Unit: Circuitry and Sensory Substitution Devices
Lesson 3: Engineering the Circuit
Author: Alexandra Pike

LESSON OVERVIEW

Activity Time:
One 90 minute and two 45 minute class periods

Lesson Plan Summary:
In this lesson, students will design their sensory substitution circuit (prototype of their sensory substitution device), build and test it, and make any necessary changes after the test.

STUDENT UNDERSTANDINGS

Big Idea & Enduring Understanding:
- Models of simplified sensory substitution devices can be designed, built, and tested using electronic input, processing, and output components.

Engineering Design Challenge:
- To build, design, test, and optimize a model of a sensory substitution device using circuits and electronic components in order to build an assistive device for someone who has a lost or impaired sense (i.e., vision, hearing, touch).

Driving Question:
- What are the steps in engineering a simplified sensory substitution device?

Learning Objectives:
*Students will know...*
- The steps in the engineering design process: asking questions, identifying a problem, brainstorming solutions, designing a prototype, testing and redesigning, evaluating the solution, and communicating the final design.
Students will be able to...

- Identify a sensory substitution device design which will meet a specific end-user need
- Draw a circuit diagram incorporating one or more input sensors, processors, and output components
- Evaluate multiple circuit designs to assess which best meets the criteria and constraints
- Build, test, troubleshoot, and iteratively improve a circuit prototype
- Design and create a scientific poster to communicate the final circuit prototype
Next Generation Science Standards:
This lesson builds toward the following bundle of Performance Expectations (PEs) and their integrated three dimensions of learning. Additional dimensions not part of these PEs are denoted with an asterisk (*).

<table>
<thead>
<tr>
<th>High School Performance Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HS-PS3-3:</strong> Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. (Grades 9-12).</td>
</tr>
<tr>
<td><strong>HS-ETS1-2:</strong> Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. (Grades 9-12).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science and Engineering Practices (SEPs)</th>
<th>Disciplinary Core Idea(s)</th>
<th>Crosscutting Concepts (CCCs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td></td>
<td></td>
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<tr>
<td>*Asking Questions and Defining Problems</td>
<td></td>
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<tr>
<td>*Developing and using models</td>
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<td>*Planning and Carrying out Investigations</td>
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<tr>
<td>*Analyzing and Interpreting Data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Constructing Explanations and Designing Solutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PS3.A: Definitions of Energy</td>
<td></td>
<td></td>
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<tr>
<td>ETS1.A: Defining and Delimiting an Engineering Problem</td>
<td></td>
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<tr>
<td>ETS1.C: Optimizing the Design Solution</td>
<td></td>
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<tr>
<td>Energy and Matter</td>
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<tr>
<td>*Structure and Function</td>
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<tr>
<td>*Cause and Effect</td>
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<tr>
<td>*Stability and Change</td>
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<tr>
<td>*Scale, Proportion, and Quantity</td>
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<tr>
<td>*Systems and System Models</td>
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<tr>
<td>Connections to Engineering, Technology, and Applications of Science</td>
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<tr>
<td>Influence of Science, Engineering, and Technology on Society and the Natural World</td>
<td></td>
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<tr>
<td>*Scientific Investigations Use a Variety of Methods</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Common Core State Standards:
- CCSS.ELA-Literacy.RST.9-10.7: Translate between forms
- CCSS.ELA-Literacy.W.9-10.1: Write arguments
- CCSS.ELA-Literacy.W.9-10.2: Write explanatory texts
CCSS.ELA-Literacy.W.9-10.3: Write narratives

IGCSE Physics Standards:
- **AO1-3**: Demonstrate knowledge and understanding of scientific instruments and apparatus
- **AO2-3**: In words or using other written forms of presentation, manipulate numeric & other data
- **AO2-6**: In words or using other written forms of presentation, make predictions and hypotheses.
- **AO3-1**: Demonstrate knowledge of how to safely use techniques, apparatus, and materials.
- **AO3-2**: Plan experiments and investigations
- **AO3-3**: Make and record observations and measurements
- **AO3-4**: Interpret and evaluate observations and data.

