Energizing Minds of Tomorrow

CURENT

CENTER FOR ULTRA-WIDE-AREA RESILIENT ELECTRIC ENERGY TRANSMISSION NETWORKS

VOLUME ONE:

K-5 ENERGY SCIENCE ACTIVITES

The interdisciplinary elements within this publication serve to supplement teaching STEM concepts focused on power and energy systems for elementary educators.

CURENT

Energizing Minds of Tomorrow

VOLUME ONE:

K-5 Energy Science Activities

EDITORS:

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CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

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Dr. Chen is the Director of Education and Diversity Programs and Research Professor at CURENT's headquarters. She is also an adjunct faculty member in the University of Tennessee Knoxville Department of Sociology. Dr. Chen received her Ph.D. in sociology from Washington State University. Since 2011, she has been the lead professor linking social psychology and grid technologies for our engineering research center. Dr. Chen's environmental research areas include energy literacy and the diffusion of renewable energy knowledge, environmental beliefs, attitudes, behaviors and public opinions over environmental issues. Her research facilitates the investigation of the social and structural processes that motivate behavioral and psychological changes in relation to issues of energy and technology.

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Ms. Qualls is the Education Coordinator Assistant for the Pre-College and University outreach programs at CURENT. Her eight years of experience in scientific research and education serve to analyze, maintain, and expand our outreach programming initiatives. She holds a BS in Geology and M.Sc. in Theory and Practice in Education with a specialization in science education. Felicia has a unique approach to education, utilizing her professional experience in the industry to invigorate curriculum development, teacher training, and K-12 student experiences.

ANNE SKUTNIK, Ph.D.
Dr. Skutnik is the Education and Diversity Coordinator at CURENT's University of Tennessee Engineering Research Center. Dr. Skutnik has over a decade of experience in education, including K-12 and higher education. She also has worked as an instructional designer, helping faculty transition their courses to the Internet. Dr. Skutnik received her Ph.D. from the University of Tennessee in Learning Environments and Educational Studies. Her research interests include engineering education epistemology and pedagogy.

Acknowledgements

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NOTABLE MENTION

The outreach program, Research Experience for Teachers (RET), responsible for the creation of this book was managed by CURENT's prior education coordinator, Erin Wills, from 2013-2017. Erin coordinated CURENT's education outreach programming and also assisted teachers in the development of curriculum during their time at our facilities. Erin earned a bachelor's degree in Chemical Engineering from Purdue University in 2007 and worked in the chemical industry as a process and automation engineer for five years with Eastman Chemical Company, BASF Corporation, and Innovative Controls, Incorporated. Erin completed his Master of Science in Education at the University of Tennessee.

SPECIAL THANKS

We at CURENT would like to express our gratitude by acknowledging Monica McNichols, for her contributions to this instructional resources project. Monica believed that with starting an ebook, CURENT could extend the outreach potential of the RET program. Monica has worked as a curriculum developer for CURENT's Research Experience for Teachers program since 2016. She has been an elementary and middle grades educator for over 11 years. Her professional experience spans early childhood development through a multitude of teaching experiences including launching her career abroad as a Peace Corps Educator.

CURENT would also like to extend our gratitude for the involvement of Jennifer Hodge. Jennifer also co-founded this project with Monica and our editors. She chose to stay with CURENT after completing the RET program in the summer of 2017. Jennifer has served as an educator for seven years, with time spent as science department head and AVID coach at her school.

Both of these women were instrumental to the development of this project.

TENNESSEE Northeastern Rensselaer TUSKEGEE

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Table of Contents

Preface

This book aggregates the work of teachers who have contributed to the research and development of the hands-on activities and content delivery suitable for enriching K-12 science, technology, engineering, and mathematics (STEM) learning experiences. The interdisciplinary elements within this publication serve to supplement the teaching of STEM concepts. It functions as a multi-faceted resource with background knowledge, step-by-step lesson plans, national education standards alignment, instructional videos, tips, and much more.

CURENT, the Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks, is an Engineering Research Center that is jointly supported by the National Science Foundation (NSF) and the Department of Energy (DOE). A collaboration between academia, industry, and national laboratories, CURENT is based at the University of Tennessee, Knoxville. The center's partner schools are Northeastern University, Rensselaer Polytechnic Institute, and Tuskegee University. Our vision is to inspire a new generation of electric power and energy systems engineering leaders with global perspectives and diverse backgrounds.

CURENT and its partners share a common education goal: to develop outreach programs that will provide multi-disciplinary, team-driven, and systems-oriented educational opportunities for K-12 students. In 2011, the Center received a grant from the National Science Foundation to support a Research Experience for Teachers (RET) program. The RET program intends to develop highly innovative curricula focused on energy literacy and electrical energy transmission system analysis. The resulting RET curricula collected demonstrates a paradigm of active-learning environments that support deeper understanding of energy concepts, develop positive student identities, and support an appreciation of science practices and engineering design. The content in this e-book is designed to foster growth in students by awakening interests and curiosities to explore twenty-first century problems such as renewable energy sources, and the power grid. For educators, the content aims to help you to stimulate and empower students to discover and design solutions through engineering.

We hope that you enjoy it!
- the education team at CURENT

Engineering Design Process

Engineering applications unite STEM fields and provide opportunities to mirror how to solve problems in the real world. The work of engineers is both inclusive and interdisciplinary. To best prepare those who will ultimately become future STEM professionals, it is vital that educators captivate students with authentic interdisciplinary projects in the classroom. The process of designing, building, and using machines and structures is central to STEM instructional design. Research agrees that the engineering design process should be emphasized in K-12 education so that young people are educated on the importance of integrated projects. Additionally, the engineering design process serves as a hands-on, creative way to explore STEM fields and ignite passion.

> "Scientists discover the world that exists; engineers CREATE a world that never was."
> – Theodore Von Karmen

Educators hold the key to increasing student interest in STEM. Lead your students on problem-solving adventures that have no 'right' designs or pathways to follow. Often young people can imagine solutions beyond the scope of an adult mind, as they are more open to novel possibilities. Support individuality in how students approach problem solving and encourage them to draw from their personal strengths, even if you anticipate that they may be on a path to failure. Learning from 'failure' can result in a deeper understanding than reaching a 'correct' answer immediately. Students develop their individualized problem-solving skills through analytical thinking, and can creatively engage in their learning experience.

In engineering, students:

- Synthesize STEM knowledge to identify and solve real-world problems
- Discover that problems have many possible solutions
- Research and collect evidence to solve problems
- Partake in interactive experiences to contextualize interdisciplinary concepts
- Conceptualize, create, and test models of solutions
- Collaborate, critique, and incorporate the ideas of their peers
- Communicate and engage in argumentation to defend solutions based on evidence

Engineering design projects are fundamentally hands-on, creative, problem-solving activities. Most importantly, engineering gives every student the opportunity to utilize their unique skills to be successful.

Engineering Design Process

To help you design meaningful engineering projects, we have outlined four steps to follow:

1. Identify the Problem
   The first step is to define a real-world problem. Choose one that not only meets your standards and content requirements, but also interests your students and integrates multiple grade-appropriate pathways for their success. The problem can lead students through a process to design a product or to find a solution. Both of these outcomes are integral to the work of engineers.

2. Define What Is Needed to Solve the Problem
   What do you explicitly want your students to accomplish before, during, and after the engineering design project? If students are designing a product, they must have an appropriate understanding of the subject, efficiently collaborate to design, create, test, and modify a product based on their prior and new knowledge, and effectively communicate and use evidence to defend their solution to their peers. Engineering projects reflect the benefit of understanding STEM content through its application to real-world problems. It should stimulate systems of thinking, modeling, and analysis. The focus for educators should also be on developing soft skills (or key skills) such as collaboration, metacognition, flexibility, and perseverance. Once you have defined the performance criteria, you can effectively outline the processes, rubrics, and checkpoints to share at the start of the project.

3. Design Activities
   By now you've successfully identified a problem for your students to solve and the performance idea, so let's start thinking about designing your project. We suggest you ask yourself these questions:
   - What is the problem?
   - What STEM standard(s) does this scenario align with?
   - What background info do students need in order to solve the problem in a meaningful way?
   - What constraints will you give the students? Consider using constraints, such as time or materials, as a strategy to focus on the individual needs of students.
   - How will students collaborate to form their solution (before, during, after)?
   - How will they test, gather data, and evaluate their products or solutions before modifying?
   - How will students share and communicate their results?

4. Prepare Student-Engineers
   All new classroom procedures require preparation and practice. Before beginning an engineering design project, it's important to take the time to prepare students so they have the opportunity to

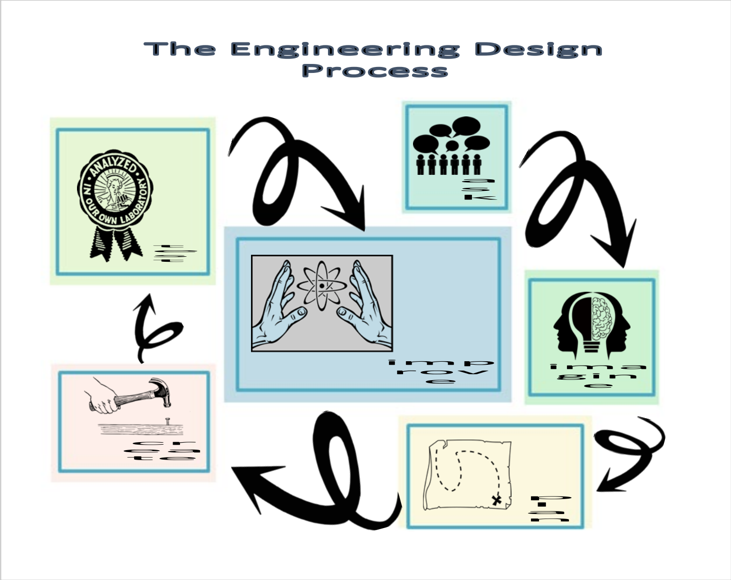

Figure 1. The engineering design process in six steps, simplified for elementary students (CURENT, 2018).

be successful. Allow ample time for testing hypotheses, sharing ideas with each other, and revising the students' solutions throughout the process.

The figure to the left shows a simplified example of the six steps that make up the engineering design process. There are many different versions of the process, some with additional intermediate steps or significant alterations. Another thing to note about the process is that it is not necessarily as linear as is shown in the example. You may reorder, repeat, or even skip steps as you work through the process.

The Engineering Design Process - Final Tips

Implementing engineering design will take some time to adjust to and may potentially shift your teaching practice. Ultimately, however, it can transform learning experiences by engaging students in mirroring the highly interactive real work of STEM professionals. Below are some final tips:

- ❑ Model expectations by communicating them effectively
- ❑ Create ground rules for successful group work (e.g., appropriate use of time, procedures for set-up and clean-up, examples of effective communication, etc.).
- ❑ Assign individual roles for group work. Provide ample opportunities and time to practice roles.
- ❑ Allow ample time for students to complete the entire engineering design process.
    - Testing outcomes, sharing results, answering questions, providing feedback, and receiving constructive criticism are all necessary actions and roles of real-world scientists and engineers.
    - Modifying and improving solutions based on test results and feedback from peers are learning opportunities. Engineers are constantly sharing ideas to tweak and refine projects. Remember, a failure is one step closer to a better solution.
- ❑ Display the engineering design process in your classroom. You can quickly reference the above cycle without sacrificing precious class time to answer questions. Providing visuals in this way allows you to be inclusive of different learning modes.

Lesson Structure

On each page you will find common themes. The first page provides general information about the lesson itself.

1 TOP LEFT CORNER

The suggested grade level for this material, as well as the anticipated time to complete the lesson, can be found in the top left corner. The content area is also listed here.

2 SIDE BAR STANDARDS

The lessons are associated with the US national science standards, the **Next Generation Science Standards (NGSS)**. These are broken into three distinct, yet equally important dimensions to learning science: core ideas, cross-cutting concepts, and science and engineering practices.

3 CENTER SECTIONS

The title of the lesson is located across the top green bar of the lesson. Below it, in bold, a sentence provides a succinct description of what the lesson is about. Separated by the dotted line is a brief overview on the lesson topic and activity. Directly below that are the objectives for students to complete during the lesson. Finally, the lesson materials are listed with some items linked to purchase.

Figure 2. Example first page of a lesson from this book.

4 BRIGHT IDEAS

Bright Ideas are "pop-up" tips to provide you with helpful supplementary information. These usually include a link to a YouTube instructional video, instructional tips, safety precautions, suggested modifications, or extensions.

The pages following the front page are expanded information about each lesson, divided into sections. The **Advanced Preparation** and **Background Knowledge** sections are for educators to use to set up the lesson and build pedagogical content knowledge. These pages include **Bright Idea** pop-ups as well as simple figures to help you visualize abstract concepts.

Lesson Structure

The lessons themselves are subdivided into three equally important parts: **Activate, Create, Deeper Connections**, or just **AC/DC** for short. Each of these sections are at least one page in length. The content on these pages also includes some optional modifications and suggestions for you to personalize the lesson for your students and your budget.

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5 ADVANCED PREPARATION

The **Advanced Preparation** section is a set of steps for what the teacher should do before the lesson. This may include suggestions for building necessary prior knowledge and vocabulary, advising students on lesson-specific safety procedures, creating models, and gathering student materials.

6 BACKGROUND KNOWLEDGE

At least one page of information specific to the lesson is provided to help you better understand the content before teaching the lesson in the **Background Knowledge** section. Figures aid in visualizing abstract concepts. Some lessons also include connecting concepts and prior knowledge recommendations. Should you need further clarification or additional information, please see the Appendices located in the back of this book. There is also a glossary to assist you with terminology.

7 ACTIVATE

The **Activate** section peaks inquiry and curiosity while addressing prior knowledge and misconceptions. Filled with pre-lesson guided questions, brain teasers, and other short, stimulating activities.

8 CREATE

The **Create** section is the bulk of the lesson, where students actively engage in the learning experience through a hands-on activity. Included in this section are step-by-step instructions outlining how a CURENT-affiliated teacher would teach this content to their class.

9 DEEPER CONNECTIONS

Deeper Connections addresses how to maximize the growth of all students. It provides insights on how to tailor the lesson to each individual student's needs. It is broken into two sections: **Modify** and **Extend**. Modify the lesson to scaffold learning. Extend connections to other lessons, activities, and/or concepts.

The final pages of each lesson are the accompanying worksheets and keys. In the back of the book you can find additional resources such as the background information appendices, glossary, and references.

Lesson Chart

The purpose of this chart is to help find lessons relevant to the topics you are teaching in class. We have categorized the topics into broad categories related to power engineering.

All lessons are geared towards students in grades 3-5.

Lesson Name	Topic: Energy	Topic: The Grid	Topic: Renewable Energy	Topic: Social and Environmental
1. Engineering Careers				X
2. Powering VOLt City	X	X	X	X
3. Solar Oven Design Challenge	X		X	
4. Exploring Hydroelectricity	X	X	X	X
5. Wind Turbine Design Challenge	X	X	X	X

Lesson Chart

The purpose of this chart is to help find lessons relevant to the topics you are teaching in class and aligned with NGSS standards. We have categorized the topics into broad categories related to power engineering.

All lessons are geared towards students in grades 3-5.

Lesson Name	PS3.A: Definitions of Energy	PS3.B: Conversation of Energy and Energy Transfer	PS3.C: Relationship between Energy and Forces	PS3.D: Energy in Chemical Processes and Everyday Life	PS4.A: Wave Properties	PS4.B: Electromagnetic Waves	ESS3.A: Natural Resources	ESS3.C: Human Impacts on Earth Systems	ETS1: Engineering Desgin
1. Engineering Careers							X	X	X
2. Powering VOLt City	X	X						X	X
3. Solar Oven Design Challenge	X	X		X	X	X			X
4. Exploring Hydroelectricity	X	X	X	X			X		X
5. Wind Turbine Design Challenge	X		X	X					X

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Lesson 1

Engineering Careers

CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

Grade: 3-5
Subject: STEM
Length: 100 minutes

Exploring Engineering Careers

CORE IDEAS

- ESS3.A: Natural Resources
- ESS3.C: Human Impacts on Earth Systems
- ETS1: Engineering Design

SCIENCE & ENGINEERING PRACTICES

- Asking Questions and Defining Problems
- Obtaining, Evaluating, and Communicating Information

CROSS CUTTING CONCEPTS

- Influence of Engineering, Technology, and Science on Society and the Natural World
- Science is a Human Endeavor

Students learn about different career opportunities in engineering.

OVERVIEW

In this lesson, students simulate the roles of civil, environmental, electrical, and mechanical engineers by researching careers in these fields. This could serve as an introductory activity at the beginning of a STEM class to help students see beneficial real-world connections between STEM concepts and future careers. This lesson could also be used as a springboard to motivate students in future lessons on careers, STEM challenges, and activities.

OBJECTIVES

Students will be able to:

- Summarize the careers of civil, environmental, electrical and mechanical engineers on their handout
- Understand the roles of each type of engineer
- Envision themselves as an engineer

MATERIALS

- ❑ Student computers or internet accessible device
- ❑ Internet Access

BRIGHT IDEA
Introduce students to engineering careers with the What is an Engineer? Crash Course Kids #12.1 YouTube video.

Figure 1.0: Norris Dam State Park, TN field trip (2018). Photograph by Jennifer Hodge.

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ACTIVATE

Part 1: Stand up if…

Gauge students' interests and connect them to engineering careers. Address the class with the following statements and ask students to stand up if they agree.

Stand up if…

- You like to grow plants.
- You are good at building things.
- You are good at fixing things.
- You are curious about how electronics or machines work.
- You like to do experiments.
- You are creative.
- You use your imagination to think of new ideas.
- You like to view objects through a magnifying glass.
- You like to visit zoos to watch the animals.
- You would like to examine dinosaur bones.
- You want to help people.

After students identify characteristics about themselves, tell them that these are a few of the properties of a great engineer. How many potential engineers do you have in the room? What other traits can be added to this list?

Part 2: What does an engineer look like?

On the "What does an engineer look like?" worksheet (p. 6), have students draw a picture of what they think an engineer looks like and what they do.

Ask students to share their artwork. Have a gallery walk or simply display student art on a wall in your classroom. Discuss the similarities and differences as a class; create a master drawing of the characteristics on the board.

Optional: Follow the "What does an engineer look like? – Foldable Instructions" (p. 7) to add the sheet to science journals.

Inquiry

Write the words "Civil Engineer," "Environmental Engineer," "Electrical Engineer," and "Mechanical Engineer" on the board. Select students to share and list ideas on their meanings, what those specific types of engineers do, etc. Allow students to extend the list after they complete the activity.

BRIGHT IDEA

Use the "Stand up if..." Activate activity in a later part of the lesson to help students make a personal connection to their initial research.

BRIGHT IDEA

Ask students these essential questions:

- **What do you think an engineer does?**
- **Do you think there are many different opportunities for engineers?**

CREATE

1. Pair up students to research a single career from the links below. The pair will work together to find information on one featured field of engineering: civil, environmental, electrical, or mechanical.
2. Students should individually complete the "___ Engineer" handout (pp. 8, 10, 12, 14) for the respective careers. Allow students 30 minutes to research on the Science Buddy website to complete the handout. Adjust research time as needed.

   Science Buddy Career Profiles (external site links):

   - Environmental Engineer
   - Electrical Engineer
   - Civil Engineer
   - Mechanical Engineer

   Plan on jigsawing these initial pairs into larger groups. Final groups should consist of one student researcher representing each career, or four students total. Jigsawing by defining and designating speaking roles between peers gives everyone an opportunity to share their knowledge.

1. Once students have completed their "___ Engineer" handouts (pp. 8, 10, 12, 14), place students into final groups of four. One student will present their research on a different type of engineering career, while the other three listen. Allow 2-3 minutes for this and be explicit in the instructions. Check to see if students need more time and adjust appropriately. Optional: Follow the "Engineering Careers – Foldable Instructions" (p. 16) to add it to their science journals.

1. Regroup as a class and revisit the students' initial ideas of engineering from the *Activate* activity (p. 3) at the beginning of the lesson.
2. Ask students how their impression of engineers changed after their research. On the board, cross out any false statements about engineering from the list. Rewrite the statements to make them true. Modify drawings to create accurate representations.
3. Have students fill out the "Engineering Careers: Reflection" worksheet (p. 17). Would your students consider a career in engineering with this new knowledge?

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DEEPER CONNECTIONS

MODIFY

- ❑ Instead of researching, invite parents or community members who are engineers to be interviewed.
- ❑ Create simplified fill-in-the-blank notes or diagrams for students who may need additional help with concepts from the websites and jigsaw activity.
- ❑ Omit the final worksheet, “Engineering Careers: Reflection” (p. 17). Have students free-write or draw; visualizing what they have learned.
- ❑ Use the foldable instructions to add worksheets into science journals.
- ❑ Instead of pairs, have students work in larger groups (4+ students) to become “experts” on a single type of engineering. Give badges or stickers to acknowledge student work. For example, name tags might say “Environmental Engineer Expert.”

EXTEND

- ❑ Consider spotlighting careers in biomedical or geotechnical engineering. Consider regularly showcasing engineering careers to help students broaden their ideas.
- ❑ Explore career mapping. Use the Office of Energy Efficiency and Renewable Energy’s interactive Wind Career Map and Solar Career Map to show how jobs span across industries, potential career progressions, and necessary training.
- ❑ Explore the need for future engineers through the Bureau of Labor and Statistics “Employment and Wages of Engineers in 2015.” This external link includes interactive data mapping engineering salaries and localities.
- ❑ Read these articles on abstract engineering professions in Design News “Cool Jobs in Engineering” and University of California’s “7 Unusual Careers that begin with an Engineering Degree.”
- ❑ Have students consider match engineers to current problems like global warming and cybersecurity, and debate what roles (if any) they would play in the solution.

BRIGHT IDEA

Extend: Have students post a question in the Ask an Expert section of the Science Buddies website.

Name:______________________________

What does an engineer look like?

What do you think an engineer looks like? Draw it in the box below.

Brainstorm some ideas on what you think engineers do.
Write down at least three ideas in the spaces below.

1.

2.

3.

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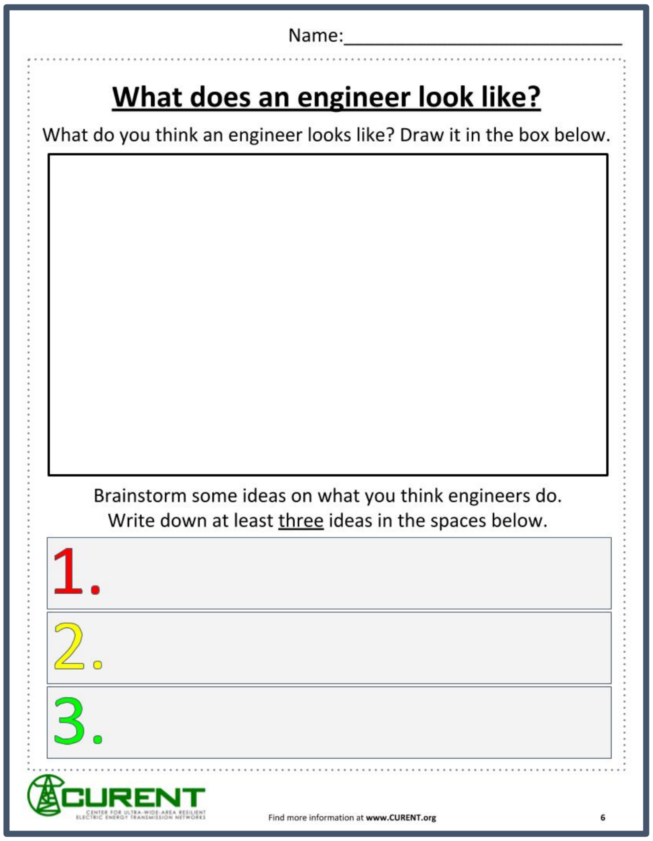
What does an engineer look like? – Foldable Instructions

Directions: Complete your worksheet then follow these steps to create a foldable.


Name:________________________

What does an engineer look like?

What do you think an engineer looks like? Draw it in the box below.

Brainstorm some ideas on what you think engineers do.
Write down at least three ideas in the spaces below.

1.

2.

3.

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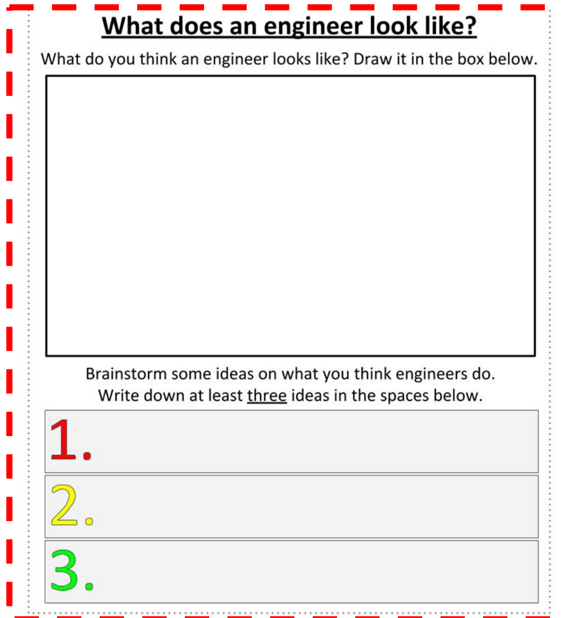
Find more information at www.CURENT.org 6

1. Cut around the top two boxes on the red line.


What does an engineer look like?

What do you think an engineer looks like? Draw it in the box below.

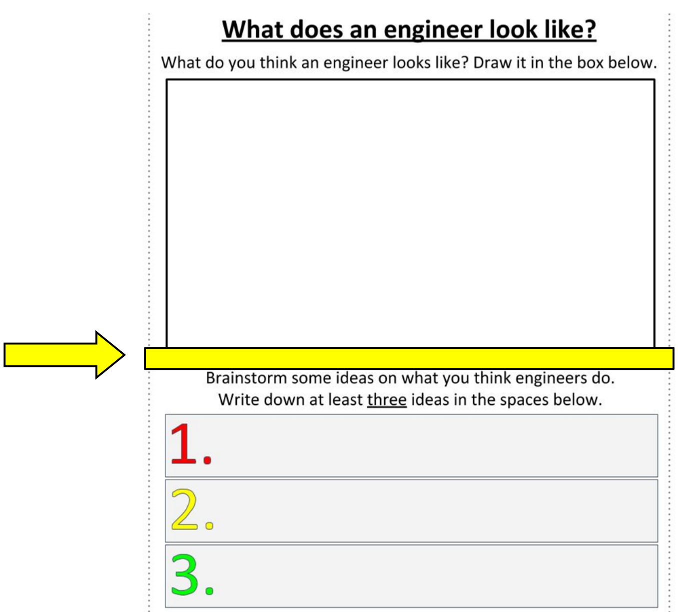
Brainstorm some ideas on what you think engineers do.
Write down at least three ideas in the spaces below.

