHIQXwEO4&list=PLmqeu38gRdJVCMUhgmF8OrjOhYpYtoh9_U&index=2

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6.H Testing Procedure

Directions:
Teams have 20-30 minutes to build their first prototype. Each team should build their initial design. Try not to change the design as you build.

Testing Procedure:

- ☐ Include an approved method for deterring a breach.
  - Which alarm did your team use?
  - Did the alarm go off?
  - How far into the box did you get before the alarm went off?
  - Can that be improved with location placement, changes to sensor sensitivity, modification to the box, etc.?
- ☐ Include at least one load.
  - What are the load(s)?
  - Can the power supply support the load(s)?
- ☐ Include a power supply.
- ☐ Include at least one parallel or series circuit.
  - Is this a parallel or series circuit?
- ☐ Work with a 3V max power supply.
- ☐ Switch between an open and closed circuit.
  - Where is the switch on the circuit?
  - Does the switch do what your team wants it to do?

6.I Testing Reflection

Teacher Directions:

This table is a decision matrix to help students organize their thoughts about what they have learned about the problem, the background, and the test results. Scaffold the filling out of this table to help students think critically about their solutions and how they might try to make modifications for improvement.

Analyze your solution based on:	The results from your tests	The expected results based on what you learned before planning	Whether or not your solution addressed the criteria and met the constraints
What went well?			
What needs improvement?			

1. **Based on your analysis of your test results, the expected results, and the criteria and constraints, what improvements to your solution do you want to make and why?**

6.J Redesign

Teacher Directions:

This table is a quality matrix to help students organize their thoughts about what they have learned about the problem, the background, the first design, and the redesign tests. Scaffold the filling out of this table to help students think critically about their solutions and how they might discuss further modifications for improvement to the client.

Directions: Fill in the table regarding the overall quality of your solution.

Analyze your redesign based on:	The results from your redesign tests	The expected results based on what you learned before redesigning	Whether or not your solution addressed the criteria and met the constraints
What went well?			
What needs improvement?			

1. **Did your redesign improve your solution? Why or why not?**

2. **If you could do another redesign, how would you try to improve your solution?**

LESSON SEVEN:

Lesson Objectives
The student will be able to:
- Explain why their secure device solve the engineering design problem.
- Communicate mastery of physics concepts and engineering ideas verbally to peers.

Time Required
Two 50-minute lessons

Materials
Per classroom
- EDP Poster

Per student
- Engineering notebook
- Laptop or equivalent device

Standards Addressed
IAS Integrated Chemistry and Physics
- HS-ICP3-2
- HS-ICP3-3

IAS Science and Engineering Practices
- SEP.2, SEP.5, SEP.6

Key Terms
rubric, design review, communication

Lesson Summary

In this lesson, students will evaluate their final design. They will develop a presentation to communicate their final product to the client. They will justify each choice for their design and they Students will share their prototypes with their classmates.

Background

Teacher Background

In this lesson, students will be making presentations to convince the client that their design is the best option. Teams will prepare a presentation. They should use information from their evidence-based reasoning poster as they justify their design choices. After students complete their presentations, you will evaluate their designs based on the Presentation Rubric.

Before the Activity

- Make copies of the duplication masters for the following amounts:
    - 7.A Client Communication Guidelines for the Final Design Review (1 per team)
    - 7.B Presentation Rubric (1 per team)
    - 7.C Content Post-Assessment (1 per student)

Classroom Instruction

Introduction

1. **Revisit the engineering design challenge.** Show the Client Letter from Lesson 6 to students, give students time to read the letter. **Ask:** *Now that we have completed the design what is it that the client asking us to do?* They should mention preparing a presentation for the Final Design Review.
2. **Introduce presentation.** Explain that communication is an important part of the Engineering Design Process. Remind students their presentations should be clear and describe why their design is effective, including evidence for their design decisions.
3. **Revisit engineering design process.** Show the *Engineering Design Process.* **Ask:** *Which phase of Engineering Design Process are we using today?* They should mention **"Decide"** where they are communicating their design decision.