TEACHER PREPARATION

Materials:

*Note: There are three sets of materials students can use to build their circuit prototypes, depending on school supplies and teacher expertise. General materials are listed first, then the materials specific to each option.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Supplies</td>
<td>Small whiteboards and whiteboard markers for the brainstorming; butcher or poster paper,</td>
<td>1-2 sets per</td>
</tr>
<tr>
<td></td>
<td>markers and colored pencils, rulers, printer, glue sticks</td>
<td>group</td>
</tr>
<tr>
<td>Documents</td>
<td>Student Handout 3.1 and Student Handout 3.2</td>
<td>1 per person</td>
</tr>
<tr>
<td>Circuit Components</td>
<td>Tilt Sensor: $2 @ <a href="https://www.sparkfun.com/products/10289">https://www.sparkfun.com/products/10289</a></td>
<td>1 per group</td>
</tr>
<tr>
<td></td>
<td>Flex Sensor: $8 @ <a href="https://www.sparkfun.com/products/10264">https://www.sparkfun.com/products/10264</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vibration Motor: $4 @ <a href="https://www.sparkfun.com/products/8449">https://www.sparkfun.com/products/8449</a></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rotary Motor:$2 @ <a href="https://www.sparkfun.com/products/11696">https://www.sparkfun.com/products/11696</a></td>
<td></td>
</tr>
</tbody>
</table>

Option 1 - SnapCircuits: Use the SnapCircuit kits and components listed in Lesson 2 along with the general materials above. The advantage of this option is that you already have the correct SnapCircuit components from Lesson 2, and that the components are large and easy to see and connect for students. The disadvantage however is that it is quite challenging for students to
know which resistors to use with the sensors, and building these circuits with transistors or relays can lead to an overwhelming amount of connectors.

**Option 2 - Elenco Electronic Playgrounds:** Use the 130-in-1 kits and the general components listed above. The advantage of this option is that the majority of the components students need are already in place on the board, and students just need to wire them together. The disadvantage is that there are a great many components students will not need and which can confuse them, there are still a great many resistors to choose from, and accidental miswiring can result in burned out components.

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elenco Electronic Playground</td>
<td>$26 from <a href="https://www.amazon.com/Elenco-Electronic-Playground-Learning-Center/dp/B0035XSZDI/ref=sr_1_1?ie=UTF8&amp;qid=1502329981&amp;sr=8-1&amp;keywords=elenco+130+in+1+playground">https://www.amazon.com/Elenco-Electronic-Playground-Learning-Center/dp/B0035XSZDI/ref=sr_1_1?ie=UTF8&amp;qid=1502329981&amp;sr=8-1&amp;keywords=elenco+130+in+1+playground</a></td>
<td>1 kit per group</td>
</tr>
<tr>
<td>External Components</td>
<td>Minibreadboards: $3.95 from <a href="https://www.sparkfun.com/products/12043">https://www.sparkfun.com/products/12043</a></td>
<td>1 per group</td>
</tr>
</tbody>
</table>

**Option 3 - Individualized Circuit Boards:** Design your own circuit boards with specifically adapted to the components students need to learn in a particular curriculum. This option requires extensive preparation and basic soldering skills, but the advantage is that by limiting the number of attachments for each input, processor, and output, as well as including the specific resistors needed for your sensors in an order that makes sense, students can work much more independently on their prototypes. The boards can be organized so that inexpensive components are easily replaceable, and students can manage the full engineering design process without the need for teacher-directed trouble-shooting. Board design depends on your particular requirements; materials for the boards used in this lesson are listed below. See Teacher Resource 3.2 for sample boards.