1.

2.

3.

2. Fold in between the two boxes on the yellow line.


What does an engineer look like?

What do you think an engineer looks like? Draw it in the box below.

Brainstorm some ideas on what you think engineers do.
Write down at least three ideas in the spaces below.

1.

2.

3.

3. Label the outside (blank side) of of the foldable with your name. Color and decorate it. Paste the finished foldable into your science journal.

Name:______________________________

Electrical Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something an electrical engineer makes in real life.

Describe what they do:

Write two examples of what they do:

1.

2.

Education

One interesting fact (or more)

Make this website accessible for your students to complete the worksheet:
https://www.sciencebuddies.org/science-engineering-careers/engineering/electrical-electronics-engineer

Electrical Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do?	Key facts & information	Education	On the Job	Project Ideas	More

Draw a picture of something an electrical engineer makes in real life.

Describe what they do:

Electrical engineers gather electricity and use it to make products that either transmit power or information. They can also specialize in the products that make or use electricity, like cellphones, electric motors, handheld games, or airline navigation systems.

Write two examples of what they do:

Answers may vary.

1. **Develop construction plans for a skyscraper's electrical lighting system**
2. **Design a remote controlled toy race car**
3. **Make a radio collar so researchers can track and study wild animals**
4. **Design the electrical system for a factory robot that welds cars**

Education	One interesting fact (or more)
At least a B.S. in some form of engineering. Some basic research positions require a graduate degree.	**Answers may vary.**

Name:______________________________

Environmental Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something an environmental engineer makes in real life.	Describe what they do:

Write two examples of what they do:

1.

2.

Education	One interesting fact (or more)

Make this website accessible for your students to complete the worksheet:
https://www.sciencebuddies.org/science-engineering-careers/engineering/environmental-engineer

Environmental Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something an environmental engineer makes in real life.

Describe what they do:

Environmental engineers plan projects around municipal areas that are essential to the people who live in that area. They also work to try and minimize the environmental impact of human developments.

Write two examples of what they do:

Answers may vary.

1. **Design Rooftop Gardens**
2. **Help refineries reduce emissions**
3. **Design water systems and water treatment plants**
4. **Design ocean water desalination plants**

Education

At least a B.S. in some form of engineering, usually civil, mechanical, chemical or environmental.

One interesting fact (or more)

Answers may vary.

Name:______________________________

Civil Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something a civil engineer makes in real life.

Describe what they do:

Write two examples of what they do:

1.

2.

Education	One interesting fact (or more)

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Make this website accessible for your students to complete the worksheet:
https://www.sciencebuddies.org/science-engineering-careers/engineering/civil-engineers

Civil Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something a civil engineer makes in real life.

Describe what they do:

Civil engineers work to improve infrastructure around the world to improve travel and commerce, provide people with safe drinking water and sanitation and protect communities from natural disasters.

Write two examples of what they do:

Answers may vary.

1. **Design buildings to withstand earthquakes**
2. **Design a dam to provide power**
3. **Design a bridge to transport people/goods**
4. **Design water treatment facilities**

Education	One interesting fact (or more)
A bachelor's degree in some form of Engineering is typically required, but there are some instances where this is not the case	**Answers may vary.**

Name:______________________________

Mechanical Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do? ✓	Key facts & information ✓	Education ✓	On the Job ✓	Project Ideas ✗	More ✗

Draw a picture of something a mechanical engineer makes in real life.	Describe what they do:

Write two examples of what they do:

1.

2.

Education	One interesting fact (or more)

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Make this website accessible for your students to complete the worksheet:
https://www.sciencebuddies.org/science-engineering-careers/engineering/mechanical-engineer

Mechanical Engineer

Directions: Read through the first four tabs on the website and complete the worksheet.

What do they do?	Key facts & information	Education	On the Job	Project Ideas	More

Draw a picture of something a mechanical engineer makes in real life.

Describe what they do:

Mechanical engineers have a part in designing almost everything you work with in everyday life, from the spoon you eat breakfast with to the car you take to school.

Write two examples of what they do:

Answers may vary.

1. **Design a safety harness for a ride**
2. **Model the movement of solar panels on a satellite/telescope in space**
3. **Design medical robots that improve precision in surgery**
4. **Design prosthetics, like the blades used for high speed running**

Education

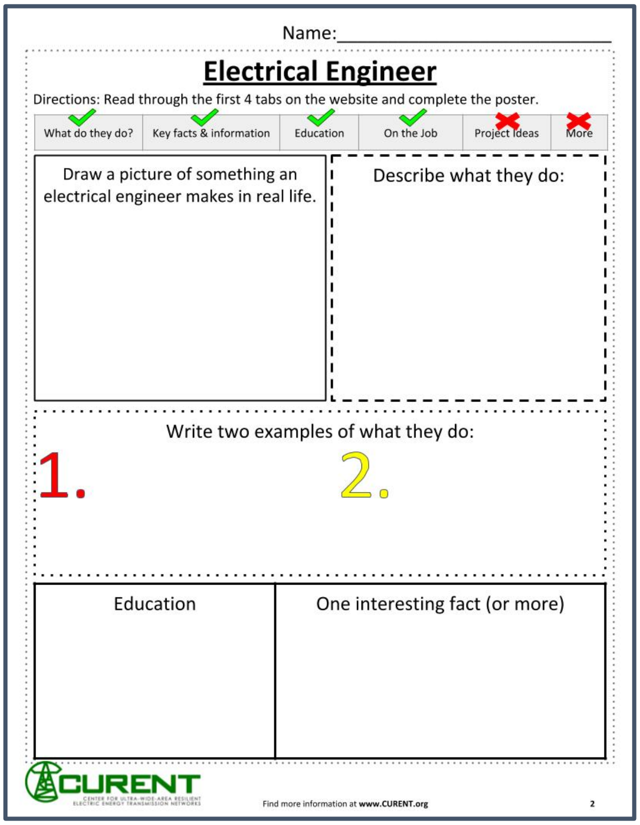
Generally a Bachelor's degree in mechanical engineering is required.

One interesting fact (or more)

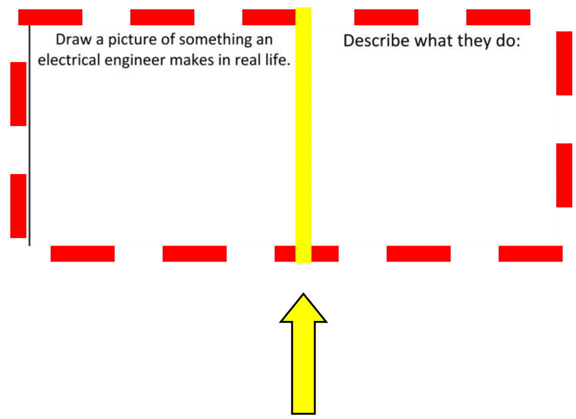
Answers may vary.

Engineering Careers – Foldable Instructions

Directions: Complete your worksheet then follow these steps to create a foldable.

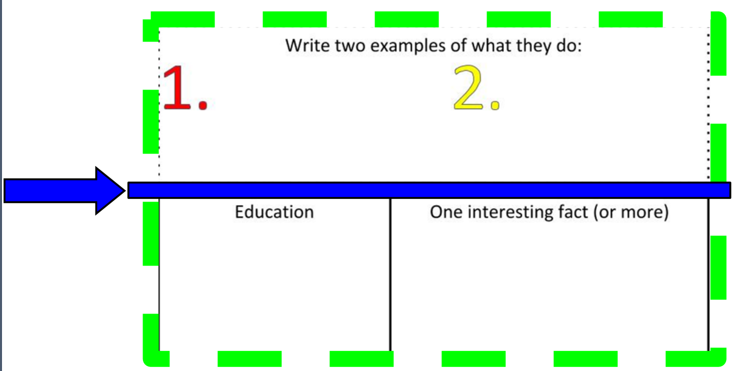


1. Cut around the top two boxes on the red line.



2. Fold in between the two boxes on the yellow line.

3. Cut around the bottom two boxes on the green line.



4. Fold in between the two boxes on the blue line.

5. Label the outside (blank side) of the two foldables with the name of the career. Color and decorate it. Paste the finished foldable into your science journal.

Name:______________________________

Engineering Careers: Reflection

1. What was the most interesting piece of information you learned?

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2. Which type of engineer was your favorite and why?

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3. Did you think about being an engineer before this lesson?

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4. What are your thoughts about being an engineer now?

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5. Think about any career you are interested in (ex. fashion designer, doctor, race car driver). How could this career apply to engineering?

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CURENT

Lesson 2

Powering VOLt City

CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

Grade: 3-5
Subject: Science
Length: 90 minutes

Powering VOLt City

Students will learn about electricity, the power grid, and make their own grid drawing.

CORE IDEAS

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- ESS3.A: Natural Resources
- ESS3.C: Earth and Human Activity
- ETS1: Engineering Design

SCIENCE & ENGINEERING PRACTICES

- Developing and Using Models
- Planning and Carrying Out Investigations
- Use Mathematics and Computational Thinking

CROSS CUTTING CONCEPTS

- Energy and Matter
- Scale, Proportion, and Quantity
- Systems and System Models
- Structures and Functions

OVERVIEW

This is an introductory lesson on different ways electricity is generated in the power grid. The students learn vocabulary terms about the different components of the power grid. Then, they will label a drawing of a power grid before brainstorming how they would power a city of their own, VOLt City.

OBJECTIVES

Students will be able to:

- Compare different ways energy is generated
- Explain what the power grid is and what it does
- Differentiate between renewable and nonrenewable resources
- Demonstrate their understanding by creating a labeled drawing of a sample grid

BRIGHT IDEA
Check out Cyber Resilient Energy Delivery Consortium's (CREDC) Power Grid applet online simulation.

MATERIALS

- ❑ Internet devices
- ❑ Paper
- ❑ Colored Pencils
- ❑ Scissors

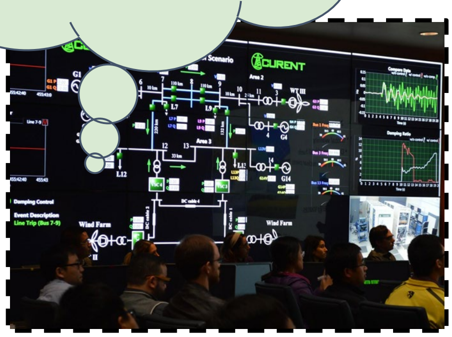

Figure 5.0: CURENT testing (2017).

BRIGHT IDEA

Activate student's interest by asking them to brainstorm things that need to come into their homes to make them work. Food, water and heat are good examples. Ask students how each of these gets into their homes.

Power Generation: Centralized

Power Generation: Decentralized

Power Transmission

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BACKGROUND INFORMATION

The grid is the web of power lines that span across modern civilizations and everything that is connected to them. This system is what connects the power generated at power plants to the power outlets in your home.

The grid can be broken down into 4 components:

Generation, of which there are two types:
A) **Centralized**: Large-scale power generation including coal, nuclear, hydro,wind and solar farms.
B) **Decentralized**: Small-scale generation where most or all of the power generated is used by the residents or property owner (ex. solar panels on a home's roof).

Transmission: Lines connect the power created in the generation stage to substations, located in areas around its destination, which operator at extremely high voltages (usually between 69kV - over 700kV). However, power is not generated at this high voltage. It is typically generated at less than 25kV. In order to increase this voltage, the power is sent through a **step-up transformer.** This will increase the voltage at the loss of current which allows the power to be transmitted with a higher efficiency through the transmission line as it travels long distances.

Distribution: The substations at the end of the transmission lines will then lower, or "step down," the voltage to be between 2.3kV and 34.5kV using **step-down transformers**. Once the voltage has been lowered, the power is sent through distribution lines to its destination. These distribution lines are the power lines that you see around your home, school or work.

Consumption: As the name implies, this is the part of the grid where power is consumed. The power will run through one last transformer mounted on a power pole close to its final destination that lowers the voltage to 120V. It is then run to wherever it is needed such as a wall outlet or the lights in a building.

BRIGHT IDEA

Ask students these essential questions:

- **What is the grid?**
- **How does electricity flow through the grid?**

ACTIVATE

Ask: How do your lights turn on? How does your TV run? How does your house get electricity? Discuss as a class to assess prior knowledge and detect any misconceptions.

Explain: Explain to students that electricity travels through the grid. Have students draw a picture of what they think the grid looks like. Have students also fill in the ten vocabulary for the words related to the grid, including drawing a picture to help them remember.

Suggested Video:
https://www.youtube.com/watch?v=pXasvq1ivnw

CREATE

1. Have students brainstorm (on the board, on paper, using a KWL chart, think-pair-share, etc.) what they know about electricity and how their house and school gets power. Write down all of the ideas somewhere that students can read them so that they can refer back to them later on.
    a. Make sure to ask specific promoting questions, like what resources are used (coal, wind, hydro) to generate power in your local area.
    b. Ask if students have seen power lines, transmission towers, and other components of the power grid.
2. Have students fill in the sequencing diagram (*How Electricity Gets to Your Home*) to explain how electricity moves from the power plant to their home.
3. As a class or in small groups, ask students to check their sequence of events. Correct any misconceptions.
4. Start the Powering VOLt City Activity by having students refer to the original brainstorming question about how they get power in their city.

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CREATE: Powering VOLt City

This activity works well in groups of four-five with the following roles:

- One student is the project manager and keeps everyone on track/reports out at the end
- One student is the adminsitrative director who handles the budget
- Two-three students are project engineers tasked with determing the pros and cons of each option.

1. Have students add up how much power their city needs to generate in megawatts. On the Powering VOLt City worksheets, have students students can calculate how much power and then extend by planning a budget and discussing environmental impacts.
2. Next, Have students brainstorm if their city will be powered completely by renewable resources, non-renewable resources, or a mixture of both.
3. Have students start to build their power grid based off how much energy is generated by each power generation source.
    a. Students will begin to fill in Step 5 of the activity, where they determine what resources, money, and/or environmental impacts will be the result of their choices.
    b. For a more tactile extension activity, have students cut out the shapes of solar, wind, nuclear/gas/coal, and hydro, and assemble them on the provided VOLt City map.
4. At the end, have students come back together and present their city to the class. Have them explain why they made the choices they made, and how that will power their city.

BRIGHT IDEA

Discuss the idea of a budget with students and point out how choosing which power sources to use is similar to creating a personal budget.

DEEPER CONNECTIONS

MODIFY

- ❑ Teachers can ask students to follow directions on website, or allow them to freely manipulate the grid.
- ❑ If students are hesitant to share ideas, put them in small groups to think, pair, and then share as a large group
- ❑ Create physical manipulatives of the power grid include components such as power plant, substations, etc and allow students to assemble these components on their desks.

EXTEND

- ❑ Students can begin to explore the different power sources that bring energy to the grid such as coal, the sun, natural gas, oil, wind, etc. Create a graphic organizer of renewable or nonrenewable resources.
- ❑ Research the local utility board to see who provides power to your neighborhood and the sources they use.

ADDITIONAL RESOURCES

1. Using animated drawings, this video shows children the path electricity takes to get to their homes.

Name:______________________________

The Power Grid - Words to Know

Vocabulary

1. Generation –
2. Transmission –
3. Distribution –
4. Generator –
5. Transmission Lines –
6. The Power Grid –
7. Current –
8. Voltage–
9. Substation –
10. Transformer –

Check your understanding…

Use each of the above vocabulary words to summarize how the power grid gets electricity to your home.

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Name:_____________________________

How Electricity Gets to your Home

When you plug something into a wall outlet to charge it at night, the power you're using may have come from hundreds of miles away, or even from a different country! But how does it get to your home? Electricity travels from source to destination in three major steps: <u>Generation, Transmission, and Distribution</u>.

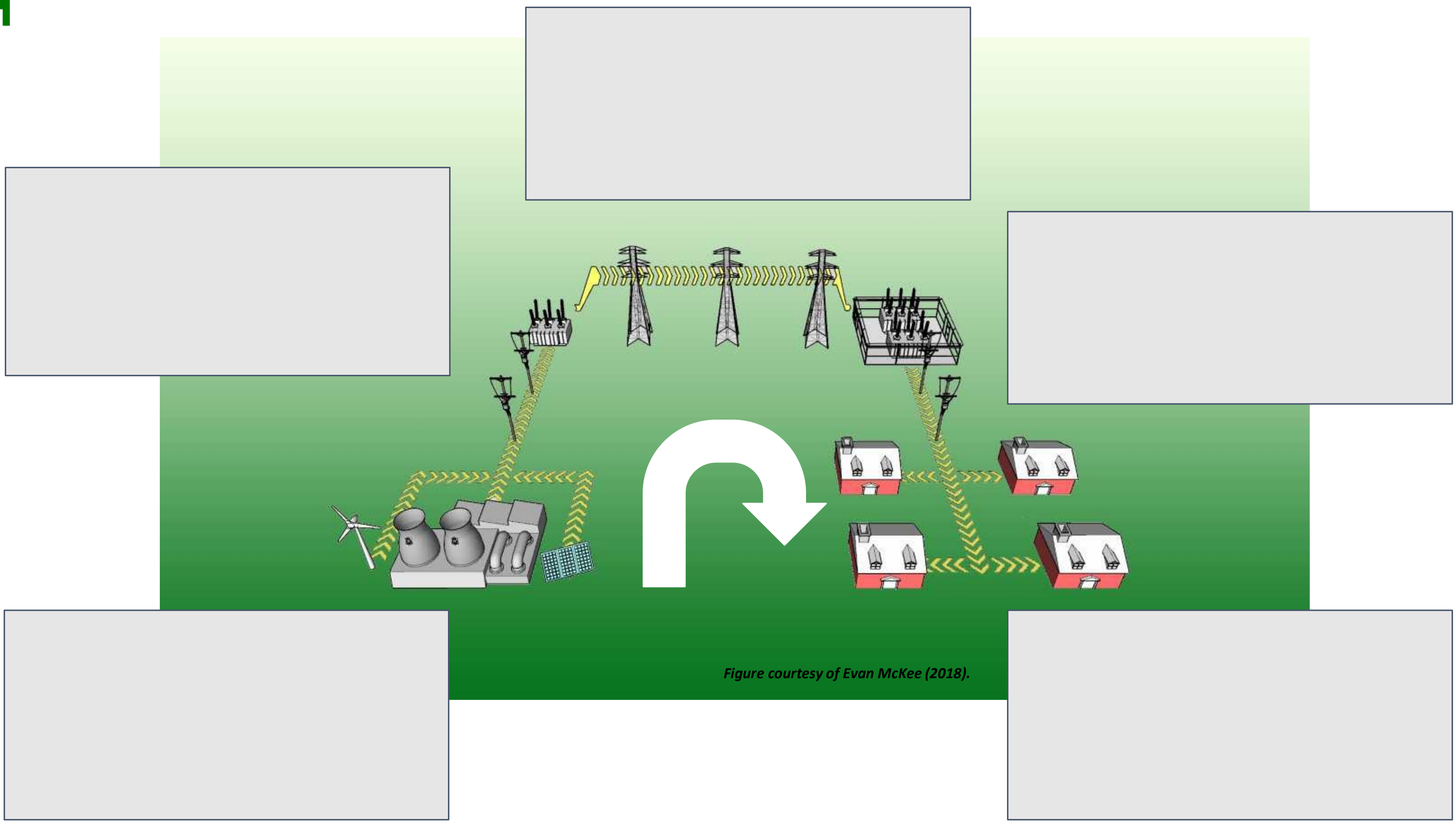


Figure courtesy of Evan McKee (2018).

Name:______________________________

How Electricity Gets to your Home (Answer Sheet)

When you plug something into a wall outlet to charge it at night, the power you're using may have come from hundreds of miles away, or even from a different country! But how does it get to your home? Electricity travels from source to destination in three major steps: Generation, Transmission, and Distribution.

3. Transmission: During **transmission**, electricity can travel for hundreds of miles across high voltage metal poles.

2. Before the power is transmitted, a **step-up transformer** converts the electricity from low to high voltage. Higher voltage allows for lighter power lines and lower cost.

4. Distribution: Distribution begins at a **substation**, where **step-down transformers** bring the voltage down to a safe level for household use.

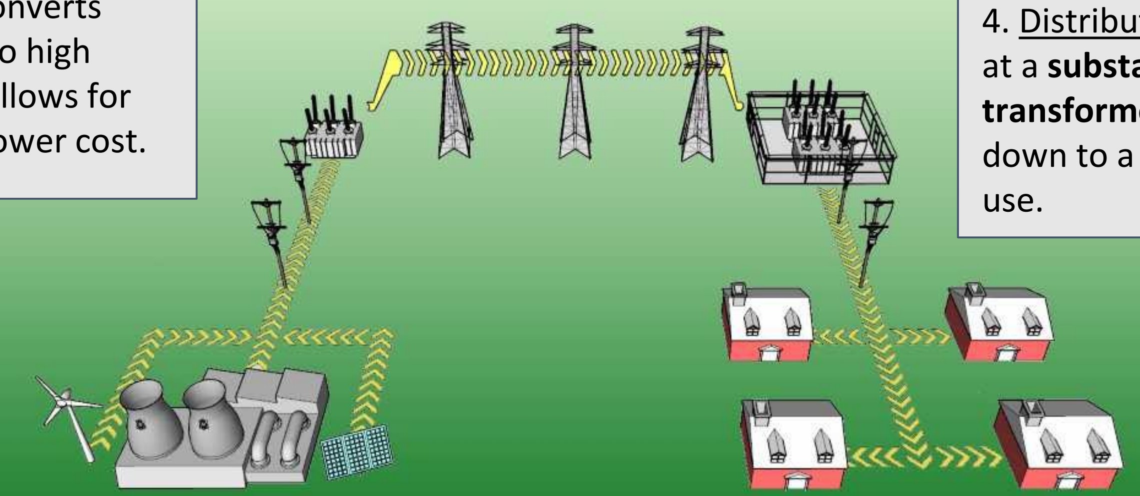


Figure courtesy of Evan McKee (2018).

1. Generation: Power sources like this **windmill**, **nuclear plant**, and **solar panel** harness the earth's resources to generate electric power.

5. Smaller wooden telephone poles send electricity out to individual homes, and connect to a control panel in your home's garage, basement, or closet.

Name:______________________________

Powering VOLt City

Congratulations, you're hired!

VOLt City needs an ENGINEER to redesign its power systems. Luckily, the environment around VOLt City has many nonrenewable and renewable resources to provide power.

Step 1 ASK: Identify the need or Problem: How much power will you need to supply? Find the total by adding up the megawatts from the chart below.

Who needs power?	How much power? (in megawatts)
School	1
Amusement park	30
Sports Stadium	15
Neighborhoods	4
Downtown	40
Total	

Step 2 ASK: Research the need or problem: Consider the constraints for the power systems project you will design. They are listed below.

1. **Every project has a budget. For this project, your budget is $500 million dollars.**
2. **The cost to run a power plant depends on the source of the power.**
3. **Certain power sources produce more power than others.**
4. **Some power plants produce pollution that can harm the environment.**

Step 3 IMAGINE: What kind of power would you want VOLt City use? Circle one of the choices below.

renewable   both   non-renewable

Name:______________________________

Step 4 PLAN: What resources will you use to power VOLt City?

How much is your budget? $________________________________ million dollars.

How much power do you need to generate? _______________________ megawatts.

Power Generation	Energy generated in Megawatts	Cost in millions of dollars	Environmental Effects
Solar Farm (Photovoltaic)	5	50	No toxic pollution or emissions Land used (habitat loss)
Wind Turbines	10	60	No toxic pollution or emissions Land used (habitat loss) Some sound produced
Hydroelectric (Dam)	15	50	No toxic pollution or emissions Land used (habitat loss) Changes aquatic ecosystems
Nuclear Power Plant	15	50	Very small emissions 1-2 tons radioactive waste Air and water pollution Needs to be near a body of water Takes longer to turn on and off
Coal Power Plant	15	25	Large amount of toxic emissions Air and water pollution Land used (habitat loss) Needs to be near a body of water Health effects of workers and community members
Natural Gas Plant	15	60	Large amount of toxic emissions but 50% less emissions than coal Air and water pollution Land used (habitat loss) Needs to be near a body of water

Name:______________________________

Powering VOLt City

Step 5 CREATE: What resources will you use to power VOLt City? Fill in the table below with the power systems VOLt City will use.

Power Generation	Energy Generated in Megawatts	Cost in millions of dollars	Environmental Effects
Total:			

Name:______________________________

Powering VOLt City

Step 6 IMPROVE: Improve/Change/Reflect

How do you think your power plants will affect the community?

Did you have any money left over after buying the power plants? How could VOLt City use that money for to improve the community?

What would you change to make your power generation plan for VOLt City better?

Name:_____________________________

Extension - Drawing the VOLt City Power Grid

Directions: Make a drawing of the power grid for VOLt City. (All drawings could look different!) Be sure to include each of the power generators you used and label them on your drawing. You can use the power generators more than once.

Power Generators		Energy Consumer	
Coal Plant	Wind Turbines	• School	• Downtown
Hydroelectric Dam	Solar Farm (Photovoltaic)	• Amusement Park	• Neighborhood
Nuclear Power Plant	Natural Gas Plant	• Sports Stadium	

Which power generators did you choose for VOLt City?	

Name:______________________________

Extension - Creating the VOLt City Power Grid

Directions: Complete the drawing of the power grid for VOLt City. (All drawings will look different!) Each square represents a place where you can generate certain types of power. You do not have to cover all of the squares. Cut out the VOLt City power types and paste them on a matching square.