Activity

4. **Describe presentation guidelines.** Pass out handout 7.A Client Communication Guidelines for the Final Design Review to each team. Briefly describe what is required for the Final Design Review. Also share with each team a copy of 7.B Presentation Rubric. This would provide guidance on what is expected as they are putting together presentations.
5. **Presentation planning.** Allow time for each team to plan their presentation. As students work in their small groups, circulate around the classroom and remind them of the guidelines.
6. **Presentations.** For the Final Design Review teams will present their complete 5-min presentations to their classmates.

Closure

7. **Reflect on the engineering design process.** Briefly remind students how they used engineering design process and microelectronics to solve the engineering challenge. Have students reflect on their learning. You may ask them to respond to the following prompts in their notebooks.
    - Look back in your *Engineering Notebook* to see how you developed your solution and how your design changed during the design process? Think in terms of what you did and how you made decisions to solve the problem.
8. **Complete summative assessment.** Pass out the 7.C Content Post-Assessment to all students (or distribute an digital version). Make sure students complete this assessment individually as it can be used as an evaluative tool to compare how their responses changed from the 1.A Content Pre-Assessment in lesson 1.

Assessments

Activity Embedded Assessment

Listen to team presentations of how they met the design challenge using 7.A Client Communication Guidelines for the Final Design Review. Assess team presentations using the provided rubric, 7.B Presentation Rubric.

Post-Activity Assessment

Assess students' understanding of the unit's concepts using the 7.C Content Post-Assessment.

Duplication Masters:

- 7.A Client Communication Guidelines for the Final Design Review
- 7.B Presentation Rubric
- 7.C Content Post-Assessment

Educator Resources:

- 7.D Content Post-Assessment Key

7.A Client Communication Guidelines for the Final Design Review

- ☐ Develop 5 minutes presentation.
- ☐ Introduce design team.
- ☐ Summarize the client's problem including criteria and constraints.
- ☐ Describe your team's solution to the problem.
- ☐ Described how your team's solution met the criteria and constraints.
- ☐ Showed data and evidence gathered and used in their design decision.
- ☐ Share at least two design improvement you team made during your test and redesign phase.

7.B Presentation Rubric

	Below Standard (1)	Approaching Standard (2)	At Standard (3)	Above Standard (4)
Explanation of Ideas and Information	Does not present client's problem, group's solutions, data and evidence gathered during design process, and justify design using data and evidence; argument lacks supporting evidence; audience cannot follow the line of reasoning Selects information, develops ideas and uses a style inappropriate to the purpose, task, and audience (may be too much or too little information, or the wrong approach) Does not address alternative or opposing perspectives	Presents client's problem, group's solutions, data and evidence gathered during design process, and justify design using data and evidence in a way that is not always clear, concise, and logical; line of reasoning is sometimes hard to follow Attempts to select information, develop ideas and use a style appropriate to the purpose, task, and audience but does not fully succeed Does not address alternative or opposing perspectives	Presents client's problem, group's solutions, data and evidence gathered during design process, and justify design using data and evidence clearly, concisely, and logically; audience can easily follow the line of reasoning Selects information, develops ideas and uses a style appropriate to the purpose, task, and audience Attempts to address alternative or opposing perspectives, but not clearly or completely	Presents client's problem, group's solutions, data and evidence gathered during design process, and justify design using data and evidence clearly, concisely, and logically; audience can easily follow the line of reasoning Selects information, develops ideas and uses a style appropriate to the purpose, task, and audience Clearly and completely addresses alternative or opposing perspectives
Demonstration of Academic Standards	Does not demonstrate knowledge or use of correct scientific language Does not apply accurate scientific knowledge as the design does not meet design requirements	Uses inaccurate scientific language and concepts Applies mostly appropriate scientific knowledge as the design minimally meets design requirements	Uses accurate language and concepts, but lacks depth of knowledge Applies appropriate scientific knowledge as the design meets most of the design requirements	Demonstrates knowledge and uses correct scientific language that are central for the product design Applies appropriate scientific knowledge as the design meets all the design requirements