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eagle</td>
<td>Free: <a href="https://www.autodesk.com/products/eagle/overview">https://www.autodesk.com/products/eagle/overview</a></td>
</tr>
<tr>
<td>PCBs</td>
<td>Print from:</td>
</tr>
</tbody>
</table>
| General Components| Resistors: [https://www.sparkfun.com/products/10969](https://www.sparkfun.com/products/10969)  
                  | Switches: [https://www.sparkfun.com/products/9276](https://www.sparkfun.com/products/9276)  
                  | LEDs: [https://www.sparkfun.com/products/12062](https://www.sparkfun.com/products/12062)  
                  | Battery holder: [https://www.sparkfun.com/products/9547](https://www.sparkfun.com/products/9547)  |
### Capacitors:
- Long M/M: [https://www.sparkfun.com/products/9387](https://www.sparkfun.com/products/9387)
- Short M/M: [https://www.sparkfun.com/products/8431](https://www.sparkfun.com/products/8431)
- F Headers: Digikey [PPPC021LFBN-VS7035-ND/810174](https://www.sparkfun.com/products/810174)

### Equipment
- Soldering iron, solder, multimeter

### Input Components
- Thermistor: [https://www.sparkfun.com/products/10988](https://www.sparkfun.com/products/10988)
- LDR: [https://www.sparkfun.com/products/9088](https://www.sparkfun.com/products/9088)
- Pressure: [https://www.sparkfun.com/products/9375](https://www.sparkfun.com/products/9375)
- Tilt Sensor: [https://www.sparkfun.com/products/10289](https://www.sparkfun.com/products/10289)
- Flex Sensor: [https://www.sparkfun.com/products/10264](https://www.sparkfun.com/products/10264)
- Potentiometer: [https://www.sparkfun.com/products/9939](https://www.sparkfun.com/products/9939)

### Processing Components
- Transistors: [https://www.sparkfun.com/products/521](https://www.sparkfun.com/products/521)
- AND Gates: Digikey SN74LS08N/296-1633-5-ND/277279
- OR Gates: Digikey SN74LS32N/296-1658-5-ND/277304
- NOT Gates: Digikey SN74LS04N/296-1629-5-ND/277275
- Button Switch: [https://www.sparkfun.com/products/10302](https://www.sparkfun.com/products/10302)
- SPDT Switch: [https://www.sparkfun.com/products/102](https://www.sparkfun.com/products/102)
- Relay: [https://www.sparkfun.com/products/100](https://www.sparkfun.com/products/100)

### Output Components
- Vibrating Motors: [https://www.sparkfun.com/products/8449](https://www.sparkfun.com/products/8449)
- Rotary Motors: [https://www.sparkfun.com/products/11696](https://www.sparkfun.com/products/11696)
- Multi LEDs: [https://www.sparkfun.com/products/12062](https://www.sparkfun.com/products/12062)
- Buzzer: [https://www.sparkfun.com/products/7950](https://www.sparkfun.com/products/7950)
- Spring Terminal: [https://www.sparkfun.com/products/8073](https://www.sparkfun.com/products/8073)

### Preparation:

1. Teacher should have an idea of the possible circuits students might design, as well as the necessary resistor to protect the components.
2. Photocopy Student Handout 3.1 and Student Handout 3.2 for students.
PROCEDURE

Engage: (10 min)
1. Discuss engineering survey results briefly, if assigned, or simply engage students in a discussion about what they think engineering is, as compared to “traditional” science.
2. Go over Student Handout 3.1 (designed to be taped into interactive journals). Suggest that students think as they work about how their work over the next few days aligns with the engineering process, and make sure to highlight that it isn’t a “procedure” to be followed step by step.

Explore, Explain, and Elaborate: (35 + 45 + 45 min)
3. Distribute Student Handout 3.2 for students to use as they work through their circuit design and testing. Monitor as they work, providing support and encouragement but not problem-solving for them.
   a) In remaining 35 min, Qs 1-3 (planning for end-use and suggesting designs).
   b) In next 45 min, Qs 4 and 6 (choosing a design and building the prototype). Assign Q5 as homework (typing up a full explanation for the design choice).
   c) In final 45 min, Q 6-7 (final testing), start 9 (making the poster). Assign Q8 (criteria for the Pugh Chart) and finishing Q9 as homework. Some groups may need to come in before/after school or during a tutorial session.