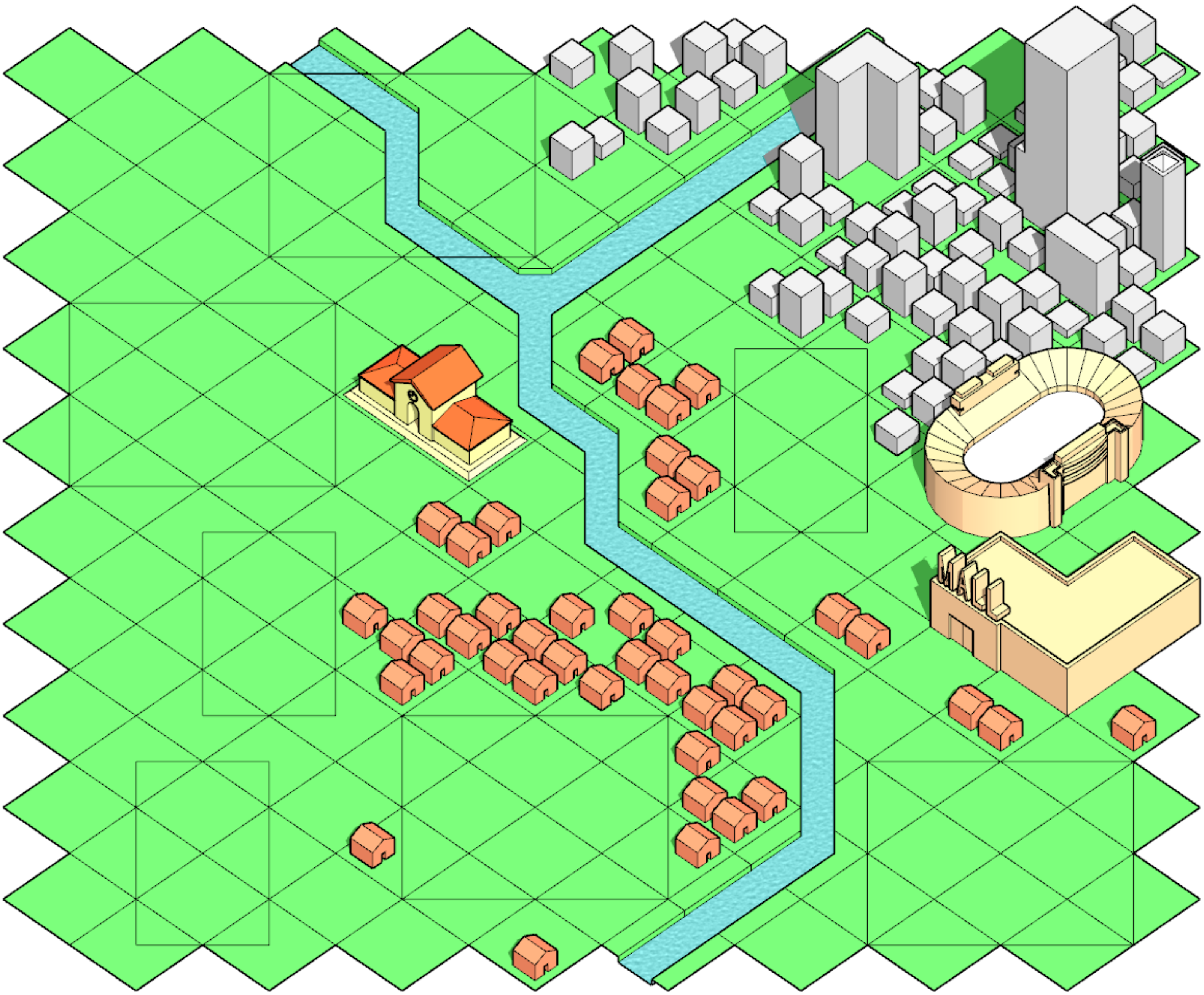
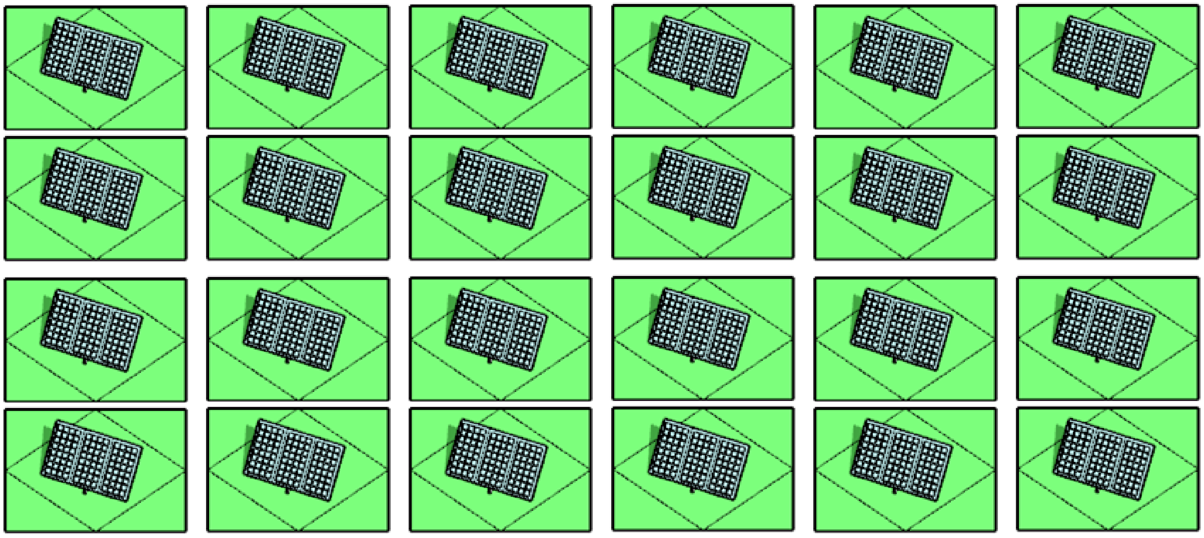


Figure courtesy of Evan McKee (2018).

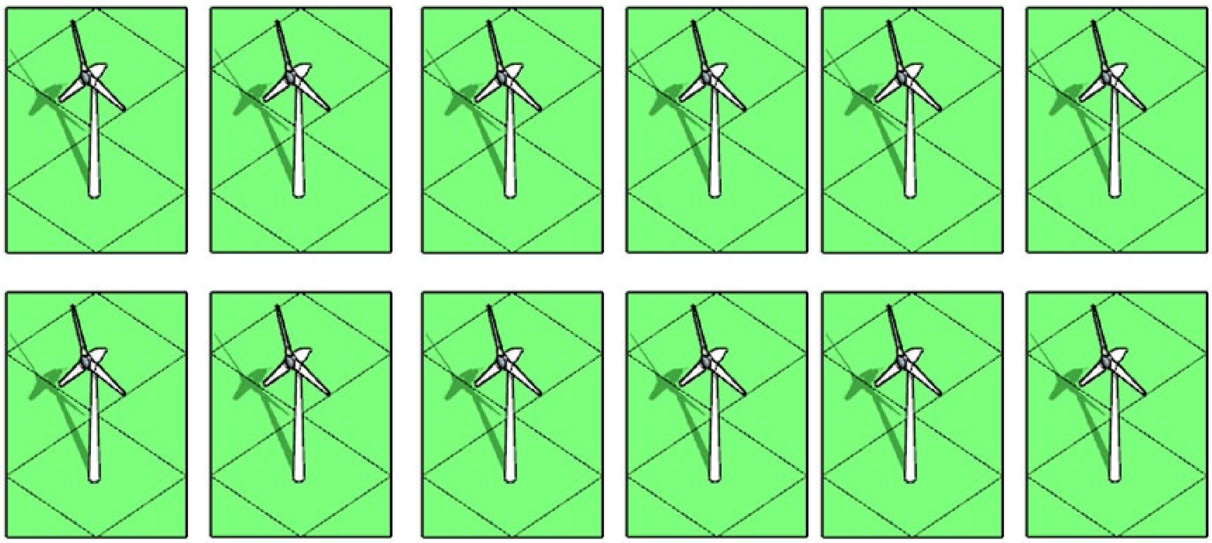
Extension - Cut-outs VOLt City Power Grid

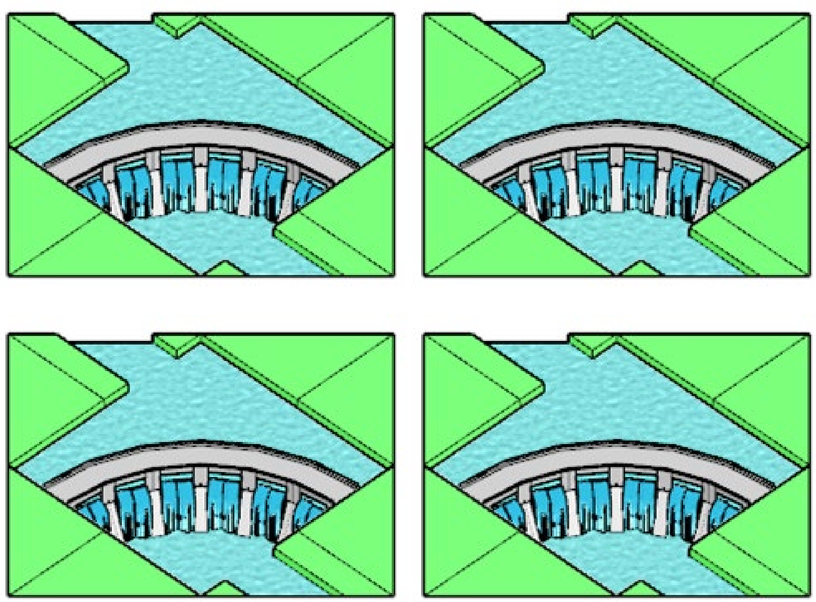
Figures courtesy of Evan McKee (2018).

Small Solar
OR
Wind
Farm



One Large Solar or Wind
OR
Two Small Solar or Wind
OR
Any size Hydroelectric Dam

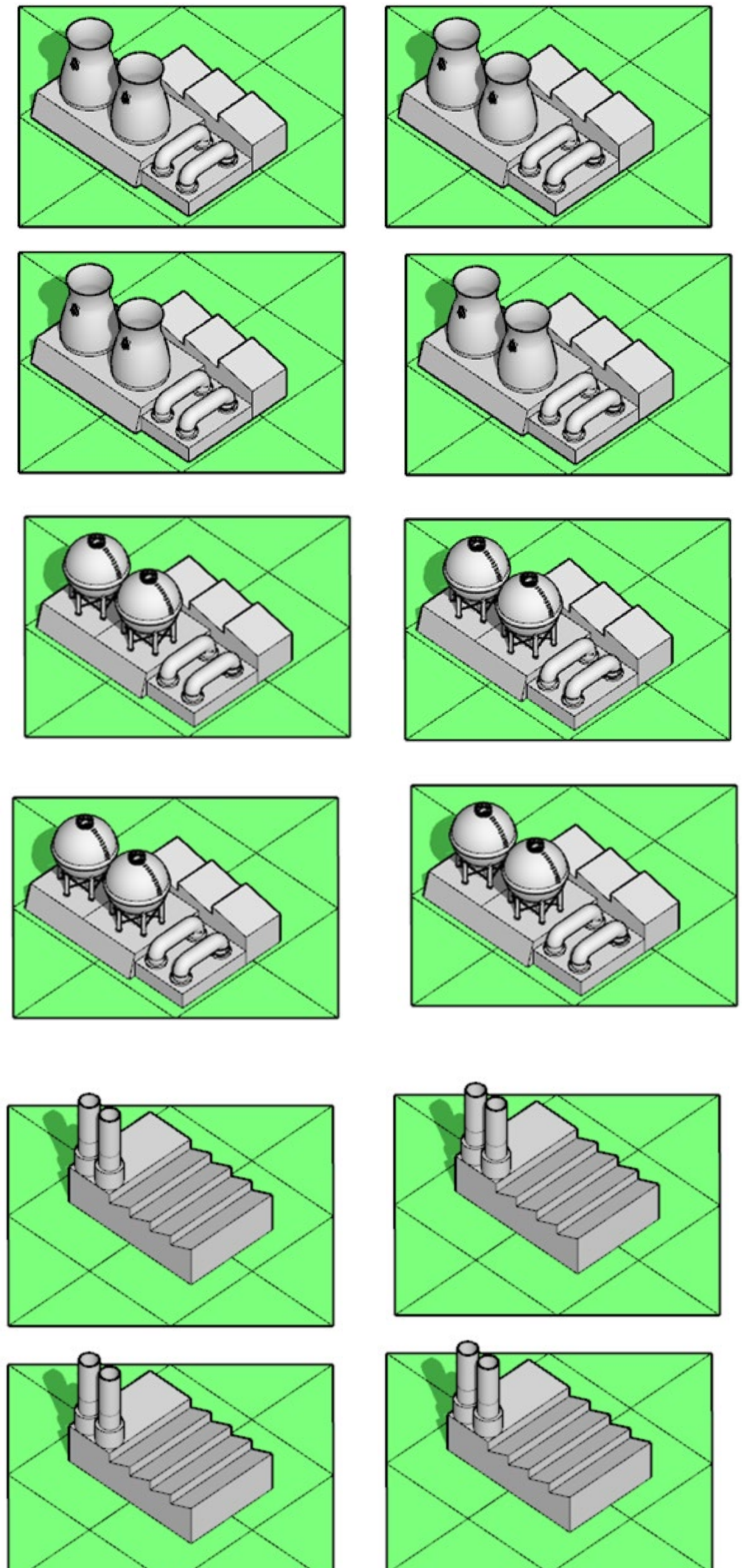




Name:______________________________

Extension - Drawing the VOLt City Power Grid

One Large Coal, Natural Gas, or Nuclear Plant
<u>OR</u>
Two small plants
<u>OR</u>
Any size hydroelectric dam



Figures courtesy of Evan McKee (2018).

Name:______________________________

The Power Grid - Words to Know

Vocabulary

1. Generation – Process of creating electric energy by transforming other forms of energy into electricity.
2. Transmission – Is the bulk movement of electricity from a generation site to a substation.
3. Distribution – Is the last step in electricity transportation, when it is supplied to individuals.
4. Generator – A machine that changes mechanical energy to electrical energy.
5. Transmission Lines – A line used to transport the electricity for long distances.
6. The Power Grid – Is the system of producers and consumers of electricity
7. Current – The flow of charged particles (electrons) through any medium.
8. Voltage– The force that is causing the flow of current.
9. Substation –The location where the voltage is transform to a lower and safer level for distribution.
10. Transformer – A machine that can raise or lower the voltage level depending on what is needed.

Use each of the above vocabulary words to summarize how the power grid gets electricity to your home.

Check your understanding…

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TENNESSEE Northeastern Rensselaer TUSKEGEE

CURENT

Lesson 3

Solar Oven Design Challenge

National Science Foundation
WHERE DISCOVERIES BEGIN

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

Solar Oven Design Challenge

Grade: K-5
Subject: STEM
Length: 90-180 minutes

NEXT GENERATION SCIENCE STANDARDS

CORE IDEAS

- ❖ **PS3.A: Definitions of Energy**
- ❖ **PS3.B: Conversion of Energy and Energy Transfer**
- ❖ **PS4.A: Wave Properties**
- ❖ **PS4.B: Electromagnetic Waves**
- ❖ **ETS1: Engineering Design**

SCIENCE & ENGINEERING PRACTICES

- ❖ **Defining Problems**
- ❖ **Developing and Using Models**
- ❖ **Planning and Carrying Out Investigations**
- ❖ **Analyzing and Interpreting Data**
- ❖ **Designing Solutions**

CROSS CUTTING CONCEPTS

- ❖ **Energy and Matter**
- ❖ **Cause and Effect**
- ❖ **Pattern**

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Students will learn about solar energy and make their own solar ovens to cook s'mores.

OVERVIEW

This lesson is focused on solar energy and the engineering design process. Students will design and create a solar oven, observing how energy is transferred from the sun to the earth. They will also observe the effects of placing objects made with different materials in the sun's path. Students can record the increase in temperature inside the solar ovens as they cook their s'mores.

OBJECTIVES

Student will be able to:

- Make observations to determine how sunlight warms Earth's surfaces.
- Make observations to provide evidence that energy can be transferred from place to place by light and heat.
- Plan and conduct an investigation to determine the effect of placing different materials in the path of a beam of light.
- Describe solar energy by creating a solar oven and explaining how it works.

MATERIALS

- ❑ Pizza boxes, one per group
- ❑ Temperature probes
- ❑ Black construction paper
- ❑ Newspaper
- ❑ Clear plastic wrap
- ❑ Aluminum Foil
- ❑ Scissors
- ❑ Tape
- ❑ Rulers
- ❑ Stopwatch or timer
- ❑ S'mores: marshmallows, graham crackers, chocolate bars
- ❑ Napkins
- ❑ Optional: Heat lamp

BRIGHT IDEA
Check out CURENT Education's YouTube channel for the DIY Solar Oven-Instructional Video.

Figure 3.0: **CURENT solar oven (2017).**

Essential Questions:

1. How does energy from the Sun get to Earth?
2. What are some ways that energy from the Sun affects life on Earth?
3. What are some other examples of renewable energy resources?

ADVANCED PREPARATION

Review

Review the engineering design process. Model the thought process aloud to the class using a simple example, or previous project. Make sure to review each step of the process, as all of the steps are vital to successful engineering. The graphic organizer on (p.44) can help.

Connect this lab to other concepts. For patterns with Earth's systems, have students predict when the best time would be to use a solar oven, or even have them consider where it might work best geographically.

Create a Model

Create a model solar oven using the "How to Make a Solar Oven Teacher Step By Step Lesson Prep" (p. 43). Use this experience to anticipate questions or issues. Test the solar oven model to make sure it is completely sealed trapping enough heat to cook a s'more. Show the model to students after they create their ovens

Optional: Have students view solar panels in the area. Allow students to work in pairs to observe the parts of the solar panel (from real-world examples or printed pictures, graphics, google images, etc.).

QESST has a good construction paper solar cell activity here: http://qesst.org/wp-content/uploads/2018/05/8-Construction-Paper-Solar-Cells.pdf

Prepare student materials:

1. Start collecting pizza boxes in advance. Send a note to families to collect and donate them. Alternatively, ask a pizza chain to donate unused pizza boxes.
2. Pre-cut square flaps out of the top off all the pizza boxes using a crafting knife to ensure student safety.
3. Make sure to check with the school nurse and parents for any food allergies the students may have.

Scout a testing location

The solar oven will work best in the afternoon of warmer months (~85°F), when the angle of the sunlight is more direct. If this isn't an option, use a heat lamp. If opting to use a heat lamp, be sure to keep children from touching the bulb.

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BACKGROUND INFORMATION

If this lesson is the student's first exposure to energy, the objective will be to introduce the idea that the sun is interacting and changing the surface of the Earth. The sun isn't physically touching the Earth nor is the heat transfer visible, so this concept may be challenging for students to understand at first. They should ultimately know that energy is present whenever there is movement, sound, light, or heat.

Students should understand that energy is not a physical substance, but more a substance-like quality that can be stored or transferred through space from place to place. Radiant energy (light) can be stored in objects as **thermal energy** (heat). Imagine that heat is a bank account, how energy and the light is stored can be thought of as an energy deposit into the bank account. For NGSS, temperature analysis can be limited to qualitative (warmer or cooler to the touch), or quantitative (measuring with devices) analysis.

There are two types of solar power: **Photovoltaic solar power** (solar panels) and **solar thermal energy** (direct solar power). Solar ovens use solar thermal energy to cook food. Designs may vary, but three basic principles are applied to most solar ovens (see *Figure 3.1)*. The three basic principles are:

1. **Concentrating sunlight:** Materials are used to reflect the sunlight and concentrate it within the device. Foil, mirrors, metal, or other reflective materials can achieve this. Another aspect is the angle of reflection, the light should be as direct as possible.
2. **Converting light to heat:** Inside the oven, surfaces are colored black to absorb and retain heat. This is when the transfer from radiant to thermal energy occurs.
3. **Greenhouse effect:** Materials isolate the air inside the oven, separating it from the air outside. The cover allows heat to enter, but not escape (see *Figure 3.2)*.

Solar ovens provide environmental and health benefits. They reduce the demand for wood fuel – a major cause of deforestation. Deforestation contributes to climate change, soil degradation and erosion, and flooding. Solar ovens prevent pollution as they eliminate the need to burn fuels. Open fires contribute to indoor pollution, health risks associated including death, and unintentional fire incidents.

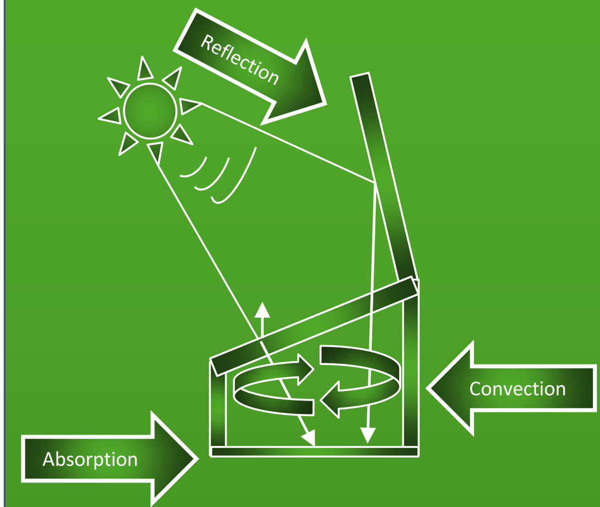

Figure 3.1. **Basic principles of a solar oven. The sun's rays are reflected from the shiny surface into the oven. They are absorbed by the dark surface and stored inside the oven. Convection occurs as the thermal energy builds. The transparent materials absorb infrared light and trap heat inside the oven during the process. The sides and lid insulate the oven, sealing the heat inside the oven.**

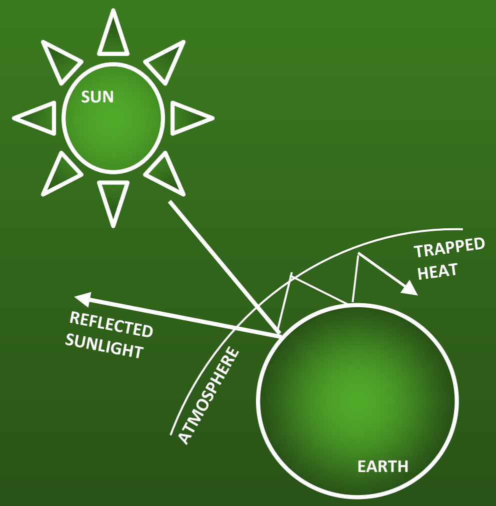

Figure 3.2. **Representation of the Greenhouse Effect. When sunlight hits earth, it can either reflect or become heat by trapping gases in the atmosphere.**

BRIGHT IDEA

If opting to use a heat lamp instead of the sun, be sure to keep the children from touching the bulbs.

ACTIVATE

Part One: Science Literacy (Optional)

Read aloud to the class this book on solar gadgets made by kid inventors by Bob Pfugfelder and Steve Hockensmith, Nick and Tesla's Solar-Powered Showdown: A Mystery with Sun-Powered Gadgets You Can Build Yourself.

Part Two: Using Inquiry

Ask: What are the forms of energy that we use for cooking?

> **Explain**: Ovens and microwaves cook using electricity or gas. Fires heat by burning wood or fuels.

Ask: What is energy poverty? How would you heat something if you lived in an area of energy poverty?

> **Explain**: These areas do not have access to modern fuels, they often use fires to cook their food.

Ask: Add a constraint. What would happen if you ran out of wood? Can you cook without a fire, oven, or microwave?

> **Explain**: You could harness the sun's radiant energy.

Ask: How does thermal energy get from the sun to the Earth when it is traveling in the form of light?

> **Explain**: Energy transfer. The light the sun produces radiant energy can be converted into thermal energy.

Ask: What affects the amount of heat that stays in the Earth's atmosphere?

> **Explain**: Cause and effect; patterns; systems. Make connections to weather and the sun's patterns here. Write the following points on the board and reference them during the testing phase.

- The angle of the sun and the Earth (i.e. geographic location or climate, time of day and year).
- Greenhouse effect (how much heat is trapped)
- Material properties (certain materials reflect or absorb energy)

Ask: What are the consequences of using certain types of resources? How do these affect the environment? How do they affect people?

> **Explain**: Engineering, technology, and science have an influence on society and the natural world. Non-renewable resources can pollute the environment and cause health problems.

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CREATE

1. Teacher proposes the design challenge: create a solar oven.
2. Model expectations explicitly for group work. Optional: Pass out the “Engineering Challenge Grading Rubric” (p. 53) and discuss how points are earned.
3. Instruct students to draw and label their initial design BEFORE getting supplies or beginning construction.
4. Go over the “Solar Oven Design Challenge” worksheet (p. 44). Review what materials are available to students and write them on the board.
5. Divide the class into groups of 2-3 students. Handout the “Solar Oven Design Challenge” worksheet (p. 44).
6. Allow students ample time to brainstorm ideas, consider material properties and draft their designs.
7. Teams should collaborate within their groups to solve problems. Instruct students to ask three of their peers and research solutions before asking the teacher for assistance. The teacher should encourage independence and facilitate only when needed.
8. Circulate the room and hand out supplies once students’ initial drawings are checked for completion.
9. Students should now work on constructing their designs. They should record all of their design changes in their journal or on the worksheet. Note: S’mores and thermometers need to go in the solar oven BEFORE sealing and testing.
10. When students finish construction, take the solar ovens outside with the temperature probes (450°F) visible. Students can observe and record the increase in temperature over time with the temperature probe as they cook their s’mores.
11. Set a 30 minute timer, and allow students to improve designs. Complete the “Solar Oven Design Challenge Reflection” (pp. 45 to close the lesson. Optional: Record the temperature data on the “Data Collection” worksheet (pp. 49). Bring an activity for students to do outside (ex. self-evaluation rubric).

BRIGHT IDEA

This is an inquiry-based discovery lesson. Little explanation is given up front by teacher, and a lot of exploration on the part of the students. Allow students to EXPLORE their ideas and FAIL, and then TRY AGAIN!

BRIGHT IDEA

Three data collection sheets are provided with one minute, five minute, and choice time intervals. If you choose a longer time interval, you can do another activity while you wait.

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DEEPER CONNECTIONS

MODIFY

- ❑ Have simplified fill-in-the-blank notes or diagrams.
- ❑ Instead of having students plan and build a solar oven, have one mostly built and have groups identify material properties.
- ❑ Pre-package group supplies for students. Allow students to trade supplies between groups.
- ❑ Use whiteboards for sketching designs instead of worksheets. Take photos of the whiteboard drawings to reference during construction.
- ❑ Make this multi-grade level: bring in older students to work with younger students and those who may need more help. This is a great opportunity to partner with middle or high school students.
- ❑ For lower grades or limited time, use the solar oven as a demonstration.

EXTEND

- ❑ Have students collect quantitative data during the process using the “Data Collection” sheets provided (pp. 49). Two data collection sheets are provided with prompts for five minute and choice time intervals. If a longer time interval is chosen, do another activity while during the wait time. Plot the data collected as temperature over time to compare and contrast designs. The “Graphing sheet Version One” (p. 51) is a blank coordinate plane, while “Graphing sheet Version Two” (p. 52) is scaffolded with prompts for the inclusion of all major elements of a graph.
- ❑ Have students write an evidence-based scientific argument for why their solar oven design works best.
- ❑ Let students research the optimal time of year to get more direct sunlight to produce the most solar energy, as well as the least optimal time of year. Students could explain how latitudes within the tropics play a role in the position of the sun and seasons.

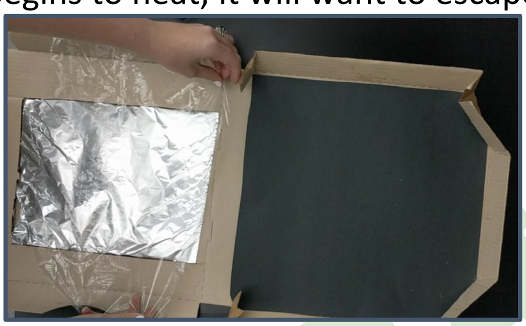
How to Make a Solar Oven

Teacher Step By Step Lesson Prep

Check out CURENT Education's YouTube channel for the DIY Solar Oven- Instructional Video.