7.B Presentation Rubric

Organization	Does not meet requirements for what should be included in the presentation Does not have an introduction and/or conclusion Uses time poorly; the whole presentation, or a part of it, is too short or too long	Meets most requirements for what should be included in the presentation Has an introduction and conclusion, but they are not clear or interesting Organizes time sometimes well, but may spend too much or too little time on a topic	Meets all requirements for what should be included in the presentation Has a clear and interesting introduction and conclusion Organizes time mostly well; some parts of the presentation were too short or too long	Meets all requirements for what should be included in the presentation Has a clear and interesting introduction and conclusion Organizes time well; no part of the presentation is too short or too long
Voice and Physical Presence	Does not make eye contact with audience, reads notes and slides the entire presentation Does not speak with clarity (hard to hear, speaks too slowly or quickly)	Makes infrequent eye contact with audience, reads notes and slides most of the presentation Sometimes speaks with clarity (sometimes hard to hear, sometimes speaks too slowly or quickly)	Makes frequent eye contact with audience, reads notes and slides some of the presentation Mostly speaks with clarity (occasionally hard to hear, occasionally speaks too slowly or quickly)	Makes constant eye contact with audience, does not read notes or slides during presentation Speaks with clarity for entire presentation (not hard to hear, speaks neither too slowly or too quickly)
Response to Questions	Does not respond to questions	Responds to some questions, but does not seek clarity if question is unclear	Responds to most questions and seeks clarity if a question is unclear	Responds to all questions and seeks clarity if a question is unclear
Team Participation	Not all team members participate, only one team member speaks	Not all team members participate, only two team members participate	All team members participate, but not all equally	All team members participate equally

*Rubric adapted from PBLWorks: https://my.pblworks.org/node/11330

Name_______________________________________ Date_______________ Period __________

7.C Content Post-Assessment

1. What is an electrical circuit?

2. What is the difference between strong and weak electrolytes?

3. What is Ohm's law?

4. Within the electromagnetic spectrum, what is the relationship between energy and wavelength?

5. What is a micro:bit?

6. What is a difference between a series and parallel circuit?

Name____ Date_______________ Period __________

7.C Content Post-Assessment

7. Sketch an example of a parallel circuit.

8. What does the term, “microelectronics” mean?

9. How are microelectronics used in the fields of chemistry and physics?

10. What jobs would you be interested in that use microelectronics?

11. Provide one example of how microelectronics is used in that job.

7.D Content Post-Assessment Key

1. What is an electrical circuit? A closed loop where electrons can flow.

2. What is the difference between strong and weak electrolytes? A strong electrolyte will completely (or almost completely) dissolve in water, forming ions making a strong conductive solution. A weak electrolyte does not completely ionize which provides weak conductive solution.

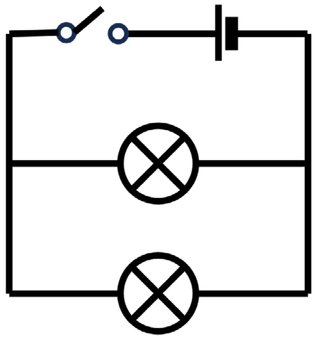
3. What is Ohm's law? V = I * R or Voltage = Current * Resistance

4. Within the electromagnetic spectrum, what is the relationship between energy and wavelength? As energy increases, wavelength decreases.

5. What is a micro:bit? A micro:bit is a small, programmable device that contains a microcontroller and built in sensors.

6. What is a difference between a series and parallel circuit? A series circuit allows one path for electrons (current) to flow, where a parallel circuit has multiple paths for electrons to flow. In a series circuit current remains the same across all devices in the circuit. The switch location matters in a parallel circuit but does not matter in a series circuit. In a series circuit all devices are connected in a parallel circuit the devices can work independently of each other.

7. Sketch an example of a parallel circuit.



8. What does the term, "microelectronics" mean? Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

9. How are microelectronics used in the fields of chemistry and physics? There are many answers to this question, but examples include test equipment, and measurement tools.

10. What jobs would you be interested in that use microelectronics? Provide one example of how microelectronics is used in that job. Students' answers will vary based on interest. Credit may be given as long as at least one job example is provided with their logic behind how that job uses microelectronics.