Evaluate:
1. As students work, assess their understanding of their decision-making process (why did they choose this particular design?), their understanding of circuit design (why is a transistor or relay necessary here?), and their understanding of what trade-offs they are making (how would you scale this to actually help someone accomplish something?).
2. Continue evaluating their design choices as they work on Q9, getting their posters ready.
3. Principal model evaluation occurs in Lesson 4.

STUDENT ASSESSMENT

Assessment Opportunities:
- No summative assessments, although Q5 could be read for a comments and a grade.

Student Metacognition:
- Students will be reflecting as they work - why they are choosing one design over another, why their circuit is not working as it should, how this activity aligns with the engineering process, etc.
- Students can also reflect on their group dynamics as they work - how all ideas are being heard or incorporated, what ways they are contributing to the design and supporting each other with problem-solving.
Scoring Guide:
- Success is students actively collaborate to design, build, and test their circuit. Success is not necessarily have their circuit fully functioning the way they want by the end of the lesson, assuming they can explain what is not working and propose possible solutions.

EXTENSION ACTIVITIES

Extension Activities:
- Students could expand their circuit design to incorporate even more input sensors - provide students with extra components that they can use either on their breadboards or suggest additional choices from SnapCircuits or Electronic Playgrounds.
- Students could write up a scientific paper in addition to designing their poster presentation - they could use sample peer-reviewed journal articles from engineering journals to guide their work.
- Students could do more independent research to determine a cost-benefit analysis of their design, particularly with regards to the cost of the components they have used vs the benefit of having that particular design, and with regards to the cost of having something like this implanted in someone vs the benefit of their particular design.

Adaptations:
- For groups who are struggling: provide a more limited list of suggested components, possibly on index cards that students need to rearrange and build in the correct order. Be prepared to suggest which sensors are easier to work with (the force sensor is much easier than the thermistor, for example), and which outputs require simpler circuitry (the buzzer usually requires a relay, for example, whereas the LEDs do not).
- For groups who are advanced: rather than using any of the existing circuit kits, provide a breadboard and all of the loose electronic components they would need to build their circuit, and challenge them to get it to work on a breadboard.
- For classes with extra time: after students have drawn their circuits on whiteboards and chosen their particular design, have them create an electronic simulation of their proposed circuit before they actually build it with physical components. This is the way most electrical engineering is done - both a computer and a physical model are built and compared to each other before production. Students can use free online software (Eagle) to design and test their boards, and then they can build the physical model and see how it compares to the computer model.
TEACHER BACKGROUND & RESOURCES

Background Information:
- Make sure to build a few example circuits beforehand, because students will likely need support troubleshooting while they build their prototypes. This is particularly important if using the SnapCircuits or Electronic Playgrounds, because there are so many more issues students might run into when choosing resistors and completing the wiring.

Resources:
Science and Engineering Practices
- https://gasstationwithoutpumps.wordpress.com/2010/06/10/engineering-vs-science/
- https://helix.northwestern.edu/blog/2013/12/what-difference-between-science-and-engineering
Science vs Engineering

Differences:

Similarities:
**Science vs Engineering**

Differences:

Similarities:
Name:_____________________________________________ Date:______________________ Period:______

Directions: Answer the following questions in your lab journal unless otherwise stated. Explain your thinking clearly.

Elicitation Question
Asking questions and identifying needs and constraints

(1) As you think about a potential sensory substitution device (SSD), identify...
   - what are some needs a SSD could address? who are your end users?
   - in what way could an SSD meet those needs? do any have particular advantages?
   - what are the constraints your SSD must operate within? think both in terms of practical considerations (materials available) and theoretical (end user requirements)
   - is there anything else you need to learn or find out in order to start designing a potential SSD?

Exploration Questions
The design process: engineering your device

(2) Create a table with three columns: inputs, processors, outputs. Generate a list of the available components in each category.

(3) With your group, discuss and make note of the following decisions:
   a. which need will you address and substitute for (and therefore which input sensor will you use?)
   b. which output(s) will you use that with that input sensor? Why is that output a good choice for a user who needs to substitute for a lost sense?
   c. how will you know if your SSD will meet the need you identified? what will you look for?