1. Select a sunny day (~85°F) with little to no wind if cooking the s'mores outside.
2. Order a delicious pizza and save the box. Some stores may just give away clean boxes if you request them on behalf of the school or students.
3. Secure black construction paper onto the bottom of the box with tape to absorb heat.
4. Using a utility knife, scissors, or box-cutter, cut three sides of a square out of the top of the pizza box, leaving the folded edge attached.

1. Attach aluminum foil to the inside of the flap cut from the top of the box. A good bit of adhesive will be necessary to do this. TIP: Flatten the foil using the ruler.
2. Open **the ENTIRE top of the box**, lift the cut flap, and tape plastic wrap around the opening, sealing the inside of the box. Tape securely so it is **AIRTIGHT-**-as air inside the box begins to heat, it will want to escape. Packing tape is recommended.



1. Place s'mores and 450℉ thermometer inside the pizza box. Use a clear plastic plate. Make sure the thermometer is visible to be able to record the increasing temperature.
2. Secure the pizza box lid by taping it down to make it airtight.
3. Let s'mores cook for 30 minutes. When placing boxes outside, place them so the angle of the sun is directly hitting the aluminum foil, so the rays can be reflected into the box to cook the s'mores. Prop the flap open with a ruler.
4. Enjoy the delicious results. **Check the temperature inside boxes, s'mores may be hot.**

Name:______________________________

Solar Oven Design Challenge

Create a solar oven using the supplies given. Your oven will need to cook a s'more in 30 minutes.

ASK

How will the black construction paper effect light waves?
How will the aluminum foil effect light waves?
How will the plastic wrap effect light waves?
When the air starts to warm up in the pizza box, it is going to want to escape! How can you prevent this from happening?

IMAGINE

Sketch & label your design idea.

PLAN

Gather your materials.

CREATE

Follow your plan.

TEST

Record your data on the sheets provided.

IMPROVE

What would you change on your design?

Name:_____________________________

Solar Oven Design Challenge Reflection

1. Describe the weather outside. (Is it cold or hot? Is it sunny or cloudy?)

____

____

____

1. Predict. What weather conditions are best for solar ovens?

____

____

____

1. What are three ways you may have lost heat from your solar oven?

Idea 1.

____

____

____ _

Idea 2.

____

____

____

Idea 3.

Name:______________________________

Solar Oven Design Challenge Reflection

How could you improve your design to fix this?

Idea 3.

____

____

____

5. Compare your design with another group's solar oven.

How was your design better?

____

____

____

____

____

____

____

____

____

Name:______________________________

Solar Oven Design Challenge Reflection

1. Describe the weather outside. (Is it cold or hot? Is it sunny or cloudy?)

Answers may vary. Appropriate examples of qualitative weather observations include sunny, cloudy,

ason or time of day. Quantitative observations (temperature) should made by students.

rainy, warm, cold, windy, etc. Examples of weather patterns include describing relative measures such as the se

Answers may vary. Appropriate answers may include warm, hot, without wind or precipitation, sunny, etc.

1. Predict. What weather conditions are best for solar ovens?

Answers may vary. Examples may include: Heat escaped from my design. Heat could have escaped from the cardboard bottom or from unsecured plastic wrap.

1. What are three ways you may have lost heat from your solar oven?

Answers may vary. Examples may include: My oven was on a cold surface.

Answers may vary. Examples may include: There was not enough light shining into my oven.

Answers may vary. Examples may include: Tape the edges or seal the box better. Use of alternative materials. Answers should not mention things students cannot control such as wind.

Answers may vary. Examples may include: Add more reflective or absorption materials. Use of alternative materials. Change the angle of reflection. Answers should not mention things students cannot control such as weather or sunlight.

Idea 3

Name:______________________________

Solar Oven Design Challenge Reflection

How could you improve your design to fix this?

Idea 3.

Answers may vary. Examples may include: Propping the oven up on a higher surface or placing the oven
____
on a darker surface to attract more light.

5. Compare your design with another group's solar oven.

   How was your design better?

   Answers may vary.

Name:______________________________

Data Collection

Your teacher will start a stopwatch and call out the time every five minutes. At the five minute mark record the temperature (°F) your thermometer shows.

Time (minutes)	Temperature (°F)
0	
5	
10	
15	
20	
25	
30	

Name:______________________________

Data Collection

Your teacher will start a stopwatch and call out the time every five minutes. At the five minute mark record the temperature (°F) your thermometer shows.

Time (minutes)	Temperature (°F)
0	
5	
10	
15	
20	
25	
30	

Name:______________________________

Data Collection

Your teacher will start a stopwatch and call out the time to take a temperature measurement. Record the time in minutes and record the temperature in degrees F.

Time (minutes)	Temperature (°F)	Time (minutes)	Temperature (°F)
0			

Name:______________________________

Data Graphing Sheet Version 1

Plot the temperature (degrees) and time (minutes) data from your solar oven to create a line graph. You may want to use a ruler to draw a straight line connecting the points.

Name:______________________________

Data Graphing Sheet Version 2

Plot the temperature (degrees) and time (minutes) data from your solar oven to create a line graph. You may want to use a ruler to draw a straight line connecting the points.

Title

Variable

Variable

Name:_______________________________ Challenge:____________________________ Date:_________________

Engineering Challenge Grading Rubric - Overall Score _________

	Needs Improvement 1	Ok 2	Good 3	Great 4	Your Score	Team Score
Teamwork	Little teamwork. Didn't allow others to speak. Usually want things your way. Not respectful of others ideas.	Some teamwork. Rarely allowed others to speak. Often sided with friends, instead of listening to the views of everyone on the team.	Good teamwork. Listened to others, but only spoke or shared sometimes. Usually considered the views of others.	Great teamwork. Listened and spoke with respect. Shared ideas and was able to reach fair decisions.		
Focus on Task	Rarely focused on the task, the requirements or constraints. Lets others do the work. Teacher directed your attention back on task.	Somewhat focused on the task, the requirements, and constraints. Other group members sometimes reminded you to stay on task.	Mostly focused on the task, the requirements, and constraints. Reliable, but not consistent with your group.	Consistently focused on the task, the requirements, and constraints. Self-motivated. No one directed your attention on task.		
Use of the Engineering Design Process	Construction without planning first.	Asked and imagined, but only some planning (incomplete or not labeled).	Completed all stages before designing, but did not improve design.	Used knowledge from previous designs to create a better final product.		
Reaction to Problem Solving	End of the world: Failure to problem-solve constraints.	Minor freak out: Overcame some constraints, but complained about having them.	Mildly chill: Overcame most of constraints with little complaint.	Cool as a cucumber: Overcame constraints and embraced the process.		
Final Product	No final product.	Final product created, but failed to solve the problem.	Final product solved part of the problem. No modifications.	Final product solved the problem with or without modification.		

CURENT

Lesson 4

Exploring Hydroelectricity: Building a Water Wheel

CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

Grade: 4
Subject: STEM
Length: 90 minutes

Exploring Hydroelectricity:
Building a Water Wheel

NEXT GENERATION SCIENCE STANDARDS

CORE IDEAS

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship between Energy and Forces
- PS3.D: Energy in Chemical Processes and Everyday Life
- ESS3.A: Natural Resources
- ETS1: Engineering Design

SCIENCE & ENGINEERING PRACTICES

- Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions

CROSS CUTTING CONCEPTS

- Energy and Matter
- Scale, Proportion, and Quantity

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Students explore the engineering design process and hydroelectricity by building a water wheel.

OVERVIEW

Students explore the engineering design process to discover how to best produce hydroelectricity. They will learn how to construct and create energy for the power grid. Students then observe how hydroelectricity works by constructing and testing their own water wheel designs. Each team collects voltage data produced from the water wheels to compare and contrast designs. They can therefore observe how much energy they are contributing to the power grid through the multimeter.

OBJECTIVES

Students will be able to:

- Construct a water wheel model
- Explain why hydropower is a renewable resource
- Measure energy using a voltmeter.

BRIGHT IDEA
Check out CURENT Education's YouTube channel for the DIY Water Wheel- Instructional Video.

MATERIALS

- ❑ Styrofoam balls ≅ 2in
- ❑ Corks
- ❑ Sink or water fountain
- ❑ Plastic spoons
- ❑ DC motor
- ❑ Multimeter or/
- ❑ Voltmeter
- ❑ Tape or glue
- ❑ Insulated Wire

ADVANCED PREPARATION

Review

Review the engineering design process. Model the process to the class using a simple example, or a previous project. For example, you might say, “When I was testing ______, I thought that changing ____ would improve ______ .” Alternatively, “I noticed that the models that had better _______ also had ______, so I decided to add that to my model.” Show students the benefits of original design as well as incorporation of others ideas. Show students the history of water wheels.

Create a Model

Create a model water wheel to show to students. Use this experience to anticipate questions or issues. You should test your model to make sure it works. Optional: have students view a water wheel in your city or town. Allow students to work in pairs to observe the parts they see on the water wheel (from real world, printed pictures or graphics, google images, etc.).

Prepare student materials:

1. Each student will need the following items: multiple plastic spoons, half of a styrofoam ball, one cork, one DC motor, one piece of insulated wire.
2. Pre-cut styrofoam balls and hot glue them to corks.
3. Cut the insulated wire into ten-inch segments.
4. Remove one-half inch of plastic insulation off the ends of each segment. Use wire strippers or simply score the plastic insulation around the wire with sharp scissors. Then, firmly but carefully pull off the plastic casing with your fingers.

Scout a testing location

Select the best location to test students’ water wheels. Remember the water must be flowing to move the spokes. It may be messy, so do this outside if weather is permitting. If there is not a natural running water source, use a baby pool. You can also use a faucet and a sink, or a pitcher of water and a large tub in the classroom. Remember: the higher the water falls, the more energy will be created.

BRIGHT IDEA

Make sure to model the thought process during engineering design. This will help students develop their own strategies.

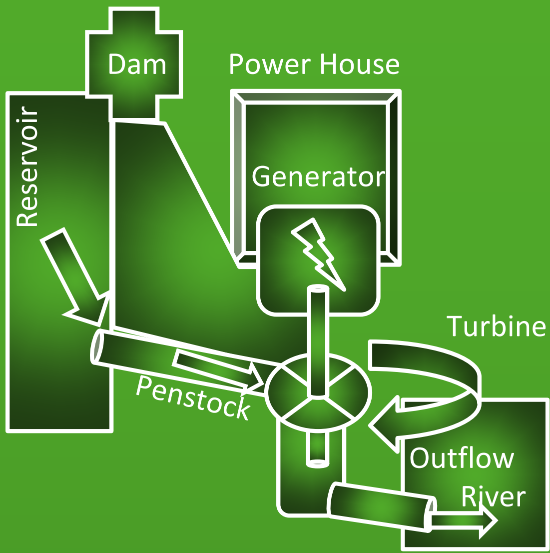

Figure 4.1.

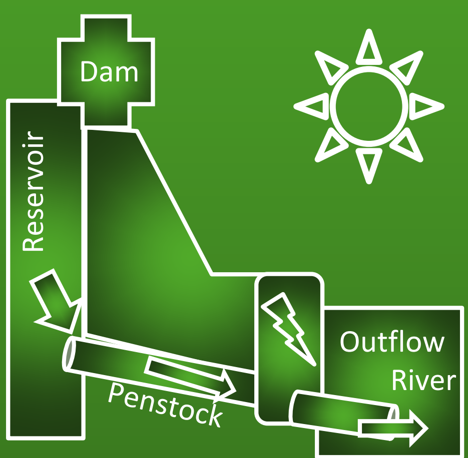

***Figure 4.2.* A hydroelectric dam. Water flows from the reservoir to the penstock to spin the turbine and then out to the outflow river.**

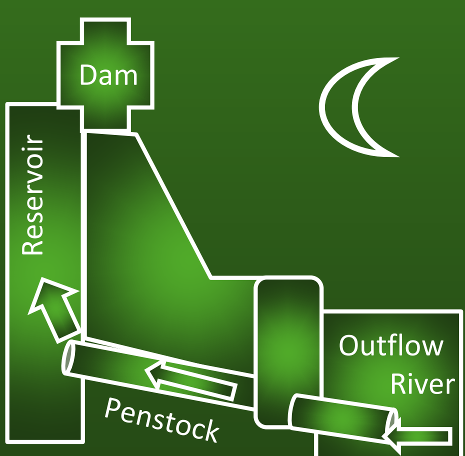

***Figure 4.3.* Some dams will pump water back into the reservoir to store it for later.**

BACKGROUND KNOWLEDGE

Hydroelectricity is a **renewable resource**.

<u>So, how do we get electricity from water?</u>
Energy occurs in many forms. To make energy useful to us, we often have to convert energy from one form to another. Hydroelectricity is one of the oldest forms of power generation. The **hydroelectric turbine** converts the **potential** and **kinetic energy** of flowing water into mechanical energy by turning the turbine. The **mechanical energy** that is produced is the desired form for practical use (electricity).

<u>How does the turbine work?</u>
Hydroelectric and **coal power plants** produce energy in a similar way. Both use a power source to turn a propeller-like mechanism called a turbine. This turns a metal shaft in an electric generator and the motor produces the electricity. A coal plant uses steam to turn the turbine, whereas a hydroelectric plant uses falling water to turn the turbine. Nuclear and gas power plants also use steam to turn the turbine.

<u>Optional</u>: If students know about generators, you can make the connection to the use of magnets in a generator.

<u>Why do we need dams?</u>
Gravity causes water to fall through the penstock within the dam to get to the turbine. At the end of the penstock is the turbine. We know that for kinetic energy - the faster an object is moving, the more energy it possesses. If we build a dam on a large river that has a massive drop in elevation, theoretically we can produce a large amount of energy.

The **dams** serve a second function. Electricity demand changes throughout the day. It is not constant. For example, overnight there is generally less of a need for electricity, but during a hot day there is a huge demand to run air conditioners. Hydroelectric plants are used to meet peak demands such as the examples listed above. The dam is also used as storage to meet these needs. Some dams works to keep water in the reserve, but also pumps water uphill back into the reserve. The reservoir acts just like a battery - it stores energy for us to use later. Unlike large coal or nuclear plants, hydroelectric generators can start and adjust their power output rapidly. They operate most efficiently when used for only a few hours at a time.

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ACTIVATE

Part One: Inquiry

Ask students to raise their hand if they agree or disagree with these guiding questions about the types of energy and hydropower.

- Is water a type of energy? Discuss: How? Why?
- What types of energy is water?
- How does water transfer energy? Discuss: How can we use water to create electricity?
- Predict whether water that is higher up will make more or less energy when it flows through a turbine.
- Do hydropower dams reduce the production of pollution?
- Do you think hydropower dams are expensive to build?
- Do you think that hydropower dams can interfere with natural wildlife?
- Discuss: What are the advantages and disadvantages of renewable energy sources? What are they for renewable energy sources?

Define hydroelectricity as a class and explain how energy from flowing water is transformed into usable power. Be specific by using the types of energy: mechanical, electrical, potential, and kinetic. Have students complete the "Forms of Energy - Word Scramble" (pp. 61).

Part Two: Real world connections

Ask students if they have seen a water wheel and/or dam in real life. How does this work? What is happening?

Optional: Compare and contrast water wheels over time. Ask:

- How is hydropower used in everyday life?
- Where have you seen this in nature?
- What is a water wheel?
- Why do we build dams?
- What about the size of the water wheel?
- The size, shape, number of the blades?
- How has the shape changed?
- How are windmills and waterwheels similar?
- What type of water conditions do engineers require to use natural water for hydroelectricity?

BRIGHT IDEA

Ask students these essential questions:

1. **Why is water renewable?**
2. **How is water used to make electricity?**

BRIGHT IDEA

Supervise the water source and multimeter if they are accessible to students while they can test to avoid messes and confusion.

CREATE

1. Brainstorm as a class what factors will affect the amount of energy produced by the water wheel (ex. amount of water, number of spokes, etc). Write these on the board and reference them during the testing phase.
2. Optional: Watch the following YouTube video(s) by BC Howard, "How a Dam Works" and "Energy 101: Hydropower" by the U.S. Dept of Energy.
3. Model expectations explicitly for group work. Instruct students to draw and label their initial design **BEFORE** beginning construction. Once the drawing is complete, they may get supplies from teacher.
4. Go over the "Hydroelectricity Challenge" worksheet (p. 63). Go over what materials are available to students. Write them on the board. Give limitations to materials if you have them.
   Optional: Pre-package group supplies for students. Allow them to trade.

1. Divide 2-3 students into small groups and handout the "Hydroelectricity Challenge" worksheet (p.63).
2. Allow students ample time to brainstorm and create their designs.
3. Circulate the room and hand out supplies once you've checked student drawings. Hand out spoons, a styrofoam ball hot-glued to a cork, wire, and DC motor to create their own water wheels.
4. Students build their design and then they will measure how much energy they can create.
5. Supervise the water source and multimeter if they are accessible to students.
6. Record the voltage of each group's water wheel on the board or in a place where all students can see it.
7. Students should redesign their model after testing and observing results. Be sure that students bring the "Hydroelectricity Challenge" handout (p. 63) to the testing center. Design changes must be recorded.
8. When students are ready for their final test, they can connect the motor to the multimeter and record their voltage and complete the "Hydroelectricity Challenge" handout (p. 63). Debrief as a class.
9. Use the "Exploring Hydroelectricity - Words to Know" (pp. 64-65) to assess student learning.

DEEPER CONNECTIONS

MODIFY

- ❑ Pre-assemble parts of the water wheel before class so that students who struggle with fine motor skills can still assemble it.
- ❑ Use whiteboards for sketching designs instead of worksheets. Take photos of the whiteboard drawings to reference during construction.
- ❑ Have students count the number of rotations their water wheel completes in a certain amount of time. Discuss how to measure the rate of rotation. Does the water wheel have to completely stop? Have students create the procedure. When will they count one complete rotation? Hint: Color components to distinguish them.
- ❑ For lower grades, use the water wheel as a demo.

EXTEND

- ❑ Give students freedom to design their water wheels using other supplies. Send out a notice to parents in advance to gather supplies such as two- liter plastic bottles, index cards, waterproofing materials (ex. foil, plastic wrap), wooden dowels larger than the length of the bottle, string, weights, etc.
- ❑ Add the "Forms of Energy - Word Scramble" (p. 61) to science notebooks.
- ❑ Explore hydroelectricity and the use of dams in your area. Research different types of water wheels.
- ❑ "Hire" student engineers to create an advertisement to sell their water wheels to the city using what they've learned. If your city does not have a water system to utilize, use the nearest town instead.
- ❑

BRIGHT IDEA

Make connections linking concepts. Use the water wheels students created in this lesson to power the circuit city created in CURENT lesson 2.

Name:_______________________________

Forms of Energy - Word Scramble

Directions: Color each square. Cut each of the squares out. Move the squares around until you can create a word. Then paste the squares on a new sheet.

M	Mechanical Energy
S	Sound Energy
T	Thermal Energy
E	Electrical Energy
L	Light Energy

Name:______________________________

Forms of Energy - Word Scramble

Directions: Cut each of the squares out. Move the forms of energy around until you can create a word. Then paste the squares on a new sheet.

M	Mechanical Energy
E	Electrical Energy
L	Light Energy
T	Thermal Energy
S	Sound Energy

Name:______________________________

Hydroelectricity Challenge

Challenge: Create a device that will produce electricity from water.

ASK

What are the problems? What factors will affect how it spins?

IMAGINE

Sketch & label your design idea.

PLAN

Gather all of your materials.

CREATE

Follow the plan you imagined.

TEST

How much voltage did your water wheel produce?

IMPROVE

What did you change on your design?

Name:______________________________

Exploring Hydroelectricity - Words to Know

Directions: Use the words in the boxes below to fill in the blanks.

Dam	Hydroelectricity	Kinetic
Mechanical Energy	Potential	Rotate
Turbine	Wheel	Power House
Reservoir	Electrical	Generator

A dam produces ____________electricity by converting energy from flowing water into ____________________________ energy. The dam stores large amounts of water (_______________________ energy) behind a large wall in a _______________ . It restricts the flow of the water to only flow through a few holes near the bottom of the ________________. As the water flows through the hole, it spins the __________________ . A water____________________ is an example of a simple turbine. The spinning turbine can _________________ the rotor in the ____________________ creating _________________ energy.

Name:______________________________

Exploring Hydroelectricity - Words to Know

Directions: Use the words in the boxes below to fill in the blanks.

Dam	Hydroelectricity	Kinetic
Mechanical Energy	Potential	Rotate
Turbine	Wheel	Power House
Reservoir	Electrical	Generator

A dam produces hydro-electricity by converting the kinetic energy from flowing water into mechanical energy. The dam stores large amounts of water (potential energy) behind a large wall in a reservoir. It restricts the flow of that water to only flow through a few holes near the bottom of the dam. As the water flows through the hole, it spins the turbine. A water wheel is an example of a simple turbine. The spinning turbine can rotate the rotor in the generator creating electrical energy.

CURENT

Lesson 5

Wind Turbine Design Challenge

CURENT is a National Science Foundation and U.S. Department of Energy funded Engineering Research Center.

Grade: 3-5
Subject: STEM
Length: 90 minutes

Wind Turbine Design Challenge

NEXT GENERATION SCIENCE STANDARDS

CORE IDEAS

- ❖ PS3.A: Definitions of Energy
- ❖ PS3.C: Relationships between Energy and Forces
- ❖ PS3.D: Energy in Chemical Processes and Everyday Life
- ❖ ETS1: Engineering Design

SCIENCE & ENGINEERING PRACTICES

- ❖ Asking Questions
- ❖ Developing and Using Models
- ❖ Planning and Carrying Out Investigations
- ❖ Constructing Explanations and Designing Solutions
- ❖ Using Mathematics

CROSS CUTTING CONCEPTS

- ❖ Energy and Matter
- ❖ Cause and Effect
- ❖ Scale, Proportion, and Quantity
- ❖ Structure and Function.

CURENT
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Students explore the engineering design process by building blades for a wind turbine.

OVERVIEW

Students read a background story to learn how a young boy engineered wind turbines for his village. They can then explain how we can use wind turbines to capture and convert wind energy into electricity. A short film demonstrates how a wind turbine works. Using the engineering design process, students work in teams to design their own blades and create wind turbines to produce energy. They observe how a wind turbine works from these designs. Each team collects data of the voltage produced from their blades to compare and contrast designs.

OBJECTIVES

Students will be able to:

- Construct a wind turbine model
- Explain why wind is a renewable resource
- Measure energy in Volts

BRIGHT IDEA
Check out CURENT Education's YouTube channel for the DIY Wind Turbine-Instructional Video.

MATERIALS

- ❑ The boy who harnessed the Wind by Bryan Mealer and William Kamkwamb.
- ❑ Styrofoam balls (≅2in)
- ❑ Corks
- ❑ Fan
- ❑ Plastic forks
- ❑ Paper plates
- ❑ Scissors
- ❑ Tape
- ❑ DC motor
- ❑ Multimeter

Figure 10.0. CURENT outreach event, building wind turbines.

ADVANCED PREPARATION

Review

Review the engineering design process. Model the process to the class using a simple example, or a previous project. For example, you might say, “When I was testing ______, I thought that changing ____ would improve ______ .” Alternatively, “I noticed that the models that had better _______ also had ______, so I decided to add that to my model.” Show students the benefits of original design as well as incorporation of others ideas.

Purchase The boy who harnessed the Wind by Bryan Mealer and William Kamkwamb. It may be available at your local library or consider asking a parent to donate it to your classroom. Read the book before you show it to the class to familiarize yourself with the content and concepts.

Connect this lab to another lesson. If you are talking about weather patterns, have students predict when or even have them consider where in the world their design might work best.

Create a Model

Create a model wind turbine to show to students. Use this experience to anticipate questions or issues. Test your model to make sure it works.

Optional: View a wind turbine in your city or town. Allow students to work in pairs to observe the parts they see (from real-world, printed pictures or graphics, google images, etc.).

Prepare student materials:

1. Each student will need the following items: multiple paper plates, half of a styrofoam ball, one cork, wooden dowels or plastic forks, scissors, and tape.
2. Pre-cut styrofoam balls and hot glue them to corks.

Prepare testing center:

Testing centers are composed of two parts. The first part is a medium-sized boxed fan which will require access to an electrical outlet, extension cords, etc. The second part is an arm to serve as the wind turbine base which you will attach your blades to. Construct the second part following the Teacher Step by Step Instructions (p. 73).

BRIGHT IDEA

Make sure to model the thought process during engineering design. This will help students develop their own strategies.

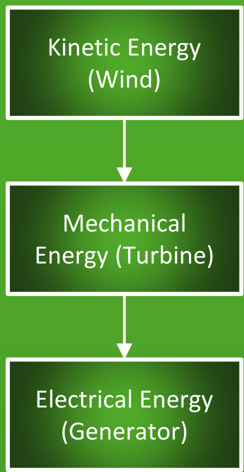

Figure 5.1. **A simplified three-step process of how energy is converted from kinetic energy to electrical energy by wind turbines.**

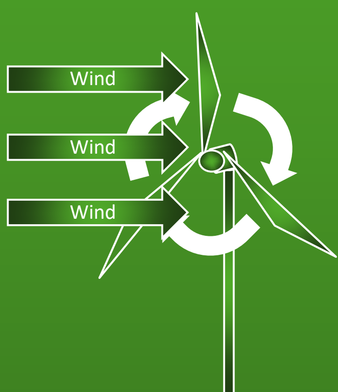

Figure 5.2. **Traditional three blade tower powers wind turbine blades on a horizontal axis. This type of wind turbine has stationary blades which must be facing the right direction in order to begin the process of generating electricity.**

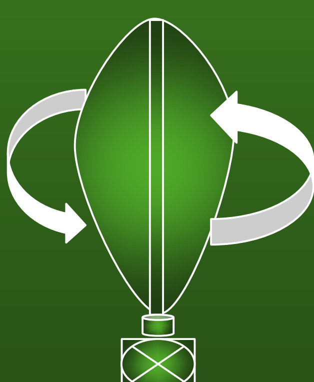

Figure 5.3. **Nontraditional vertical axis wind turbine. This type of turbine has the same components as a horizontal axis wind turbine but they are arranged differently. The blades are perpendicular to the wind and the turbine is at the base. This allows the machine to harness kinetic energy from the wind in any direction.**

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BACKGROUND INFORMATION

The wind is produced as a result of giant convection currents in the Earth's atmosphere, driven by the Sun. **Wind power** is generated by harnessing potential energy from the wind. So, as long as the sun exists, the kinetic energy or the motion created by the wind will too. Because it will not run out, we call this a renewable energy source.

<u>What do we use to capture the kinetic energy from the wind?</u>

Wind energy is harnessed by using a mechanism called a turbine. The **turbine** is connected to blades that are moved by the wind. As the wind spins the blades, the blades spin the turbine, which is attached to a generator. The kinetic energy is converted into mechanical energy as it spins the turbine. Then generators convert this energy into electrical energy that can be added to the power grid.