(4) Sketch four possible circuit diagrams for your SSD on four small whiteboards.
   - You must use the same principal input component for all four design possibilities, but can change the secondary inputs as well as the processors and outputs
   - You must use at least two different processors in your proposed circuits (extra kudos if you design a circuit with two processors in the single circuit!)
   - Each circuit design must include at least two “if...then” sentences for your input and output choices, based on changing input conditions. Write these on the whiteboards.
   - Before you erase your whiteboards, take a picture of each to tape into your journal

(5) As a group, decide which of your four circuits best addresses the sensory substitution scenario you have chosen. Write (or type and tape in) a paragraph or two in which you address the following ....
   - the need for your chosen SSD,
   - why this design is the best choice in your constraints to meet this need
   - what advantages and disadvantages it will potentially have
   - what you expect should happen when your SSD is put to work (in terms of current, voltage, etc)
   - how you will judge whether it is effective or not
(6) Build and test your chosen circuit. As you work, make a note of what changes were necessary as you built and tested your circuit and why these changes were necessary. Also make a note of any changes that were not necessary, but which you thought might optimize your SSD design.

(7) When you have successfully built, tested, and optimized your SSD, evaluate how effectively it meets your identified need, fits your criteria and constraints, and any unresolved issues.

**Conclusion Questions**

*Evaluate your solution in relation to other proposals*

(8) Generate a list of 5-8 criteria you would use to evaluate similar proposed SSD. Some examples might include how well it follows design regulations, how easy the proposed final form is for an end-user, how much energy it uses, etc.

(9) Design a poster presentation for your SSD. It should follow the general academic poster format below and be easily readable on poster paper. You will be working in pairs to present your device and evaluate others’, so make sure you are prepared for questions and have a working prototype! Take a picture of your completed poster and tape it into your lab journal.

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Name of your SSD</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>- what need does your SSD seek to address?</td>
<td><strong>Your names</strong></td>
<td>- what are some of the more important changes you made as you worked, and why?</td>
</tr>
<tr>
<td>- how does your SSD address this need?</td>
<td></td>
<td>- what would be your next steps or improvements now?</td>
</tr>
<tr>
<td>- ?</td>
<td></td>
<td>- ?</td>
</tr>
</tbody>
</table>

Explain in words how your circuit functions. Be specific but brief.

(10) In pairs, present your poster and then evaluate others’ using your Pugh chart. Tape your completed Pugh chart into your lab journal.
Active Substitution for Human Data

1. Examples of using sensors:
   - Sensors have infrared
   - Machines in hospitals for x-rays
   - Machines in cars for radar
   - Forn pick up heat and odor
   - Bats pick up compression waves

2. Brain:
   - Sense electrical signals - doesn't know where these come from,
   - Uses all information

3. Polyto Head:
   - Our senses are plug-ins on the outside
   - We use it to perceive
   - Sensory substitution using different senses to send information to
   - Your brain to take it place or a different sense

4. VEST:
   - Sound goes to tablet which goes to vest vibrations

5. Pros/Cons:
   - Gain an extra sense (pro)
   - Overwhelming (con)
   - Can be expensive (con)

Notes - Intro to SHINE

1/30/17

1. Examples of using sensors:
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   - Machines in cars for radar
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   - Gain an extra sense (pro)
   - Overwhelming (con)
   - Can be expensive (con)
A voltage to operate something, can be called an Input voltage.

Other circuits use a step up of zero or high voltage to operate.

Rectifier small circuit is used to change direct current to alternating current.

Switching Circuits says turning magnets on and off, electromagnets attract.

Current goes through magnets, which pulls to affect the output of the magnet.

Rollover resistance (R) increases as voltage decreases to pull changes.

As image increases, resistance decreases to pull changes.

2017

Article 1
- Sound lets humans recognize objects
- Grows awareness, letting people drive, making plans, and communicating
- Helps for a map
- People could not be comfortable with people driving,
- Have sound must be recorded.