<u>Different types of blades</u>

There are a few different configurations of blades, but the most common by far is the horizontal axis wind turbine as shown in *Figure 5.2.* The giant three-blade tower in *Figure 5.2* is what most people think of when they imagine wind farms.

The horizontal axis wind turbine must have the wind flowing in a certain direction in order for the blades to turn, but there are other designs that will work regardless of the direction of the wind such as the vertical axis wind turbine as shown in *Figure 5.3*.

<u>Where do we place wind turbines?</u>

Figuring out the most efficient location for wind farms and wind turbines is an important job. There are many factors that can affect the flow of wind, including proximity to other turbines. Ideally, the wind would move at a constant, steady pace in a uniform direction. Unfortunately, there is almost always turbulence to deal with regardless of where a wind turbine is placed.

Technology has advanced to the point where wind turbines can now be located on land or water. This is very beneficial because the area above the ocean is very windy. This allows for a large amount of energy generation at a location that doesn't use viable land, potentially reducing a wind turbine's disruption to people.

ACTIVATE

Part One: Read the book, "The Boy Who Harnessed the Wind" by Bryan Mealer and William Kamkwamb. The book is about a young boy in Malawi who builds a windmill from materials he collects around his village. The village was suffering from drought which affected their food source. The windmill he builds brings electricity and water to his village, improving the life of all of those around him. William Kamkwamba also shares his story in a Ted Talk he presented in 2009 called How I harnessed the wind.

Part Two: Inquiry

Ask: How can we harness energy from the wind? Is wind a renewable or nonrenewable resource?

Explain: Discuss with the class the parts of a wind turbine, and draw a picture of them. You also may want to use the "Wind Turbine – Words to Know" worksheet (pp. 74-75) for this part of the lesson. Focus on which parts must move. Introduce the materials they will use.

Part Three: Connect the engineering design process

Over time, designs are modified and improved. Show students examples of how wind turbines changed over time. Search the internet for an image of a horizontal axis windmill with a large base and four square wooden blades. This type of windmill could date back to the 12th century A.D. Now find an image of a modern horizontal axis wind turbine. There should be three thin metal blades that look similar to airplane wings.

Compare and contrast wind turbines:

- How many blades are there?
- What about the size of the wind turbines? (make connection to technology here, as before people would have to go inside to control turbines, now we can remote in)
- The size of the blades?
- How has the shape of the blades changed?
- How are windmills and waterwheels similar?
- What type of conditions do engineers require to harness wind for electricity?

BRIGHT IDEA

Make interdisciplinary connections with the history of wind turbines.

BRIGHT IDEA

This is an inquiry-based DISCOVERY lesson. There is little explanation given up front by teacher, and a lot of exploration on the part of the students. Allow them to EXPLORE their ideas and FAIL, and then TRY AGAIN!

CREATE

1. Brainstorm as a class what factors will affect how much energy is produced by the wind turbine. Hint: these are what have changed through the design over time (ex. number of blades, angle, length, shape, material, etc.). Write these on the board and reference them during the testing phase.
2. Model expectations explicitly for group work. Instruct students to draw and label their initial design **BEFORE** beginning construction. Once the drawing is complete, they may get supplies from teacher.
3. Go over the "Wind Turbine Design Challenge" worksheet (p. 76). Go over what materials are available to students. Write them on the board. Give limitations to materials if you have them.
   Optional: Pre-package group supplies for students. Allow them to trade as needed.

1. Divide students into small groups (2-3 students per group) and handout the "Wind Turbine Design Challenge" worksheet (p. 76).
2. Allow students ample time to brainstorm designs.
3. Circulate the room and hand out supplies once you've checked student drawings.
4. Students build their design. Students will cut the paper plates to create their blades, attach them to forks, and stick forks into Styrofoam balls at different positions to create their wind turbines.
5. Set up a testing center with a fan, wind turbine base, and multimeter. Supervise the fan and multimeter if they are accessible to students.
6. Record the voltage results of best trials on the board.
7. Students will redesign their blades after they test and observe the results. Be sure that students bring their worksheets with them to the testing center. Any design changes must be recorded on the "Wind Turbine Challenge" handout (p. 76).
8. When students are ready for their final test, they connect the motor to the multimeter and record their voltage and complete the worksheet. Debrief.
9. Have students finish the project by comparing their blade design with another group's. Use the "Wind Turbine Design – Compare and Contrast" sheet (p. 77). This sheet would also work during the Improve step.

DEEPEN CONNECTIONS

MODIFY

- ❑ Pre-assemble parts of the wind turbine before class so that students who struggle with fine motor skills can still assemble it.
- ❑ Use whiteboards for sketching designs instead of worksheets. Take photos to have references.
- ❑ Have pictures for students who may need additional help with concepts from the video, websites, etc.
- ❑ After initial testing, watch the US Department of Energy's YouTube video Energy 101: Wind Turbines, and make observations to improve student designs.
- ❑ For lower grades, just use the model as a demo.

EXTEND

- ❑ Make connection to energy conservation, carbon emissions, and becoming energy dependent. Read the book, "Energy island: How one community harnessed the wind and changed their world." by Allan Drummond.
- ❑ Give students the freedom to design their wind turbine using other supplies. Send out a notice to parents in advance to gather supplies such as two-liter plastic bottles, index cards, wooden dowels, string, weights, etc. Divide supplies amongst the class to be inclusive. You may decide to allow them to trade materials.
- ❑ Research how many wind turbines are in your city, town, or region. Compare and contrast the amount of power they can produce.
- ❑ Explore the materials that windmills are made of and consider why they are used.
- ❑

BRIGHT IDEA

Make connections/linking concepts. Use the wind turbines students created in this lesson to power your circuit city from lesson 2.

Wind Turbine Base
Teacher Step by Step

Check out CURENT Education's YouTube channel for the
DIY Wind Turbine- Instructional Video.

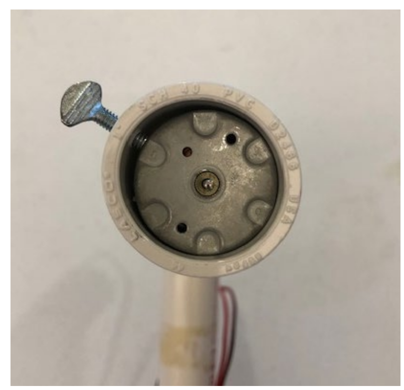
Materials Needed

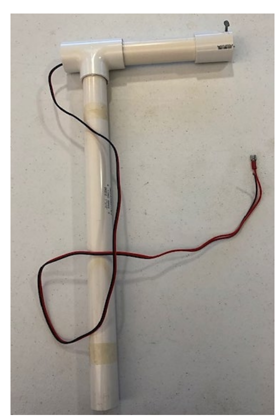
Here are some of the materials you'll need to complete the activity:

- ❑ (4) 8X1" PVC pipes
- ❑ (3) 1" diameter PVC Caps
- ❑ (3) 1" diameter PVC T's
- ❑ (1) 1" diameter PVC Joint
- ❑ (1) 2'x1" PVC Pipe
- ❑ (1) 6"x1" PVC Pipe
- ❑ DC Motor
- ❑ Screw
- ❑ DC Lines with leads

Procedure

1. Connect the four 8 inch pipes in a 'T" shape, using a T-joint to extend the long leg.
2. Place caps on the ends of the pipes. Set aside.
3. Take the two foot PVC Pipe and top it with the last T-joint.
4. Attach the six-inch PVC pipe with the standard joint to one of the horizontals on the T-joint.
5. Feed the DC motor and lines through the top of the six-inch pipe, securing it with a screw punched through the standard joint.
6. Attach the two separate pieces using the last open space on the PVC joint to create your wind turbine base.



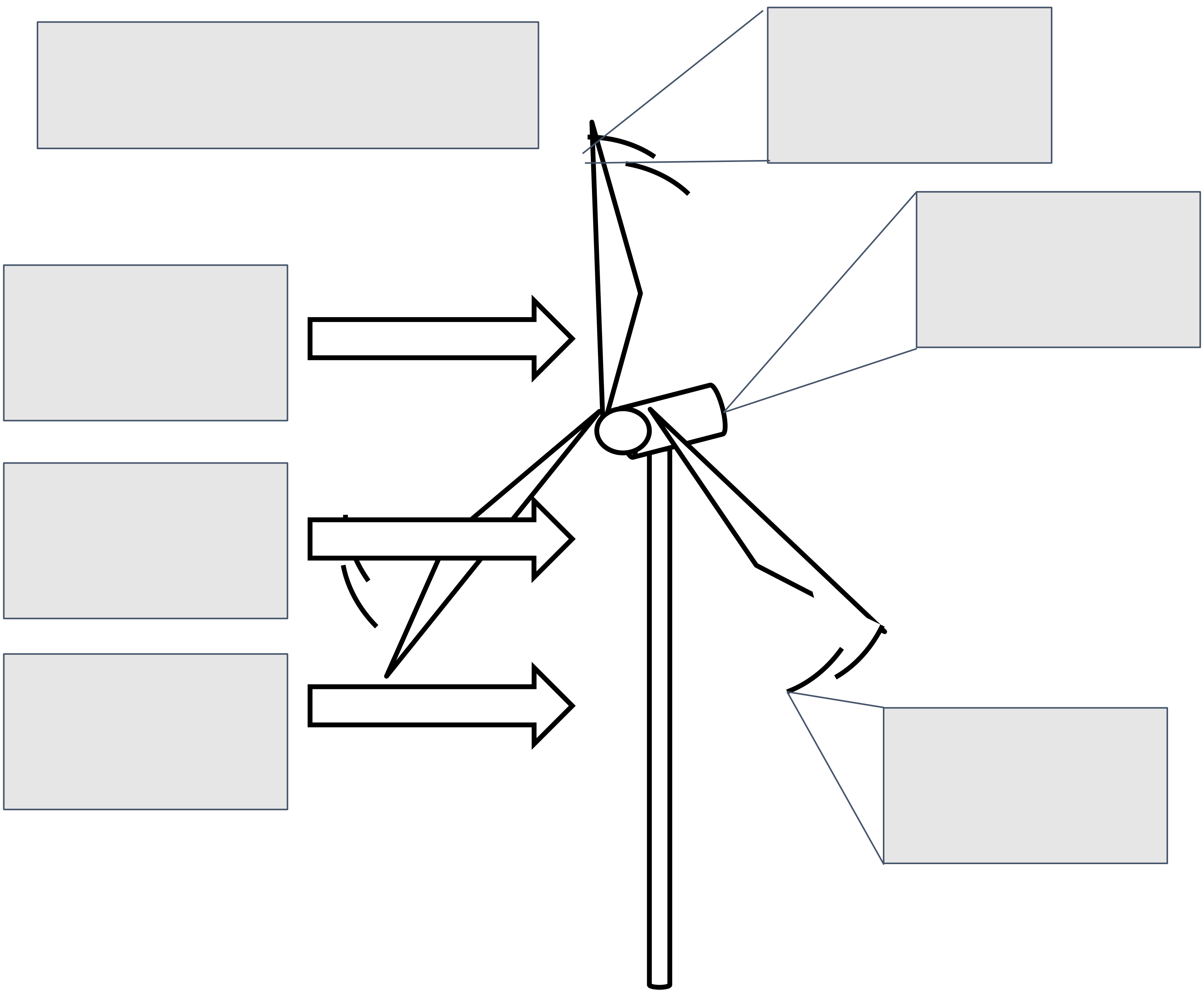


Name:______________________________

Wind Turbine Design – Words to Know

Directions: Use the words in the boxes below to label the wind turbine drawing.

Electrical	Generator	Kinetic Energy
Mechanical Energy	Potential Energy	Rotate
Wind Turbine	Wind	Blade



Name:_____________________________

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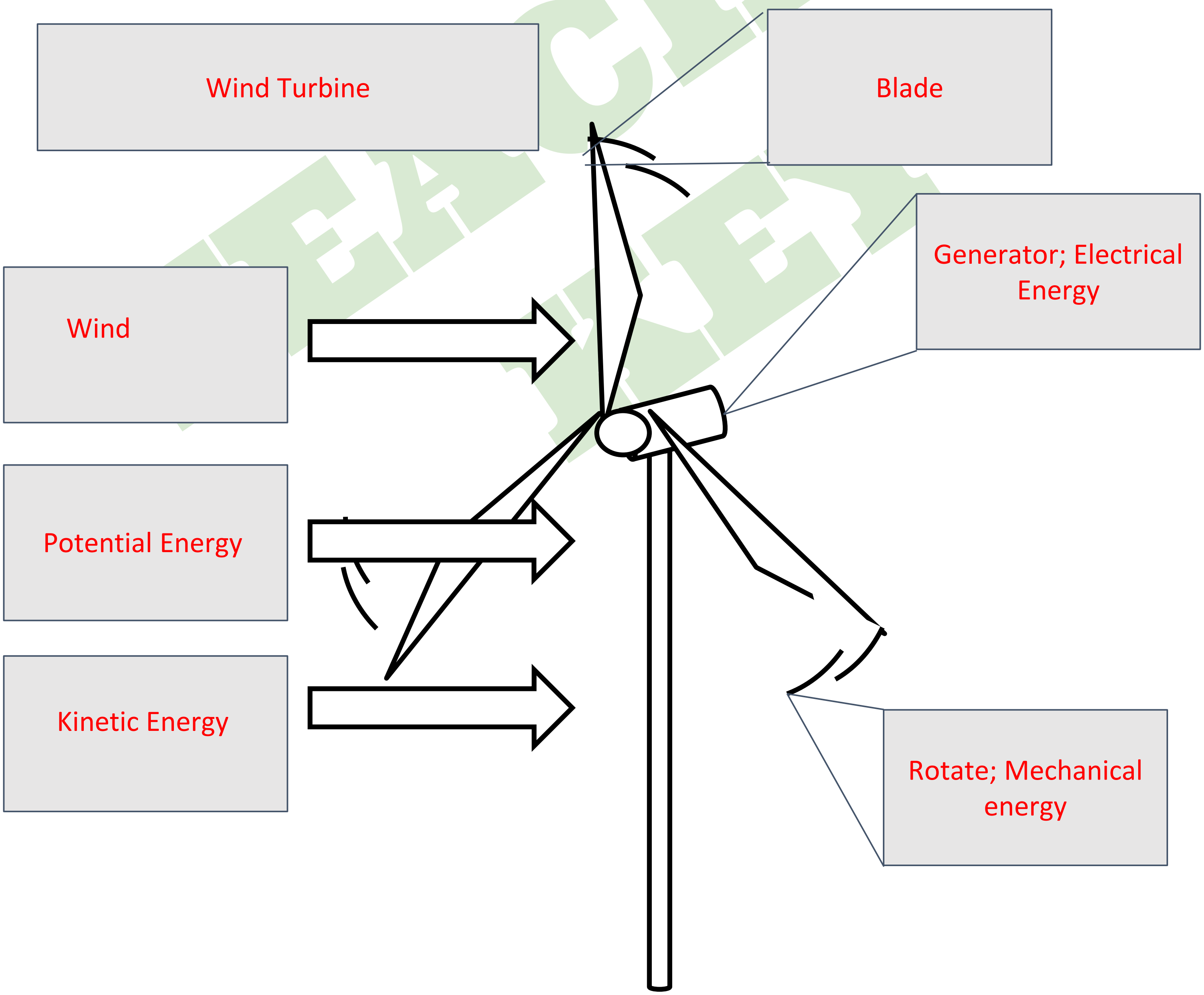


Name:_______________________________

Wind Turbine Design Challenge

Challenge: Generate the most ENERGY (measured in Volts) from wind.

ASK

What are the problems? What factors will affect how it spins?

IMAGINE

Sketch & label your design idea.

PLAN

Gather all of your materials.

CREATE

Follow the plan you imagined.

TEST

How much energy (in Volts) did your wind turbine produce?

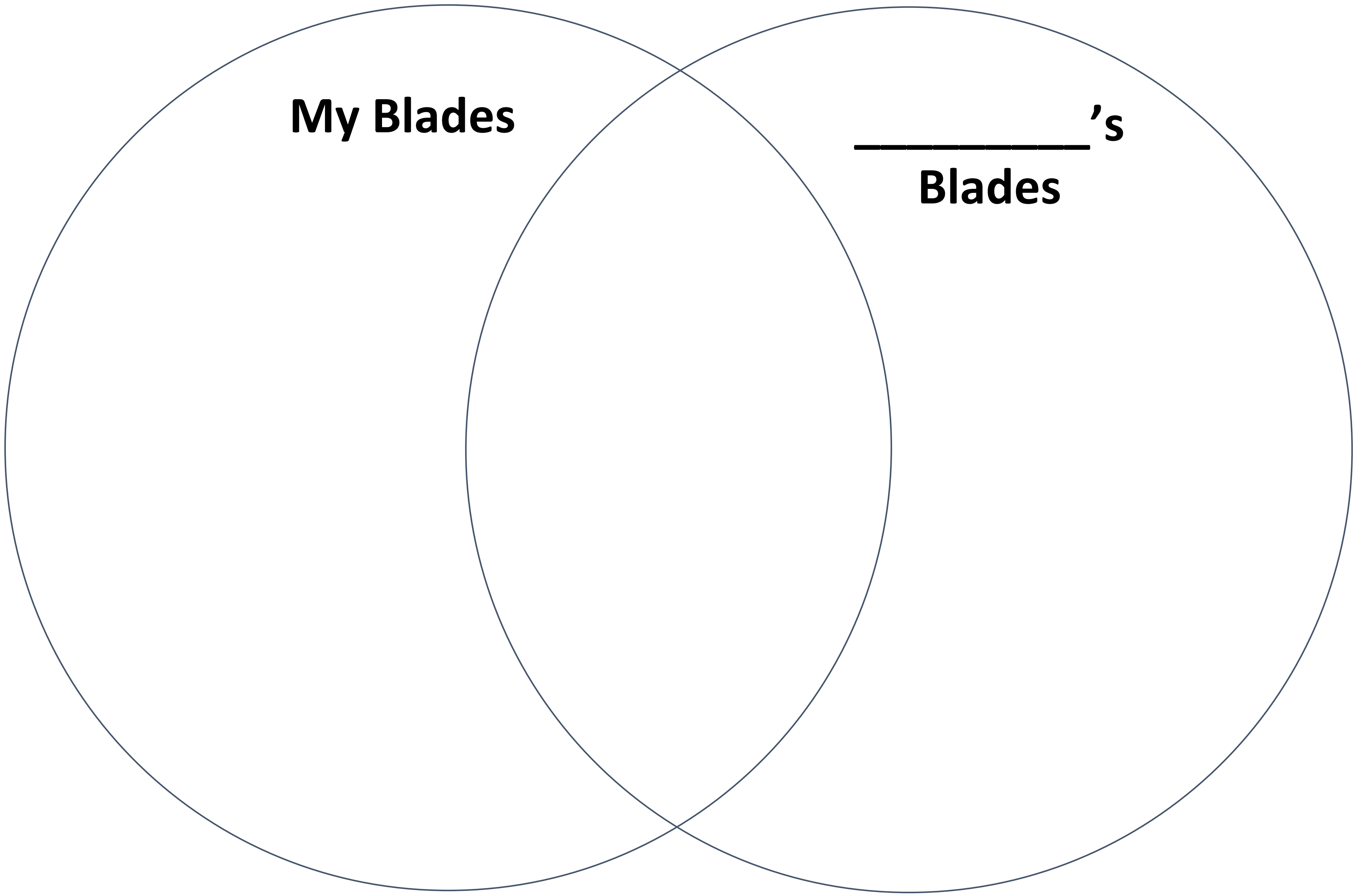
IMPROVE

What did you change on your design?

Wind Turbine Design – Compare and Contrast

Name:_______________________________

Directions: Compare and contrast your wind turbine blade design with another group's.



Name:______________________________ Challenge:___________________________ Date:________________

Engineering Challenge Grading Rubric – Overall Score _________

	Needs Improvement 1	Ok 2	Good 3	Great 4	Your Score	Team Score
Teamwork	Little teamwork. Didn't allow others to speak. Usually want things your way. Not respectful of others ideas.	Some teamwork. Rarely allowed others to speak. Often sided with friends, instead of listening to the views of everyone on the team.	Good teamwork. Listened to others, but only spoke or shared sometimes. Usually considered the views of others.	Great teamwork. Listened and spoke with respect. Shared ideas and was able to reach fair decisions.		
Focus on Task	Rarely focused on the task, the requirements or constraints. Lets others do the work. Teacher directed your attention back on task.	Somewhat focused on the task, the requirements, and constraints. Other group members sometimes reminded you to stay on task.	Mostly focused on the task, the requirements, and constraints. Reliable, but not consistent with your group.	Consistently focused on the task, the requirements, and constraints. Self-motivated. No one directed your attention on task.		
Use of the Engineering Design Process	Construction without planning first.	Asked and imagined, but only some planning (incomplete or not labeled).	Completed all stages before designing, but did not improve design.	Used knowledge from previous designs to create a better final product.		
Reaction to Problem Solving	End of the world: Failure to problem-solve constraints.	Minor freak out: Overcame some constraints, but complained about having them.	Mildly chill: Overcame most of constraints with little complaint.	Cool as a cucumber: Overcame constraints and embraced the process.		
Final Product	No final product.	Final product created, but failed to solve the problem.	Final product solved part of the problem. No modifications.	Final product solved the problem with or without modification.		

Appendices:

Background Information

The following pages contain background information that may be helpful in implementing the lessons found within this book.

OVERVIEW

Appendix A: Energy Basics
- fundamentals of energy

Appendix B: Circuit Analysis
- basic and fundamental circuit concepts using simple circuits and methods of analysis.

Appendix C: Types of Power
- an explanation on both alternating current and direct current and the differences between the two.

Appendix E: Special topics
- real-world applications and problems associated with electric power including discussion on the power grid, renewable resources, and energy poverty.

Appendix F: Material Properties
- differences in the types of materials used in electrical engineering.

TOPICS

- Energy Basics
  1. Energy
  2. Electron
  3. Charge
  4. Current
  5. Voltage
  6. Resistance
  7. Power
- Circuit Analysis
  1. Simple
  2. Series
  3. Parallel
- Types of Power
  1. Direct current (DC)
  2. Alternating current (AC)
- Special Topics
  1. The Grid
  2. Solar Power
  3. Wind Power
  4. Hydropower
- Material Properties
  1. Conductors
  2. Insulators

Appendix A: Energy Basics

APPENDIX A: Energy Basics

A1. ENERGY

WHAT IS IT?

Energy is the ability of a system to do **work**. It comes from the use of physical or chemical resources (or materials). Energy can exist in many different forms that are either potential or kinetic (See *Table A1.1*). The **law of conservation of energy** states that energy cannot be destroyed or created but can only be transformed from one form into another.

OVERVIEW

- To measure energy, we quantify the amount of work done. This is usually expressed as joules (J), in which one **joule (1J)** is equal to force acting over the displacement.
  1 Joule = 1 Newton X 1 meter
- **Potential energy** is the energy stored within a system. It is classified based on the type of applied **force**. Energy forms that are stored could be further classified as **chemical**, **nuclear**, **gravitational**, or **mechanical**.
- **Kinetic energy** forms are doing work. They include **radiant** (light), **electrical**, **thermal** (heat), **kinetic** (motion), or **sound**.
- **Energy transformations** occur when one form of energy is changed to another. These transformations occur everywhere, constantly. We use specific devices to transform energy to the desired form every day (See *Table A1.2).* For example, a toaster transforms electrical energy into thermal energy.
- **Energy sources** can be categorized as renewable or nonrenewable. **Renewable energy** comes from sources that can easily be replenished such as solar or wind. **Nonrenewable energy** comes from sources that cannot easily be replenished such as petroleum or uranium. Both sources can be used as a **primary source** to transform energy into a **secondary form** such as heat or electricity.

EXTENSION

Electrical energy begins as stored **electric potential energy**. When **electrons** flow due to an **applied force**, the energy stored within electrons transforms into electrical energy. **Power** is quantified by how much electric energy is transferred and how fast it occurs. We measure the amount of work done over time, in watts (W). One **watt (1W)** is equivalent to one joule (1J) expended for one second (1s). For more information about power see Appendix A7.

Table A1.1 - Energy Forms

Kinetic Energy Forms	Potential Energy Forms
Electromagnetic	Chemical
Thermal (Heat)	Nuclear
Radiant (light)	Gravitational
Kinetic (motion)	Mechanical
Sound	-------

Table A1.1. Example forms of potential and kinetic energy. Potential energy is the energy stored within an object or system. Kinetic energy are energy forms that are doing work.

Table A1.2 - Energy Transformations

Primary Energy type	Transformed by	Secondary Energy type
Mechanical	Electric Motor	Electrical
Electrical	LED	Radiant, thermal
Electrical	Resistor	Thermal
Chemical	Battery	Electrical
Kinetic	Windmill	Mechanical, Electrical

Table A1.2. Example of electronic components that can transfer primary energy types to secondary energy types.

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A2. ELECTRON

WHAT IS IT?

Subatomic (incredibly small) particles that carry a **negative charge**, **electrons** are referred to as charge carriers. Electrons are commonly bound to orbit an atom's **nucleus** (see *Figure A2.1)*. The electron orbits in spherical shells of varying radii. The bigger radii results in greater distance from the nucleus and higher the **energy** of the electron. Some electrons, **free electrons**, are not attached to **atoms**.

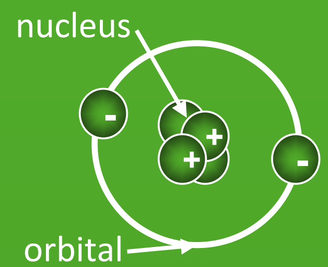

*Figure A2.1.*An example of a helium atom. In the center is the nucleus, consisting of two protons (circles with a positive sign) and two neutrons (circles without a charge sign). The ring surrounding the nucleus is the electron orbital, the pathways that electrons orbit the nucleus. The electrons are denoted by the circles with a negative sign.

OVERVIEW

- ❑ Electrons are symbolized by e−, in which the minus sign indicates the negative charge. In an atom, the electron has an equal yet opposite charge to the **proton** (subatomic particle with a positive charge; See *Figure A2.1*).
- ❑ Electrons are the source of charge within the system. In **conductors** (material which allows energy to flow), we harness electrons to flow (as current) through the system and do work.
- ❑ When we talk about **voltage (V)**, **current (I)**, and **resistance (R)**, we are describing the behavior of electrons within a conductive or semiconductive material (See *Figure A2.2*).
- ❑ Specific elements have different **atomic properties** which affect an electron's behavior. These properties are what make some materials function better than others for specific purposes, such as **insulators** or conductors. Material properties are discussed further in Appendix F of this book.
- ❑ Imagine the **current** as a movement of electrons from individual atom to atom to fill empty spaces in the **electron orbitals**. Electrons work as charge carriers to move from place to place to make positively charged atoms **stable** (neutral) again. The empty spaces in the electron orbitals are referred to as holes (See *Figure A2.3*).