Article 2
- Sound lets people see
- Sunglasses with camera, which goes to computer to change images into sound which come out headphones
- Not good with color and depth perception
- Deep
Notes - Sensor Components

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential divider</td>
<td>![divider symbol]</td>
<td>2 or more resistors in series to divide the potential.</td>
</tr>
<tr>
<td>Thermistor</td>
<td>![thermistor symbol]</td>
<td>Resistance decreases as temperature increases.</td>
</tr>
<tr>
<td>LOG</td>
<td>![log symbol]</td>
<td>Resistance decreases as brightness increases.</td>
</tr>
<tr>
<td>Transceiver</td>
<td>![transceiver symbol]</td>
<td>&quot;A special switch&quot; used when want to disconnect power sources or switches.</td>
</tr>
<tr>
<td>Diode</td>
<td>![diode symbol]</td>
<td>Blocks current in one direction.</td>
</tr>
</tbody>
</table>

Logic Circuits in Control

A common system usually has input sensors, then a control circuit, then an output device. Sensors send electronic signals depending on a variable changing. Using the transistor and variable resistor or a high-ohm device.
Pressure switch could also be used as a sensor.

**Gate Symbol** | **Truth Table** | **Description/Application**
---|---|---
**NOT** | \[
\begin{array}{c|c}
\text{In} & \text{Out} \\
0 & 1 \\
1 & 0 \\
\end{array}
\] | Inverts its input changes low to high. 

**AND** | \[
\begin{array}{c|c}
\text{In} & \text{Out} \\
0 & 0 \\
0 & 1 \\
1 & 0 \\
1 & 1 \\
\end{array}
\] | Both inputs must be high/low, for its output to be high.

**OR** | \[
\begin{array}{c|c}
\text{In} & \text{Out} \\
0 & 0 \\
0 & 1 \\
1 & 1 \\
1 & 1 \\
\end{array}
\] | One or both inputs must be high for its output to be high.

**NAND** | \[
\begin{array}{c|c}
\text{In} & \text{Out} \\
0 & 1 \\
1 & 0 \\
1 & 0 \\
1 & 1 \\
\end{array}
\] | AND and NOT - both inputs must be high for its output to be low.

**NOR** | \[
\begin{array}{c|c}
\text{In} & \text{Out} \\
0 & 1 \\
1 & 0 \\
1 & 0 \\
1 & 1 \\
\end{array}
\] | OR and NOT - if either of its inputs is high, its output is low.

Digital (with) not an analogue (continuous)
Science vs Engineering: very similar

Differences:
- Engineering results in a design/product
- Engineering tries to solve existing problems
  not just understand

Similarities:
- Both have a process
- Iterative
- Both rely on results
1. We can use the circuit diagram above to understand the basic components of the circuit. The diagram shows the various components and their connections. The components include:

- Battery
- Motor
- Switch
- LED
- Resistor

The circuit diagram is useful for understanding the flow of electricity and how each component interacts with the others.

2. Now, let's discuss the loss of power and energy. In a circuit, power is lost due to various factors such as resistance, voltage drop, and inefficiencies in the components. The loss of power can be minimized by using high-quality components and ensuring that the circuit is designed efficiently.

3. In SSDs, power loss can be significant due to the high density of data storage and the need for constant power to maintain data integrity. The loss of power can lead to data corruption and system failures. Therefore, it is crucial to design SSDs with efficient power management techniques to minimize power loss and ensure data integrity.

4. Finally, we need to address the issue of sudden power outages and how they affect the system. Power outages can cause data loss and system failures, especially in critical applications. Therefore, it is essential to have backup power sources and robust software designs to handle power outages and maintain system integrity.
5. There is a need to substitute touch for sight and hearing as there are people who can’t feel. The design we chose is the best choice because it only includes the necessary components, but has two outputs to ensure that it works, along with having a switch so that it can also be switched on manually. The advantages of this design are that it has two outputs, it can be switched on and off manually, the transistor allows the bulb to be brighter and the buzzer to be louder, the variable resistor lets you control the amount of heat needed to light the bulb and make the buzzer buzz. The disadvantages of this design are that the transistor can only sense a certain amount of heat, you have to adjust the variable resistor many times, and we aren’t positive that it will work yet. The current in the circuit will go to the thermistor, and depending on where the variable resistor is set, the more heat there is, the less resistance so there will be more current which will then flow into the base of the transistor, then letting current flow through the buzzer and the light bulb. So the current in the battery is equal to the current going through the thermistor which is also equal to the current going through the buzzer and light bulb combined, as the current is split between the buzzer and the light bulb. The voltage in the battery is equal to the voltage in the buzzer, the light bulb, and the thermistor combined. This is what makes the buzzer buzz and the light bulb light. We will judge whether it is effective or not by bringing warm objects and cold objects near the thermistor, and if the buzzer buzzes and the light bulb lights when the warm object is by it, and neither of them work when the cold object is by it, then we will see if it is effective.
Hi, circuit connected and was complete.

We had to change the resistor in front of the transistor from a 10k Ω resistor to a 200k Ω resistor because the 10k Ω resistor had too much resistance so not enough current got through.

7. Our SSD need our needs pretty well when the thermistor came in contact with boiling water the light bulb lit up and the buzzer went off. Taking into account that we had only certain motion are the device with it does fit the criteria. Although if it were going to be used for a real SSD it would need to be more transportable. The only unexpected issues were with the buzzer. The thermistor had to be held in the boiling water for a while until the buzzer went off and when it did, it was very loud and the thermometer was close to being damaged from being in the boiling water for too long. We should need to use a better thermometer that works quicker and on things that are still not hot but not as hot as the water had to be for it to work, and a louder buzzer so that it could be heard better. But, due to our limited materials and constraints, our SSD fit the criteria well. We could push this all in a glove to be transported easier.

8. * Does it work?  
* Does the circuit have unnecessary components?  
* Is it easy to use?  
* Is it easy to reproduce?  
* Is it practical? Could people use it?  
* Is it reliable?

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**Introduction**

Our SSD needs to be simple and easy to make. First things are the basics. Then we need to make sure to have a resistor between the battery and the transistor. This is to make sure it works. Our SSD will function through red and blue colors by the battery. If we have blue in our lamp at all it will show heat to the device and will also show on our meter. The things in line to the red and blue colors, this is a new sensor. The current will change the color and it will also show the correct color.

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**Conclusion**

The only change we had to add was to add the meter and put it in parallel with the resistor to see if the meter was going to work. We added a 330k ohm resistor to see if the meter was going to work. We added a 330k ohm resistor to the meter and put it in parallel with the resistor. We also added a 330k ohm resistor to the meter and put it in parallel with the resistor. We also added a 330k ohm resistor to the meter and put it in parallel with the resistor. We also added a 330k ohm resistor to the meter and put it in parallel with the resistor.

- Our next step is to use our solar panel to get power to our device. We also have a new sensor that shows the amount of power it is getting. We also have a new sensor that shows the amount of power it is getting. We also have a new sensor that shows the amount of power it is getting. We also have a new sensor that shows the amount of power it is getting.
| Criteria                  | 1/3 | 4/5 | 5/5 | 2/4 | 5/5 | 5/5 | 4/4 | 5/5 | 2/4 | 5/5 | 3/3 | 4/4 | 5/5 | 5/5 | 5/5 | 5/5 | 3/3 | 3/3 | 4/4 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 5/5 | 30  |
|--------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Efficiency               |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Functionality - does it work? | 5/5 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Practical to use - is it important? | 5/5 |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Ease of use / design     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Reliability              |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Durability               |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Follows Coherence        |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Total
A - Switch (Red)
B - Capacitor
C - Sensor (LDR, pressure, flex, thermistor)
D - R1
E - R2
F - R3
G - Variable Resistor
H - R for Transistor
I - Transistor

A - Switch (White)
B - Capacitor
C - AND 1
D - AND 2
E - AND OR 1
F - OR 2
G - NOT 1
H - NOT 2
I - Switch 1
J - Switch 2
K - Switch 3

A - Switch (Blue)
B - Capacitor
C - LED 1
D - LED 2
E - LED 3
F - Bulb
G - Motor 1
H - Motor 2
I - Buzzer
J - Relay