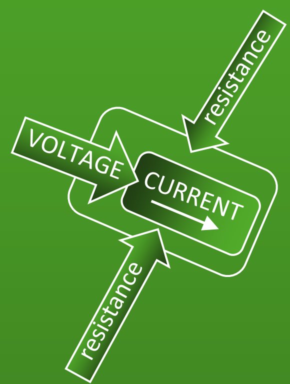

Figure A2.2. Voltage, current, and resistance within a conductor (wire).

EXTENSION

An electron in motion generates a **magnetic field** and electric field that exerts an attractive force on a positively charged particle, and repels negatively charged particles. When electrons are paired they spin in opposite directions and their magnetic fields negate each other. **Diamagnetic elements** have unpaired electrons that weakly repel magnets.

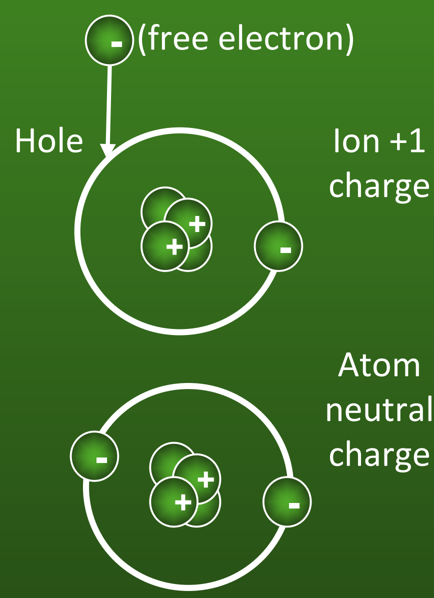

Figure A2.3. An example of the movement of electrons to fill 'holes.' The top image is a cation with a positive charge of 1. It has two protons, two neutrons, and one electron. To become in its ideal state the ion desires a neutral charge or an additional electron. This leaves a 'hole' or a space in the electron orbital for the electron to fill. The second picture is the stable atom with both electrons filling the orbital,

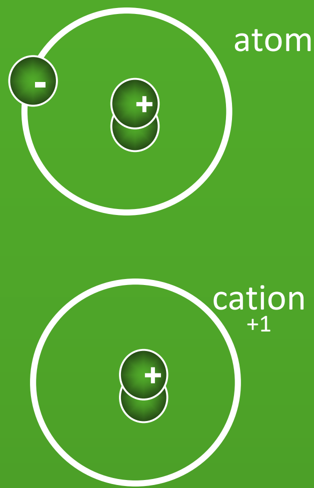

Figure A3.1. Atom and ion. On the top figure the center is the nucleus, consisting of one proton and neutron. One electron is orbiting the nucleus in this atom. To find the net charge, add up the charges from all the subatomic particles. (+1) + (-1) = 0 for the atom; (+1) + (-0) = +1 for the ion.

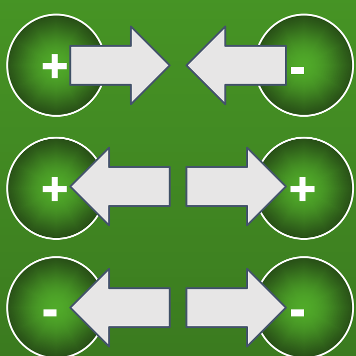

Figure A3.2. Electrical forces. Opposing charges attract, the top two particles, a proton and electron want to move toward one another. The bottom two pairs of particles with like charges want to move away from one another.

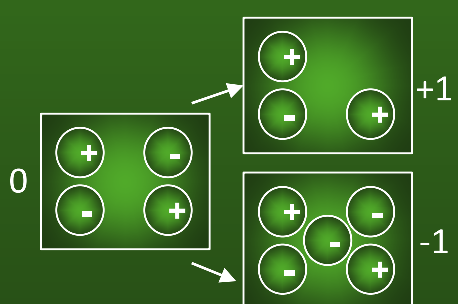

Figure A3.3. A neutral charge is represented by the system on the left. The box on the top right has lost an electron, producing a positive net charge. The box on the bottom right has gained an electron, producing a negative net charge.

A3. CHARGE

WHAT IS IT?

The electric **charge** is the physical property that causes matter to experience a force when placed in an **electromagnetic field.** This fundamental property of **matter** is neither created nor destroyed. A charge can be **positive**, **negative**, or **neutral** (no charge). Our applied knowledge of charge is the basis for electromagnetics.

OVERVIEW

- ❑ Charge is measured in **Coulombs (C).**
- ❑ Subatomic particles have known charges - an **electron** is negative (-1), a **proton** is positive (+1), and a **neutron** has no charge (0). These particles do not create charge, it is their inherent property.
- ❑ Chemical elements, called **ions**, can have a net charge - an **anion** is an ion with a negative charge and a **cation** is an ion with a positive charge. We can calculate the **net charge** of a system by adding up the charges of the particles within the system. For example, in *Figure A3.1*, the cation has one proton (+1) and one neutron (+0). We can add the charges of the system together to find it has a +1 charge.
- ❑ Charge is responsible for electrical forces. The most common attribute of charges is that pairs of like charges repel each other. Opposing charges attract. See *Figure A3.2.*
- ❑ Most objects that we interact with in daily life have a neutral charge because atoms typically bond in a way that the net charge is zero. This means that you rub a balloon through your hair, you aren't creating a new charge. You are pulling electrons from one object (hair) and sticking them with the other (balloon) giving one object a net positive charge and the other a net negative charge. See *Figure A3.3* for examples of net charge.
- ❑ A charge will produce an **electric field** and the movement of charge will produce a **magnetic field.** Because of this, it is the basis through which all of electric and magnetic properties operate.

EXTENSION

The flow of charge is called current. It is easy for charge to move through a **conductor**, but difficult to move through an **insulator**. A **semiconductor** can act as either a conductor or an insulator, depending on the charge conditions. Material properties are discussed further in Appendix F of this book.

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A4. CURRENT

WHAT IS IT?

Current is the rate at which electric **charge** flows (see *Figure A4.1)*. Similar to how water flows through a pipe, charge carriers (electrons) also can flow through a wire or other conductor. In this comparison, the water would act similar to the charge carriers and the pipe would act similar to the wire. However, one important difference to keep in mind is that a wire is not hollow like a pipe. Instead, the charge carriers flow along the solid conductors of a wire.

OVERVIEW

- The symbol for current is I.
- Current is measured in **Amperes (A),** or simply amps.
- Current is the average number of charge carriers (in Coulombs, C) moving through a point per second (s): 1A = 1 C/s. You can imagine it like pressure in the water pipe.
- To understand how energy is transferred in circuits, you must understand how current flows. Current flows from relatively positive points to relatively negative points. The flow of positive charge is called **conventional current.** The flow stops when the **potential difference** between two points is zero.
- What is the difference between a 1 Amp and 2 Amp **circuit**? Flowing through the 2A circuit are twice as many charge carriers passing through any given cross section of the object at any given time (*Figure A4.2* and *Figure A4.3)*. Imagine the flow of water coming out of a water faucet that is turned on halfway compared to on all the way. (*Figure A4.4*)

EXTENSION

- **Free electrons** are already present in a wire, but if they are not flowing, there will be no current. They need a **force** to push or pull them along to create a current- this is the role that voltage plays in the system (see Appendix A5).
- There are two different types of current: **alternating current** (AC) and **direct current** (DC). See Appendix C for more information on AC and DC concepts.

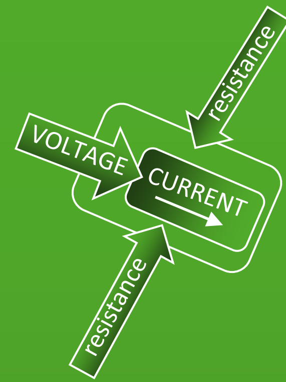

Figure A4.1. Voltage, current, and resistance within a conductor (wire). Current travels through a wire or other conductor.

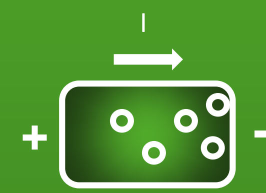

Figure A4.2. A cross section of a small current with only a few charges flows in one direction (to the right) from positive to negative. I is the symbol for current. The rings represent charges.

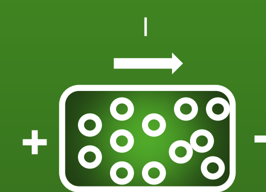

Figure A4.3. A cross section of a large current with many charges flows in one direction (to the right) from positive to negative. I is the symbol for current. The rings represent charges.

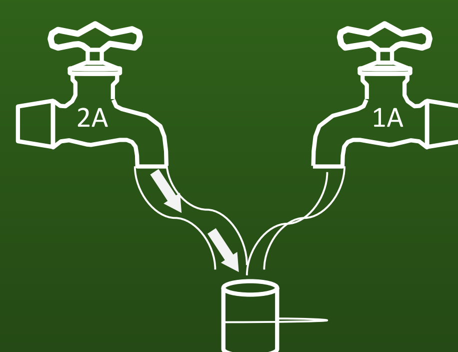

Figure A4.4. Modeling the flow of current in 1A and 2A circuits, water faucet analogy. More water is flowing from the 2A faucet than the 1A faucet.

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A5. VOLTAGE

WHAT IS IT?

Voltage is also known as the **electric(al) potential** or the electromotive force (EMF). In our water pipe analogy, voltage would act similar to the pump (*Figure 5.1)*. It is the energy required to move charge between two points, which is why it is known as an **electromotive force (EMF)**. Voltage is the difference in electric charge between two points as shown in *Figure A5.2*.

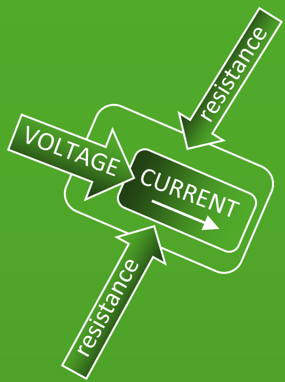

Figure A5.1 Voltage, current, and resistance within a conductor (wire).

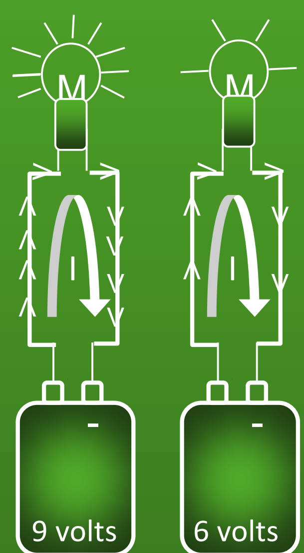

Figure A5.2. Comparison of current denoted by arrows following a circuit path sourced from a 9 volt (left) and 6 volt (right) battery. The 9 volt battery has a higher voltage, so therefore it also has a larger current.

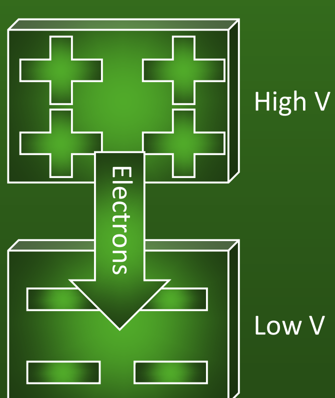

Figure A5.3. The movement of electrons is from high voltage to low voltage.

OVERVIEW

- ❑ The symbol for voltage is V.
- ❑ The standard unit is the **Volt (V)**, which is 1 Joule (unit of energy) per Coulomb (unit of charge).

$$1 \text{ Volt} = \frac{1 \text{ Joule}}{1 \text{ Coulomb}}$$

- ❑ We can measure voltage using devices such as a **voltmeter**, **multimeter**, or even a **oscilloscope**, **arduino**, or **raspberry pi**.
- ❑ We measure current as the movement of charge from the higher voltage to the lower voltage as shown in *Figure A5.3*. The flow of positive charge is called **conventional current.** The flow stops when the potential difference between the two points is zero. Voltage is a quantitative expression for the difference in electrical potential between two objects or points. The bigger the difference (in electrical potential) the more current could flow in the same circuit.
- ❑ The voltage of a circuit must come from a voltage source. Some examples of voltage sources include batteries and wall outlets.

EXTENSION

There is a very important relationship between **voltage**, **current** and **resistance.** Electricity in a circuit can be described by these three terms. If you increase the resistance in a circuit and the current stayed the same, the voltage would decrease at that point. In our water pipe analogy, increasing resistance would be representative of smaller sized pipes. To learn more about resistance and the relationship called Ohm’s law, see Appendix A6.

A6. RESISTANCE

WHAT IS IT?

Resistance is an obstacle to the flow of current - how much it can resist **charge** (see *Figure A6.1* and *A6.2)*. Returning to our water pipe analogy, resistance is comparable to the diameter of the piping. A high resistance is akin to a narrow pipe through which very little water can travel at one time with a certain pressure. A low resistance is akin to a wide pipe through which a lot of water can travel at one time with that same pressure.

OVERVIEW

- The common symbol for resistance is R.
- The unit for resistance is the **Ohm (Ω)**.
- We assume that an ideal wiring has a negligible resistance. A **resistor** is the standard component used to add resistance to a circuit, but in the real world everything in a **circuit** has some amount of resistance associated with it, even the wiring.
- Resistors are often used to reduce and regulate the current traveling through the circuit. Starting at the battery in *Figure A6.3* and moving clockwise around the circuit current is constant, after each resistor is passed, the voltage is reduced.
- A resistor can also be referred to as a **load,** a component that consumes **power**. Other loads include lights and appliances.
- Using the water pipe analogy: ideally, all pipes would be large and would easily deliver water. The bigger pipes can allow water to flow easier with less pressure, so there is less resistance to flow (see *Figure A6.4).* In the same way, some materials allow electrons to move more easily than others. These materials have a higher **conductivity** than others and allow electrons to move more easily, while others have a lower conductivity which provides resistance to the flow. The resistance in *Figure A6.2* can be imagined as a clogged pipe.

EXTENSION

There is a very important relationship between voltage, current and resistance known as **Ohm's Law.** The voltage is equal to the amount of current (in amps) in an object multiplied by the total resistance measured in ohms. Ohm's Law tells us that voltage (V) is equal to current (I) multiplied by resistance (R). This is shown by the equation:

$$V = I*R.$$

See A4 and A5 for more information.

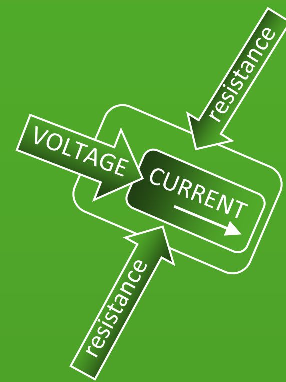

Figure A6.1 Voltage, current, and resistance within a conductor (wire).

Figure A6.2 Voltage, current, and resistance within a conductor (wire). You can see that the resistance is an obstacle in the way of the flow of electrons (current).

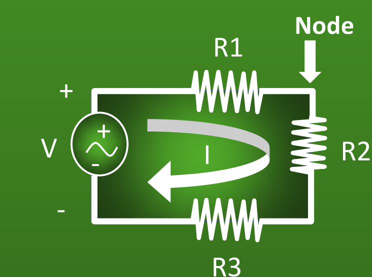

Figure A6.3. A series circuit schematic. V is the symbol for voltage, in this case the voltage or energy source is a battery. R1, R2, and R3 are resistors. In this circuit, I, or current, travels from high to low voltage clockwise starting from the positive terminal of the battery through R1, R2, and R3 where it then returns to the negative terminal of the battery. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

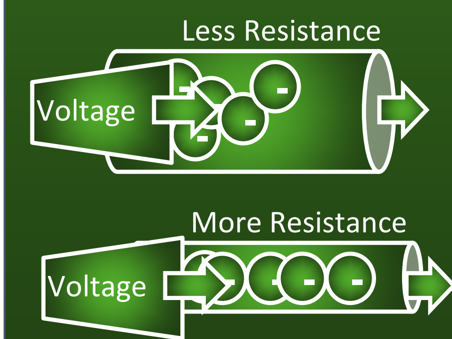

Figure A6.4 Materials with less resistance allow more flow, materials with more resistance allow less flow at one time.

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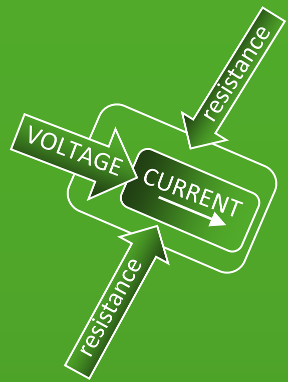

Figure A7.1 Voltage, current, and resistance within a conductor (wire). Power is the rate at which the energy is generated or consumed.

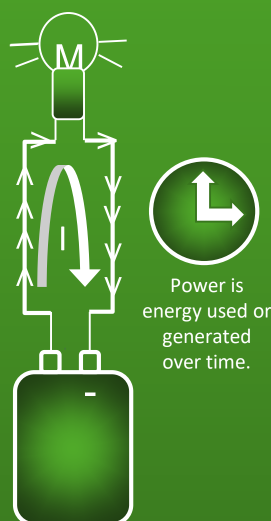

Figure A7.2 A typical incandescent bulb draws 60 watts of power. But what does this mean? That means when you turn it on, it's drawing 60W of electricity for every second it's lit.

***Table A7.3.* Example of electrical components**	
Energy type converted	**Converted by**
Mechanical	Electric Motor
Electromagnetic	LED
Heat	Resistor
Chemical	Battery
Wind	Windmill

Table A7.3. Example of electrical components that can transfer electrical energy to another form.

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A7. POWER

WHAT IS IT?

Electrical power is the rate at which electrical energy is used or generated. In the same way that mechanical power is measured by how much mechanical work is generated or consumed in a given time, electrical power is determined by how much electrical work is created or used in a given time.

OVERVIEW

- ❑ The common symbol for power is P.
- ❑ Electrical Power (P) can be defined as voltage (V) multiplied by current

  (I): P = VI.
- ❑ See *Figure A7.1* to visualize (V) and (I).
- ❑ The standard unit for power is the **Watt (W)**. The Watt is equal to 1 Joule (J) per second (s), so

  $$1\ W = 1\ J/s.$$
- ❑ The more energy or work done by a voltage source in a given unit of time, the more power is present (see *Figure A7.2).* Each component in a **circuit** either consumes or stores energy (see *Figure A7.2).*
- ❑ When electrical energy is used, it is often converted to another form of energy, such as motion (kinetic) or heat (thermal). For example, when an LED transforms electrical energy into light (radiant) it consumes power (over time).
- ❑ Electric power is produced when energy is transferred from another form to electrical energy. For example, a battery is a power producer as it produces electrical energy from chemical energy (See *Table A7.3)*.

EXTENSION

- ❑ Often when we talk about power, we also talk about what is called a **load,** or anything that consumes power. A load can be a **resistor**, **capacitor**, **inductor**, or a combination of these.
- ❑ Using Ohm's Law (V = IR), we can rearrange this to write electrical power being used by a resistor as:

$$P = VI;\ I = V/R$$

$$P = V\,(V/R) \text{ or } P = (V^2)/R \text{ or } P = (I^2)*R$$

Appendix B: Circuit Analysis

B1. SIMPLE CIRCUIT

WHAT IS IT?

The most basic type of circuit, a **simple circuit**, consists of few components: a **voltage source** (battery) connected to a single **resistor** (a component with a designed resistance to the passage of **current**, aka load) as shown in *Figure B1.1.* See *Table B1.4* as a key for circuit diagrams or schematics.

OVERVIEW

- ❑ So what exactly is going on in the circuit? The voltage source is creating a difference in electric potential which causes **charge carriers** to flow in the direction of the current shown in *Figure B1.1*. As these charge carriers flow through the resistor, they lose **energy**, which is equivalent to the voltage dropping across a resistor.
- ❑ Because charge carriers need a path to follow in order to flow, there needs to be a continuous path. If the circuit pathway is incomplete, as shown in the *Figure B1.2*, it is known as an **open circuit**. If the circuit has a continuous path, as shown in in the *Figure B1.3*, it is known as a **closed circuit**.
- ❑ In an open circuit, no electricity will flow through the circuit because current cannot flow through the circuit. In a closed circuit, electricity will flow through the circuit because current can flow through the circuit.

EXTENSION

- ❑ We can add more components to a simple circuit, we can wire the circuit in a **series** or **parallel** connection. For series and parallel circuits see Appendix B2 and B3 (pp. 184-185).
- ❑ A simple circuit is a great demonstrator of **Ohm's Law**: voltage is equal to current multiplied by resistance, symbolically shown as I = V/R or V = I*R. The voltage drop across the resistor is equal and opposite to the voltage across the voltage source. Note: Assume an ideal scenario where there is no resistance in the **conductor** (wire).

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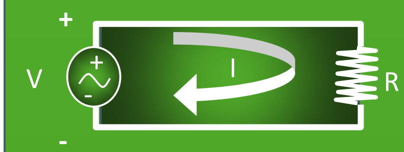

Figure B1.1. A simple circuit schematic. V is the symbol for voltage, in this case the voltage or energy source is a battery. R is a resistor. In this circuit, I, or current, travels from high to low voltage, clockwise starting from the positive terminal of the battery through R where it returns to the negative terminal of the battery.

Figure B1.2

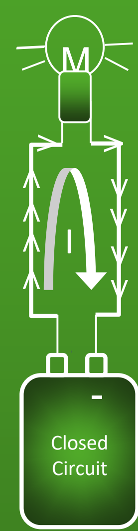

Figure B1.3

Table B1.4 - Circuit Schematic Symbols

Component	Symbol
Resistor/load	
Voltage source (ex. battery)	
Pathway for current (ex. wires)	
Current	I + direction arrow
Resistor (load)	R, R1, R2, R3...
Voltage	V

Table B1.4. the symbols for circuit schematics/diagrams found throughout the appendix and the lessons.

B2. SERIES CIRCUIT

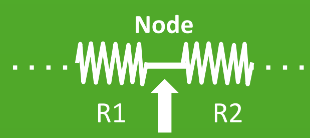

Figure B2.1. A series connection node (see arrow) is a connection between two resistors, in this case our resistors are R1 and R2.

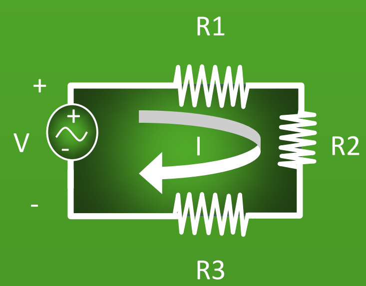

Figure B2.2. A series circuit schematic. In this circuit, I, or current, travels from high to low voltage, clockwise starting from the positive terminal of the battery through R where it returns to the negative terminal of the battery. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

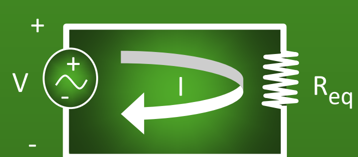

Figure B2.3. A simple circuit schematic. In this circuit, I, or current, travels from high to low voltage, clockwise starting from the positive terminal of the battery through R where it returns to the negative terminal of the battery. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

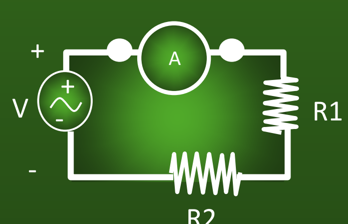

Figure B2.4. To measure the current on a series connection, you will need to "break" the circuit. A is the ammeter. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

WHAT IS IT?

Resistors are in a series connection or series circuit when there is only one pathway for the **current** to flow. More specifically, if resistors are lined up end-to-end, they are connected in series as shown in *Figure B2.1* and *B2.2*. If all resistors in a circuit are in series, the circuit is called a **series circuit** as shown in *Figure B2.2*.

OVERVIEW

- ❑ When the two components share a single common **node**, the same current flows through them (*Figure B2.1*). In *Figure B2.2*, the current flows straight from the positive terminal of the battery to resistor R2, then to resistor R3, and back to the terminal. It only has one pathway to flow.
- ❑ Think about a series circuit like water flowing through a pipe. The water flowing through the pipe is just like the current flowing through the circuit pathway. In a series circuit, all of the water flows through the same path (*Figure B2.2*).
- ❑ We can use a real-life example to explain how current can flow in these two types of circuits. You may remember how older Christmas lights were wired – if one bulb burnt out, the entire string of lights would not light up. It was very difficult to find the one bulb that created a break in the closed circuit and caused the problem. This is an example of a series circuit – there is just one pathway for the current to flow. Modern Christmas lights are wired in a parallel connection, so when a single bulb burns out the rest of the lights on the string still function.

EXTENSION

Assemble *Figure B2.2* on a breadboard and measure the series connection's current using an **ammeter** (see *Figure B2.4*). There are different voltage drops across each resistor, but the current is the same throughout the circuit resulting in each resistor having the same current. With the current and resistance known, solve for the voltage across each resistor on *Figure B2.2* using **Ohm's Law** (V = IR). Check your solution using a voltmeter or ammeter. See A4, A5, and A6 for more on current, resistance, voltage, and Ohm's law.

LESSONS

Lesson 2: Circuit City

Lesson 5: Powering VOLt City

B3. PARALLEL CIRCUIT

WHAT IS IT?

Resistors are wired in a parallel connection when there are multiple paths for the current to flow. See *Figure B3.1* and *Figure B3.2.*

OVERVIEW

- ❑ The main difference between series and parallel circuits is HOW **current** can flow. We know that current always flows from high to low voltage in a circuit. In the **simple circuit**, there is only one way the current could flow (*Figure B3.3)*. When we add a node and more components, we can wire the circuit in a series or parallel connection.
- ❑ Specifically, if both ends of a **resistor** are connected to both ends of another resistor, they are in parallel as shown in *Figure B3.1*. If all resistors in a circuit are connected in parallel, it is called a **parallel circuit** as shown in *Figure B3.2*.
- ❑ If components share TWO common nodes, there are multiple pathways for the current to flow. The circuit is in a parallel connection (*Figure B3.2* and *Figure B3.4*). In *Figure B3.2*, the current flows from the battery's **positive terminal** to resistors R1, R2, R3 and then to the battery's **negative terminal**. But, because the node connecting the battery to R1 is also connected to the other resistors, there are three paths the current can take before it returns. The water pipe analogy can also explain a parallel connection. This time, the water (i.e. current flowing in the circuit) is distributed across three pipes (*Figure B3.3*).

EXTENSION

Assemble *Figure B3.2* on a breadboard and measure the voltage using a voltmeter. The **equivalent resistance** (R_{eq}) of a circuit is the amount of resistance that a single resistor would need in order to model the overall effect of all of the resistors in a circuit. With the **voltage** and resistance known, solve for the current through each resistor on *Figure B3.2* using **Ohm's Law (V = IR)**. Check your solution using an ammeter. See B1 and B2 for more on Ohm's Law.

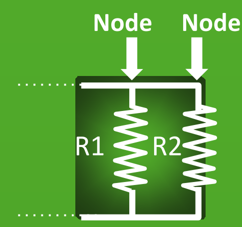

Figure B3.1. A parallel connection node. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

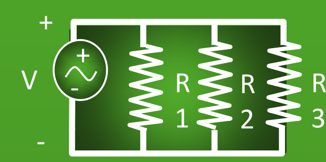

Figure B3.2. A parallel circuit schematic. In this circuit, I, or current, travels from high to low voltage, but can follow multiple pathways between resistors (R1, R2, R3). See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

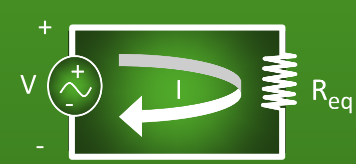

Figure B3.3. A simple circuit schematic. In this circuit, I, or current, travels from high to low voltage, clockwise starting from the positive terminal of the battery through R where it returns to the negative terminal of the battery. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

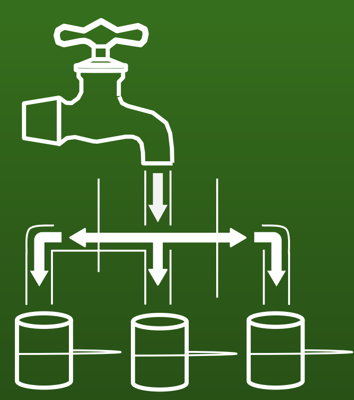

Figure B3.4. Modeling the flow of current in a parallel circuit. Water (current) distributed across three pipes.

Appendix C: Types of Power

APPENDIX C: Types of Power

C1. DIRECT CURRENT 'DC'

WHAT IS IT?

There is more than one way to produce electricity. We know that electrical current is the flow of charged particles, or specifically the flow of electrons. There are two different types of current: **direct current (DC)** and **alternating current (AC)** as shown in *Figure C1.1*. The difference between the two types is distinguished by how the current flows within a circuit. In DC power, the current is constantly flowing in one direction over time. You can visualize this flow of electrons as a flat line as shown in *Figure C1.1.*

OVERVIEW

- ❑ DC power is typically provided by batteries. Any appliance that runs on a battery, is charged by a USB cable, or plugs into a wall with an AC adapter uses DC power. To visualize DC current imagine a battery's positive and negative terminals, now imagine that the current, or charge carriers (electrons), move in one direction from the positive terminal to the negative terminal. See *Figures C1.2 and C1.3* for how current moves in a DC circuit (assuming nothing is modified within the circuit, the current will flow in one direction).
- ❑ Cell phones, laptops, TVs, and hybrid or electric vehicles are examples of everyday items that use DC power. In some electronics, such as TVs, the AC adaptor is inside the device.
- ❑ DC current can flow from very small currents such as 20 **micro-amps** up to large currents of 15-30 amps within a home's circuit breaker or 700 amps within a **low voltage distribution line (power line)**.
- ❑ The **electrical potential difference** of the voltage source will also be constant regardless of time with DC.

EXTENSION

- ❑ DC can be converted to AC using an inverter; AC can be converted to DC using a **rectifier**. Some electronics use both because of the functionality of the devices.
- ❑ DC is preferred in lower voltage applications like power supplies, batteries, & solar power systems.

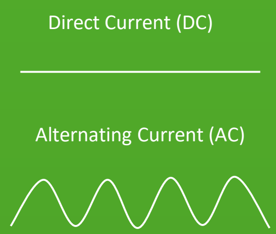

Figure C1.1 AC vs. DC frequency waves. In DC power, the current is constantly flowing in one direction over time, denoted by the flat line.

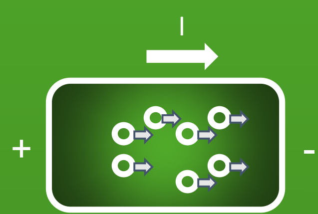

Figure C1.2. Direct current flows in one direction, from high to low voltage. The rings represent electrons which can flow in only one direction as DC power.

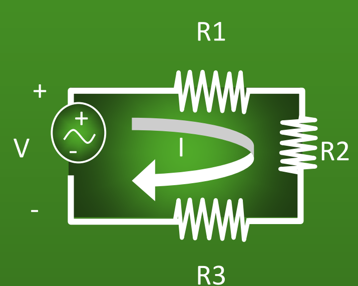

Figure C1.3. Direct current travels clockwise in this circuit. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

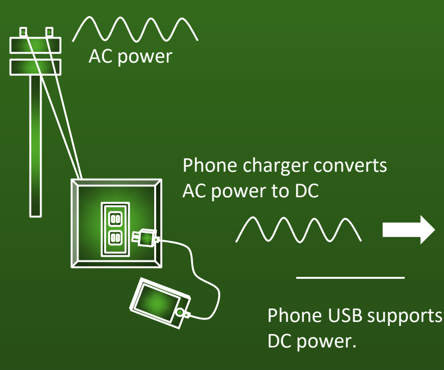

Figure C1.4. AC travels over long distances on and delivered to homes. Certain electronics require DC power and devices such as a cell phone charger converts the AC to DC power to fit these needs.

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C2. ALTERNATING CURRENT 'AC'

WHAT IS IT?

Current, the flow of electrons, can also be transmitted in what we call **alternating current.** We often refer to this as "AC" power, an example of which is shown in *Figure C2.1*. AC power is the more common of the two forms of power transmission. It is the type of power that is consumed from power outlets and that generators produce.

OVERVIEW

- ❑ In AC power, the flow of **charge** changes direction with time. The current in an AC circuit reverses direction many times per second, also known as the **frequency**. As shown in *Figure C2.2 and Figure C2.3*, the current can flow in the direction of the solid arrows or in the direction of the dotted arrows.
- ❑ To provide this changing current direction, the **voltage** source must change **polarity** periodically. A voltage source has a **positive pole** and a **negative pole.** The voltage source changes polarity when positive and negative poles switch.
- ❑ "The flow of AC on a graph makes a **sinusoid** or wave-like pattern," says Berggren. "This is because AC changes over time in an oscillating repetition — the up curve indicates the current flowing in a positive direction and the down curve signifies the alternate cycle where the current moves in a negative direction. This back and forth is what gives AC its name [Alternating Current]."
- ❑ Examples of appliances that use AC power include washing machines, blenders, garage door motors and anything else that plugs directly into a wall.

EXTENSION

After a long series of events in the late 19th century called the war of the currents, AC power became the power transmission systems standard because the frequency and current are more efficient in distributing electricity over long distances. For more information on the power grid see Appendix D1.

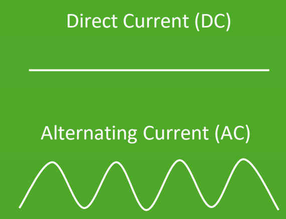


Figure C2.1 AC vs. DC frequency waves. Alternating current most commonly reveals a waveform known as a sine wave, due to the voltage (the force interacting with current) and current alternating.

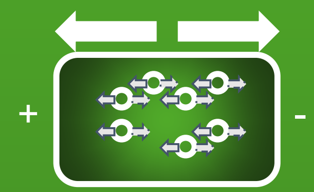


Figure C2.2. Alternating current flows in both directions. The rings represent electrons which can flow in different directions as AC power.

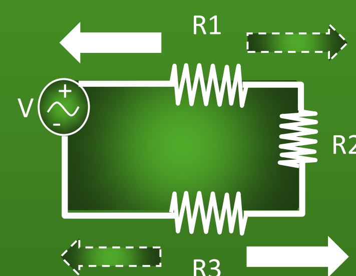


Figure C2.3. Alternating current can travel in either direction in this circuit. See Table B1.4 for a key to the circuit symbol diagrams (Appendix p. 183).

Table C2.4 - Common items powered by AC and DC	
AC power items	**DC power items**
Audio Speaker	Battery operated toy car
Refrigerator	Cell phone
Microwave	Laptop
Hair dryer	Calculator
Lamp	Solar Power

Table C2.4. Common items powered by alternating current and direct current.

Appendix D: Special Topics

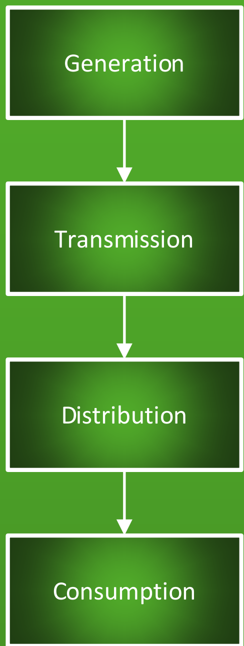


Figure D1.1. A simplified four step process of how energy is produced and consumed in the power grid.

Table D1.2 - The Power Grid Components	
Generation	Non-renewable sources: coal, nuclear, natural gas
	Renewable sources: hydro, wind, solar
Transmission	Power lines (transmission lines)
	Substations/ Step up Transformers
Distribution	Transmission lines
	Substations/ Step down Transformers
Consumption	Transmission lines
	Transformers

Table D1.2. The power grid components.

D1. THE GRID

WHAT IS IT?

The grid is the web of power lines that span across modern civilizations delivering electricity to those that are connected to them. This complex system is what connects the energy generated at power plants to the power outlets in your home. Generating stations produce power that is transmitted to meet the demands of consumers (ranging from entire cities to individual homes).

OVERVIEW

The grid can be categorized by four components (see *Figure D1.1* and *Figure D1.2*):

- ❑ <u>**Generation**</u>, of which there are two types:

  A) **Centralized**: Large-scale power generation including coal, nuclear, hydro, natural gas, wind and solar farms.

  B) **Decentralized**: Small-scale generation where most or all of the power generated is used by the residents or owner of the property. An example of this is people installing solar panels on their roof.

- ❑ <u>**Transmission**</u>: Transmission lines connect the energy created in the generation stage to **substations** located in areas around its destination at extremely high **voltages** (usually between 69kV - over 700kV). However, energy is not generated at this high voltage. It is typically generated at less than 25kV. In order to increase this voltage, the energy is sent through a **step-up transformer**. This will increase the voltage which allows for the energy to be transmitted with a much higher efficiency through longer distances in the transmission lines.
- ❑ <u>**Distribution**</u>: The substations at the end of the transmission lines will then lower the voltage to be between 2.3kV to 34.5kV using **step-down transformers**. Once the voltage has been lowered, the energy is sent through distributions lines to its destination. These distribution lines are the "power lines" that you see around your home, school or job.
- ❑ <u>**Consumption**</u>: As the name implies, this is the part of the grid where energy is consumed. The energy will run through one last transformer mounted on a power pole close to its final destination that lowers the voltage to 120V for homes and low power applications. It is then run to wherever it is needed such as a wall outlet or the lights in a building.

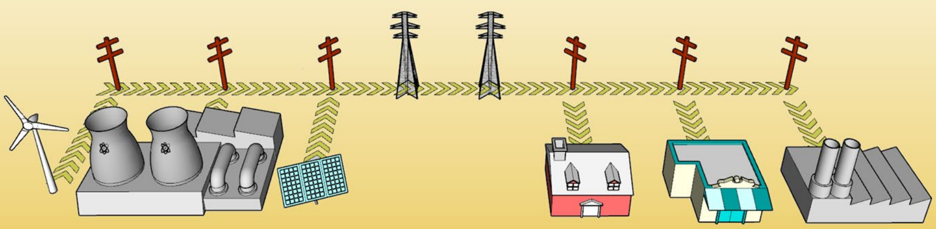
D1. THE GRID

EXTENSION

Figure D1.3.

During Generation, power sources like coal plants, solar fields, and wind farms harness the earth's resources and turn them into electric power.

In Transmission, the electricity is sent on high voltage power lines wherever it needs to go. Electricity can travel hundreds of miles before it reaches its destination.



For Distribution, local power companies sell power to residential customers (like homes), commercial customers (like stores), and industrial customers (like factories).

Figure D1.3. Generation, Transmission, and Distribution for the power grid. Model courtesy of CURENT student, Evan McKee (2018).

<u>The Fully Connected Grid</u>

From the smallest wall outlet to the largest city, every power component in the country is connected to a single power grid (See *Figure D1.3*, *Figure D1.4,* and *Figure D1.5*). Sources, like wind and solar plants, create energy and feed it into the grid. Loads, or power consumers like homes and factories, buy power from the grid. Table D1.6 lists power grid sources and consumers. The entire network is connected through telephone poles, substations, and above or below ground power lines.

Figure D1.4.

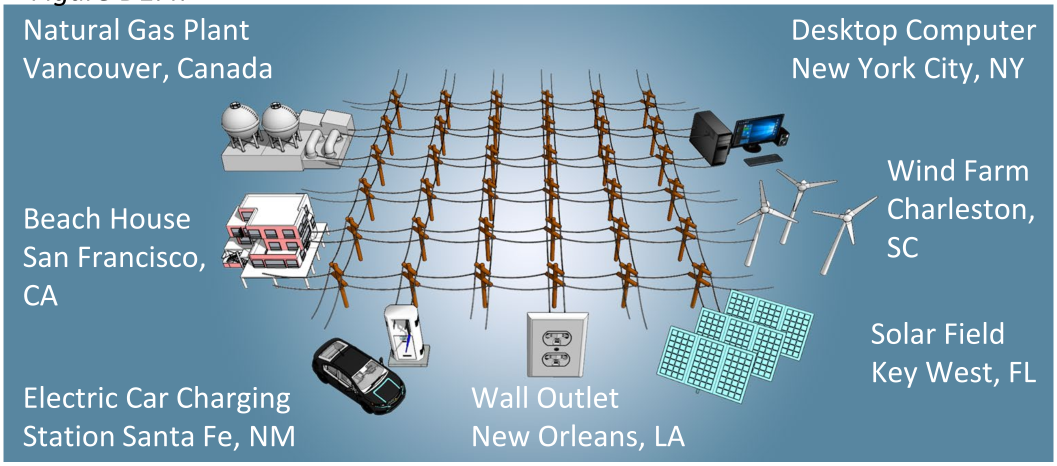


Figure D1.4. The entire network is connected through telephone poles, substations, and above or below ground power lines. Model courtesy of CURENT student, Evan McKee (2018).

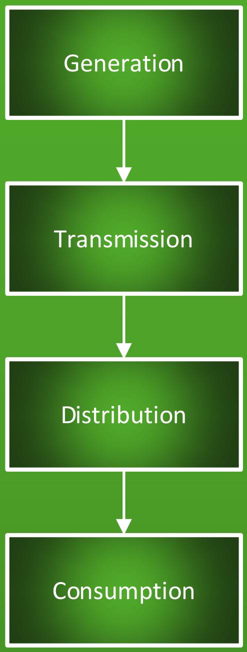


Figure D1.5. A simplified four step process of how energy is produced and consumed in the power grid.

Table D1.6 - The Power Grid Sources and Consumers	
Sources	Non-renewable sources: coal, nuclear, natural gas
	Renewable sources: hydro, wind, solar
Consumers	Residential customers: single family homes, multi-family housing
	Industrial customers: government facilities, public and private organizations
	Commercial customers: manufacturing facilities, industrial sector

Table D1.6. The power grid sources and consumers. Examples of sources and consumers connected to the power grid.

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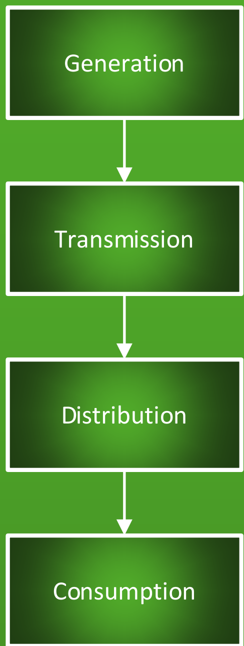

Figure D1.8. A simplified four step process of how energy is produced and consumed in the power grid.

Table D1.9 - Smart Grid Components	
Generation	Isolated microgrids are equipped with integrated communications and renewable resources.
Transmission	Power lines enabled with power flow control devices such as sensors and processors.
Distribution	Use real time data from sensing equipment and monitoring systems to balance loads.
Consumption	Smart technologies reduce load fluctuations and blackouts. Generators and storage reduce overall demand.

Table D1.9. Optimizing the power grid with smart grid components.

D1. THE GRID

EXTENSION

New advancements in technology allow for a smarter, safer grid. If one section of the grid experiences a **power outage** because of a natural disaster (like a hurricane), the rest of the grid can isolate that section to minimize damage. In the past, major blackouts have taken the power away from whole cities like New York and Chicago, and have cost billions of dollars in lost commerce.

A **microgrid** is an individual network that has independent loads and energy resources that can be interconnected with the overall power grid or act independently in an "island-mode."

A **smart grid** is an electricity network that can intelligently manipulate the actions of all users connected to it – generators, consumers, and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.

The smart grid can achieve this in many different ways. **Smart appliances** can shut off in response to frequency fluctuations and can be shifted to off-peak times to save money. **Sensors** can detect fluctuations and disturbances, signaling for certain areas to be isolated. **Smart grid processors** can execute special protection schemes in microseconds. **Storage** on the smart grid can use the energy generated at off-peak times to be stored in batteries for later use. **Generators** can reduce the overall demand on the grid.

Figure D1.7. The Smart Grid

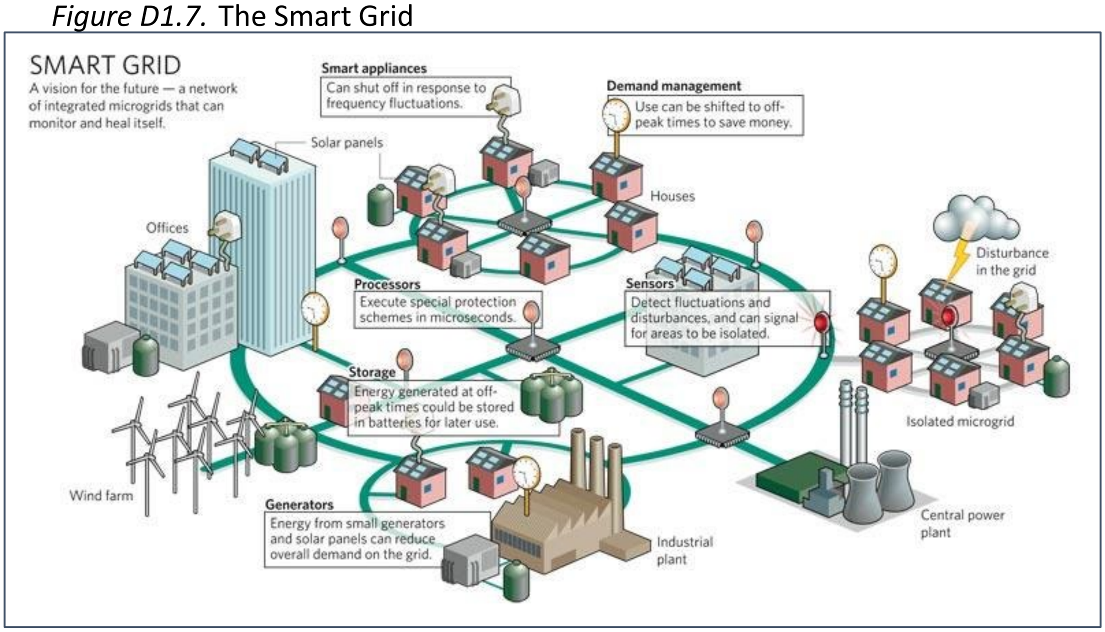

Figure D1.3. Generation, Transmission, and Distribution for the power grid. Internet of Things (2017).

LESSONS

Lesson 3: AC/DC

Lesson 9: Water Wheel

Lesson 5: Powering VOLt City

Lesson 10: Wind Turbine

D2. SOLAR POWER

WHAT IS IT?

Solar power is generated by collecting radiant (light) or thermal (heat) energy from the sun and converting it into electrical energy. There are two different types of solar power generation: **Photovoltaic (PV)** and **Concentrated Solar Power (CSP)**. Photovoltaic solar panels are typically what we think of when we imagine solar power (See *Figure D2.1*).

OVERVIEW

- ❑ **PV** solar power involves solar panels that are made up of individual solar cells connected together as shown in *Figure D2.1*. When sunlight hits the back of each **solar cell**, it energizes the electrons and frees them from the atoms to which they are attached. Once free, these electrons begin to flow and create a current. This current results in electrical energy that can be used as power as shown in *Figure D2.2*.
- ❑ **CSP** solar power is less well known. Instead of generating electrical energy, it generates thermal energy which is then used to create electrical energy. The most common type of CSP is the **parabolic trough**. In the parabolic trough system, thermal energy is created by having the sun rays reflect off of mirrors onto a focal point. A pipe full of oil runs along this focal point causing the oil to heat up as shown in *Figure D2.3.* This hot oil is then used to boil water into steam. This steam is then sent through a generator to create electricity.

EXTENSION

- ❑ Two other common types of CSP are **solar towers** and **dish stirling systems**. Solar towers use mirrors to focus solar rays on a desired area. Dish stirling systems work similarly, but they are attached to a heat engine to generate power.
- ❑ Solar power is being integrated into new applications. For example, solar cells and batteries are installed on airplane wings to generate and store power without the use of fuel.

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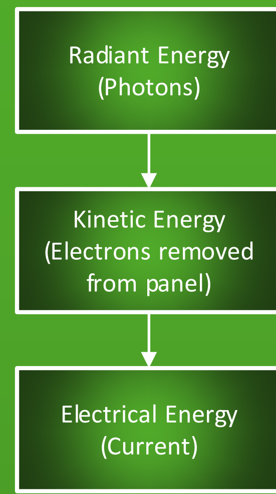

Figure D2.1. A simplified three-step process of PV energy transformation.

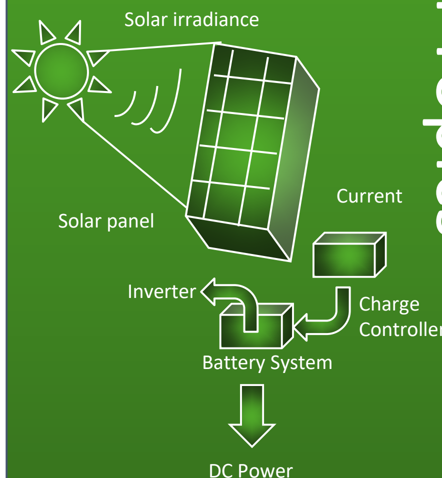

Figure D2.2: The process of transforming radiant energy (light) into electrical energy as DC power. The traditional PV solar panel transforms energy through a series of steps.

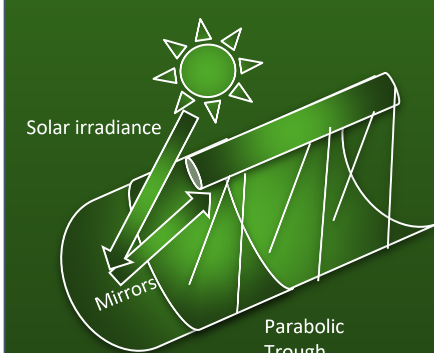

Figure D2.3 Concentrated Solar Power (CSP) system. Thermal energy sourced from the sun is harnessed by reflecting energy off a series of mirrors. This thermal energy is used to heat a pipe full of oil that boils steam. The steam runs a generator that generates electricity.

D3. WIND POWER

WHAT IS IT?

Wind power is power that is generated by harnessing kinetic energy from the wind and transforming it into electricity through a series of steps. See *Figure D3.1* for the simplified three-step process.

OVERVIEW

- ❑ **Wind energy** is harnessed by using a mechanism called a **turbine** connected to blades that are moved by the wind. As the wind spins the blades, the blades spin the turbine, which is attached to a generator. It is very similar in design to a hand-cranked generator. The main difference is that the wind is spinning the generator instead of your arm.
- ❑ There are a few different configurations of blades, but the most common by far is the **horizontal axis wind turbine** as shown in *Figure D3.1.* This giant **t**hree-blade tower is what most people think of when they imagine **wind farms**.
- ❑ The horizontal axis wind turbine must have the wind flowing in a certain direction in order for the blades to turn, but there are other designs that will function regardless of the direction of the wind such as the vertical axis wind turbine as shown in *Figure D3.2*. The **vertical axis wind turbine** has an axis perpendicular to the wind and vertical to the ground, as opposed to the horizontal axis wind turbine which faces one specific direction. This negates the need for the need to have a specific orientation aligned to the wind direction. The vertical axis wind turbine also differs in that its main components are located at the base.

EXTENSION

- ❑ Identifying the most efficient locations for wind farms and turbines is an important job. Many factors affect wind flow, including proximity to other turbines. Ideally, wind would move at a constant, steady pace in a uniform direction. But, there is almost always turbulence regardless of locality.
- ❑ Technology has advanced so wind turbines can now be located on land or water. The area above the ocean is very windy which allows for more energy generation.

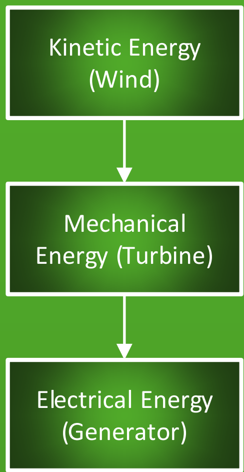

Figure D3.1. A simplified three-step process of how energy is converted from kinetic energy to electrical energy by wind turbines.

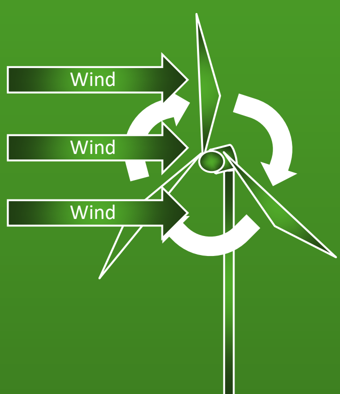

Figure D3.2. Traditional three blade tower powers wind turbine blades on a horizontal axis. This type of wind turbine has stationary blades which must be facing the right direction in order to begin the process of generating electricity.

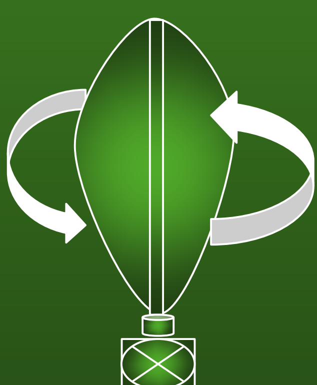

Figure D3.3. Nontraditional vertical axis wind turbine. This type of turbine has the same components as a horizontal axis wind turbine but they are arranged differently. The blades are perpendicular to the wind and the turbine is at the base. This allows the machine to harness kinetic energy from the wind in any direction.

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D4. HYDROPOWER

WHAT IS IT?

Energy occurs in many forms. To make energy useful to us, we often have to convert energy from one form to another. **Hydroelectricity** is one of the oldest forms of power generation. The **hydroelectric turbine** converts the flowing water's mechanical energy. The mechanical energy that is produced is the desired form for practical use (electricity).

OVERVIEW

- Hydroelectric and coal power plants produce energy in a similar way. Both use a power source to turn a propeller-like mechanism called a turbine. This turns a metal shaft in an electric generator and the motor is what produces the electricity. A **coal plant** uses steam to turn the turbine, whereas a **hydroelectric plant** uses falling water to turn the turbine. (Nuclear and gas power plants also use steam to turn the turbine.)
- Gravity causes water to fall through the **penstock** within the dam to get to the turbine. At the end of the penstock is the turbine. We know that for kinetic energy - the faster an object is moving, the more energy it possesses. If we build a dam on a large river that has a massive drop in elevation, theoretically we can produce a large amount of energy.
- **Dams** serve a secondary function in hydropower as electricity demands change throughout the day. The demand for power is not constant. For example, overnight there is generally less of a need for electricity, but during a hot day there is a huge demand to run appliances such as air conditioners.
- **Hydroelectric plants** are used to meet peak demands such as the example listed above. The dam is used as storage to meet these needs - it not only functions to keep water in the **reservoir**, but it also pumps water uphill back into the reservoir. The reservoir acts just like a battery - it stores energy to use later. Unlike large coal or nuclear plants, hydroelectric generators can start and adjust their power output rapidly. They operate most efficiently when used for only a few hours at a time.

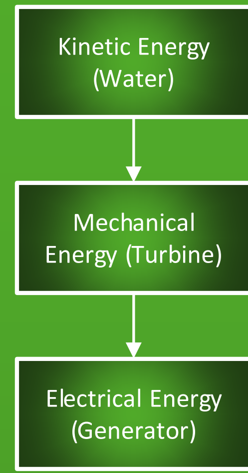


Figure D4.1. A simplified three-step process of how energy is converted from kinetic energy to electrical energy by wind turbines.

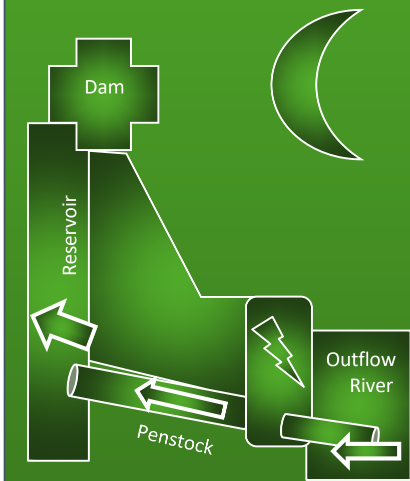


Figure D4.1. At night, the dam will pump water back into the reservoir to store it for later.

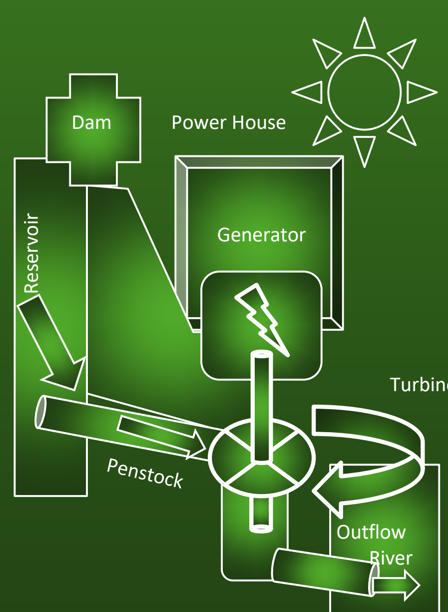


Figure D4.3 A hydroelectric dam. Water flows from the reservoir to the penstock to spin the turbine and then out to the outflow river.

Appendix E: Material Properties

E1. CONDUCTORS

WHAT IS IT?

A **conductor** is a type of material through which **free electrons** can easily flow. They are used to wire electronics because they allow the electrical current to flow in one or more direction. Any charged particle may be transmitted, but it's much more common for electrons to flow than protons as electrons surround atoms while protons are usually bound to the nucleus.

OVERVIEW

- ❑ Conductors are typically **metallic**, but not all metals are good conductors. Certain metals conduct electricity better than others because of their internal crystalline structure. See *Figure E1.1* for the atomic structure of common conductors.
- ❑ One of the most common conductors used in wiring is **copper**, which is used almost anywhere you can imagine electricity flowing. There is copper wiring inside of larger structures, but also in your computer, phone, and other electronics. See *Figure E1.2* for copper wiring.
- ❑ When conductors are not very good at conducting, much of the electrical power flowing will be lost as heat. To avoid wasting power, we try to use the best conductor possible.
- ❑ We also have to balance the type of conductor we use with cost. **Gold** is an even better conductor than copper, but can you imagine how expensive it would be to wire your house with gold? See *Table E1.3* for more examples of conductors.
- ❑ How well a material allows charge to flow depends not only its chemical composition, but also on the dimensions. For example, thicker copper wire will be a better conductor than a thinner one; it is also true that a short wire conducts better than a longer one.

EXTENSION

Conductors behave this way because metals usually bond by forming a solid lattice of nuclei surrounded by a cloud of electrons. This makes it is easy for electrons to flow since they are not strongly bonded to any one nucleus.

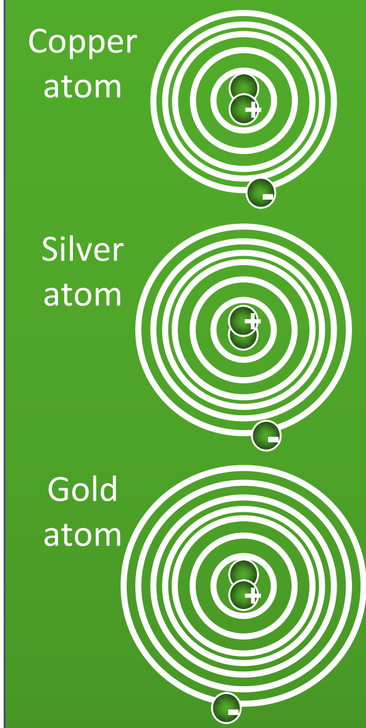


Figure E1.1. The internal structure of three common conductors copper, silver, and gold. Conductors have an internal structure that allows free electrons to flow. They normally have 1-3 valence electrons in their outermost orbital shell. With fewer electrons, they are less resistant to the flow of current.

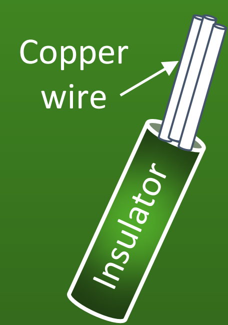


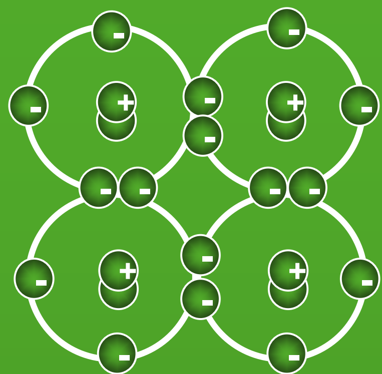
Figure E1.2. A common product used in residential, commercial, or industrial buildings is copper wire. The wire provides connections that will not corrode or creep and requires less insulative material than other conductors.

Table E1.1 Conductor examples

Silver	All other metals
Copper	**Human body**
Gold	**Water**

Table E1.3. A list of some common conductors includes silver, copper, gold, all other metals, the human body, and water.

E2. INSULATORS



WHAT IS IT?

An **insulator** is a material through which free electrons cannot easily flow. Insulators are necessary to protect conductors that are carrying electric current. They have a very high resistance to electrical current.

OVERVIEW

- They are typically nonmetallic.
- Insulators function to isolate conductors and make sure all of the electricity only flows where you want it to flow.
- Insulators resist the flow of electrons because electrons in the insulator material are closely bonded to specific nuclei.
- Some common insulators include glass, plastic, rubber, air, and wood.
- **Rubber** is one of the most commonly used insulators. The rubber that surrounds all of the power cords is an insulator helping to protect you from shocking yourself when you try to touch the conductor. The conductor builds up a charge on its bare surface which can be transferred to you if there is not a good insulator protecting your hands.

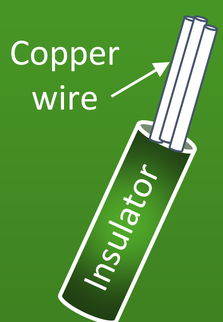


Figure E1.2. A common product used in residential, commercial, or industrial buildings is copper wire. The wire provides connections that will not corrode or creep and requires less insulative material than other conductors.

Table E1.1 Insulator examples

Poor Insulator	Good Insulator
Metal	Rubber
Paper	Plastic
Fabric	Glass

EXTENSION

All insulators can become conductive if a large enough voltage is applied and tears electrons away from atoms. The property that measures how strong an insulator can be is called resistivity. All insulators have higher resistivity than conductors or semiconductors. But some insulators have higher resistivity than others. This is why certain materials are used for electrical wiring and cables and other materials are chosen to prevent more significant current from flowing.

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Appendix Two:
Engineering Design Process

Students learn to channel their creative urges to design and build things through the engineering design process.

OVERVIEW

Introduction to Engineering Design
An overview of the process including general objectives, instructions on using CURENT's Engineering Plans (p.?), and the lessons that these materials can be applied to within this book.

Engineering Design Process Workbook
A comprehensive guide to the process for students working on an engineering design project or problem-based learning. Please note that there are modified versions on the final step for appropriating materials.

Student Reflection Rubric
Nine questions for students to reflect on their engineering skills and performance during the project. Give this rubric to students with each engineering design project so they can map their improvement over time.

K-2 Rubric for meeting NGSS standards
Evidence statements for meeting the ETS1.1, ETS1.2, and ETS1.3 standards. K-2 teachers may use these rubrics to map student progressions during projects over the year.

3-5 Rubric for meeting NGSS standards
Evidence statements for meeting the ETS1.1, ETS1.2, and ETS1.3 standards. 3-5 teachers may use these rubrics to map student progressions during projects over the year.

NEXT GENERATION SCIENCE STANDARDS

CORE IDEAS

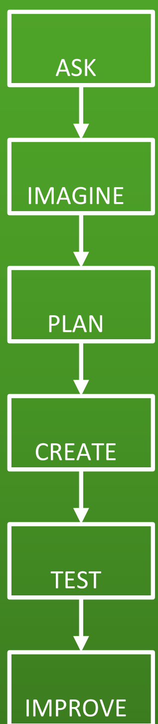
- **K-2: Engineering Design**
- **3-5: Engineering Design**

SCIENCE & ENGINEERING PRACTICES

- **Asking Questions and Defining Problems**
- **Developing and Using Models**
- **Planning and Carrying Out Investigations**
- **Analyzing and Interpreting Data**
- **Constructing Explanations and Designing Solutions**
- **Obtaining, Evaluating, and Communicating Information**

CROSS CUTTING CONCEPTS

- **Cause and Effect**
- **Structure and Function**
- **Influence of Engineering, technology, and Science on Society and the Natural World**



ENGINEERING DESIGN PROCESS

OVERVIEW

These materials serve to guide students through the engineering design process (EDP) as a supplement to any engineering design or project based learning lesson. CURENT's Engineering Plans take students through six steps to channel the natural tendencies of children's creative urges into problem-solving strategies. The engineering design process is not exclusively a linear process, but one that can teach students how to systematically find solutions. All of the steps of the process are beneficial to elementary students as they are applicable to many contexts.

Students are now expected to begin building simple devices in kindergarten. By the time students are in second grade, all three NGSS performance expectations for engineering design should be applied to a single problem. These help students understand the interconnected processes of engineering design.

The six steps of the engineering design process we chose to emphasize for elementary students are the following: ask, imagine, plan, create, test, improve. You will notice that Step 6 - Improve (p.112) has multiple pages while the other steps only consist of one page. The variations are there for you to tailor the book to the specific needs of your project and students. Younger students may benefit more from the simple flow chart or the venn diagram (p.113). For complex group projects, the cycle (p.114) provides prompts for problem solving in the improve stage.

OBJECTIVES

- Ask questions
- Make observations
- Gather information
- Define problems
- Developing solutions
- Develop visual representation of how a solution functions
- Analyze and interpret data
- Optimizing the design solution
- Compare strengths and weaknesses in function

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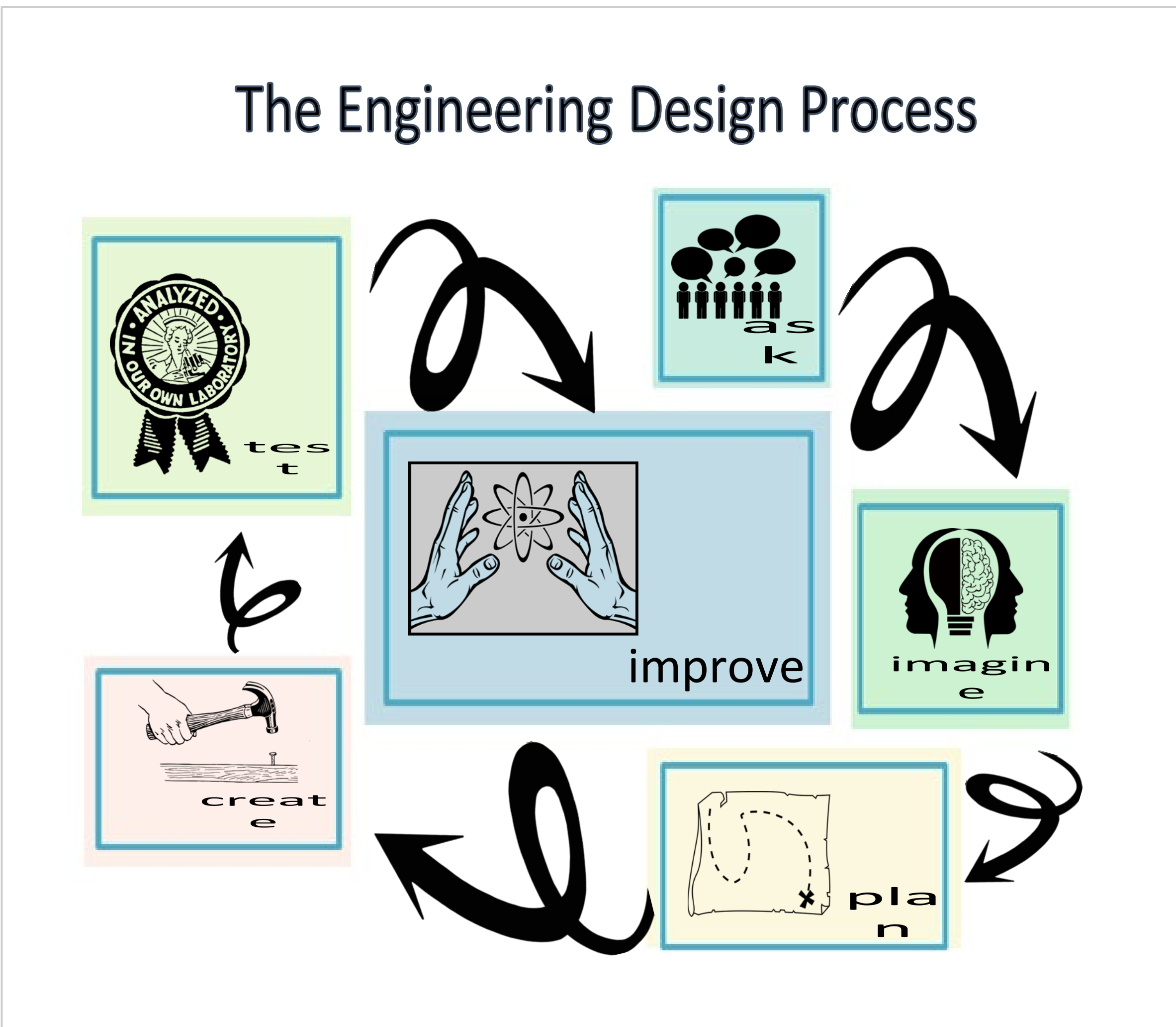
15

Engineering plans



STEP 1

ASK

What is the problem?

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____

____

What information do I need?

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____

____

What limits do I have?

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STEP 2
IMAGINE

Idea #1

Idea #2

Idea #3

Circle your BEST design: #1 #2 #3

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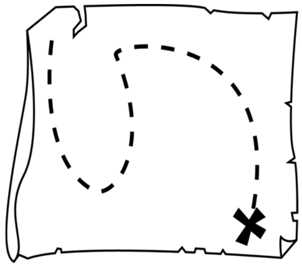
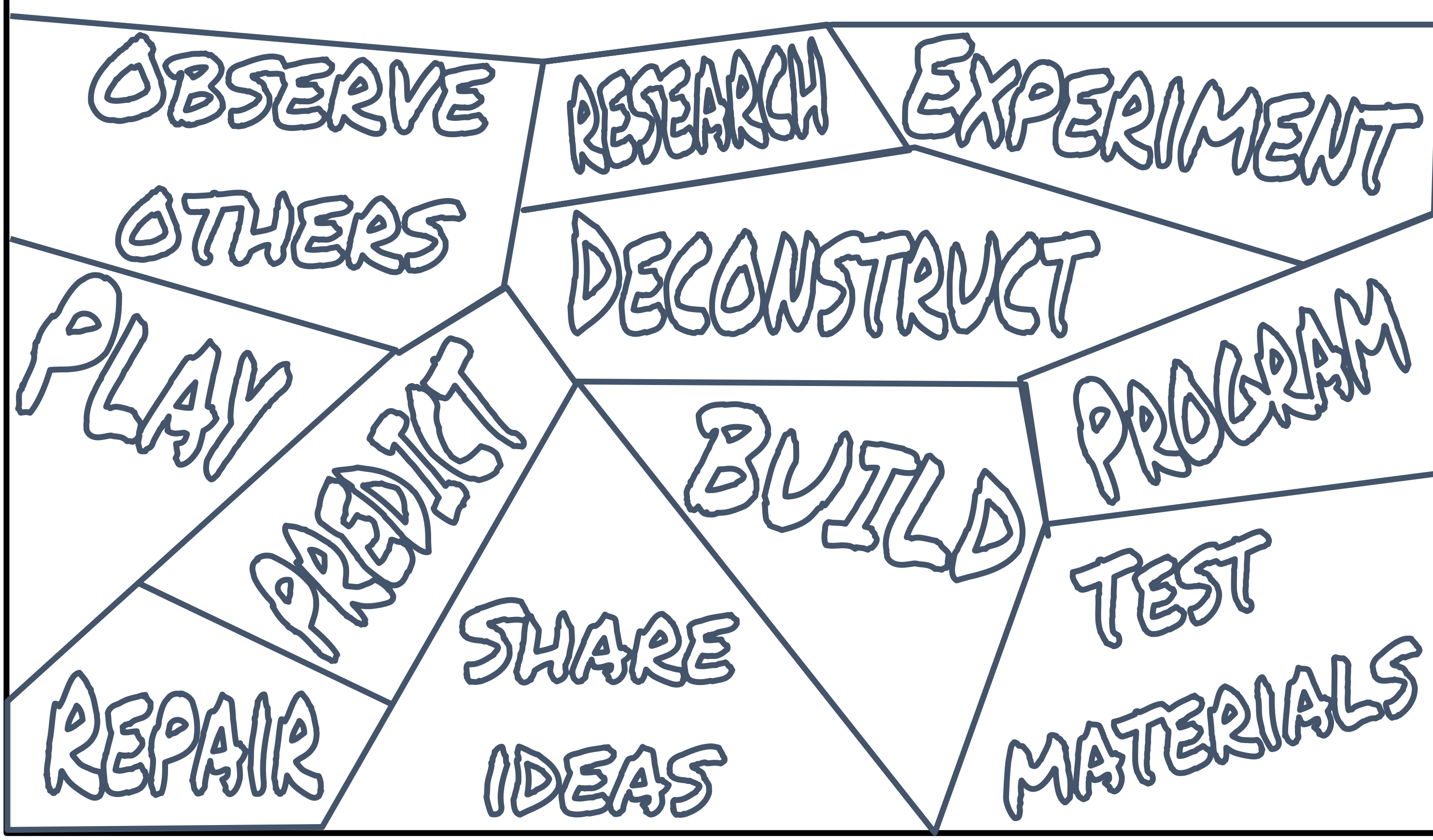


STEP 3

PLAN

Material	Amount	✓

COLOR YOUR ACTIONS FOR THE NEXT STEP!



STEP 4
CREATE

PREPARE TO CREATE YOUR DESIGN.	Check each ✓
Follow safety and rules.	
Gather your materials and tools.	
Follow your plan.	
Collaborate with your team.	
Change your plan as needed.	

DRAW A MODEL OF YOUR DESIGN BELOW.

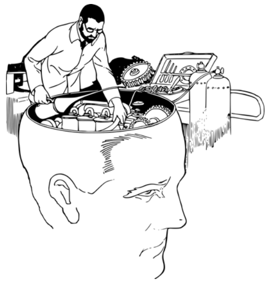
REMEMBER TO LABEL YOUR DESIGN.

STEP 5

TEST

HOW WILL I KNOW MY DESIGN SOLVED THE PROBLEM?

RECORD DATA AND OBSERVATIONS:



STEP 6

IMPROVE

~~FAILURE~~ **OPPORTUNITY!**

DID YOUR DESIGN SOLVE THE PROBLEM?

no

WHAT I THINK CAUSED THE FAILURE?

yes

WHAT CAN I IMPROVE TO MAKE IT BETTER?

Go back to the top of this chart or return to an earlier part of the design process.

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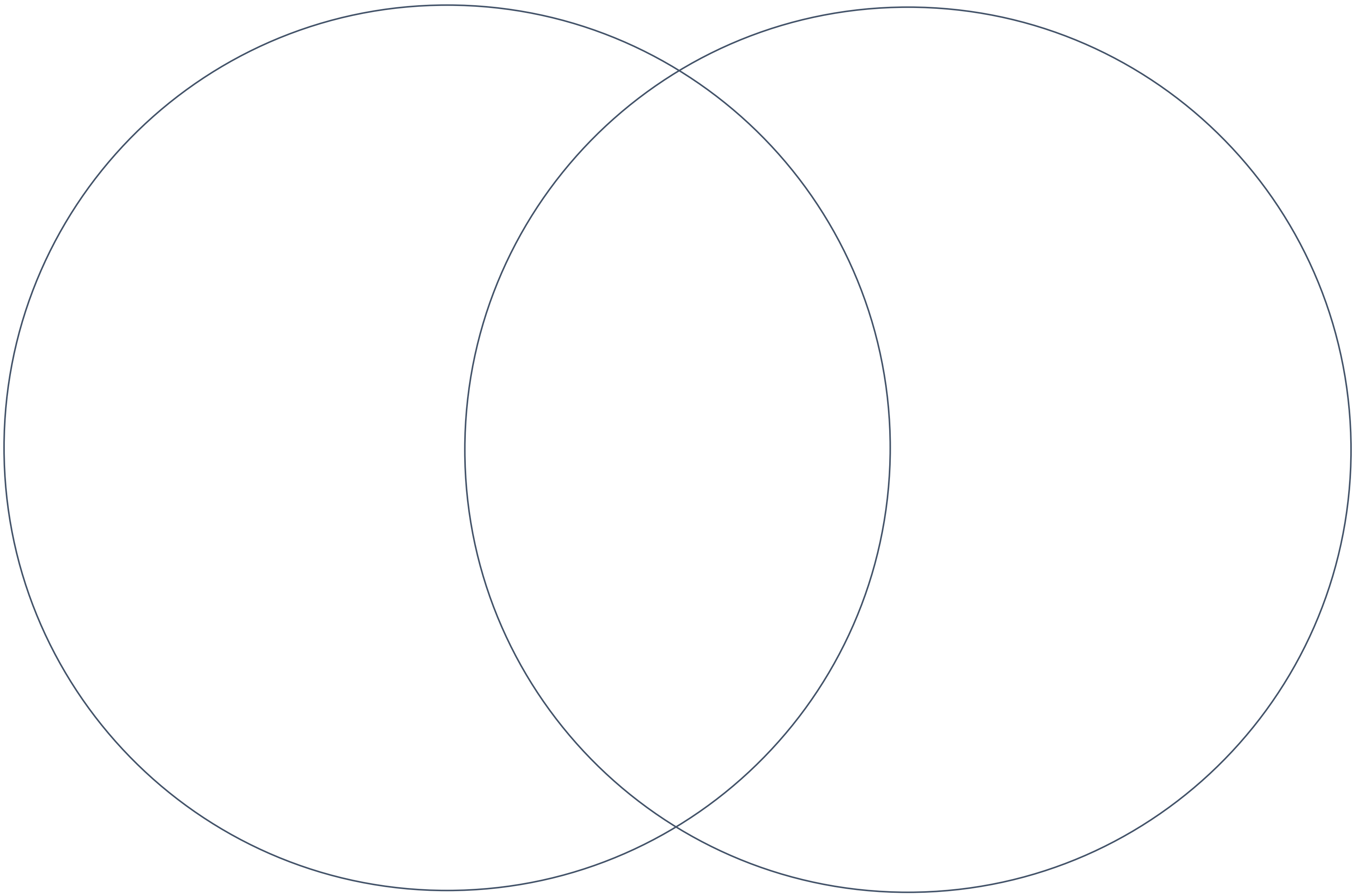
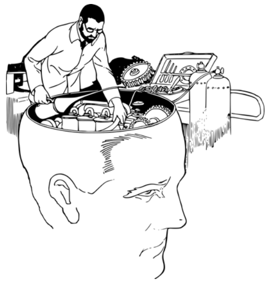
STEP 6
IMPROVE

Directions: Compare and contrast your blade design with another one.

~~FAILURE~~ OPPORTUNITY!





STEP 6
IMPROVE

~~FAILURE~~ OPPORTUNITY!

EVALUATE: DID MY DESIGN SOLVE THE PROBLEM?

TEST

- Did my modification solve the problem? What happened?
- Am I satisfied with the result?
- Can I try a different solution?
- What else can I improve?

IMPROVE YOUR THINKING ABOUT THE PROBLEM OR FIND ANOTHER STRATEGY!

- Conduct research
- Talk it out
- Discuss with peers
- Make observations
- Try another perspective

EVALUATE: HOW CAN I IMPROVE MY DESIGN?

How are your engineering skills?

Name: ______________________________

Engineering Skills	**Color the face that describes you best.**
I followed safety rules.	
I followed the requirements for the design.	
I thought of several ideas to solve the same problem.	
I shared my ideas about the plan with my team.	
I listened to other people's ideas.	
I asked questions to get more information when I did not understand.	
I changed my plan as needed.	
I tried to improve my design.	
I allowed others to work on the project too.	

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Student performance engineering design k - 2

Name: ______________________________

Engineering Skills - ETS1 - 1 - Asking questions and Identifying the problem to be solved	Color the face that describes you best.
Ask questions to gather information about a situation people want to change.	
Make observations to gather information about a situation people want to change.	
Student identifies any given situation.	
Student focuses on why they want to change the situation.	
Student focuses on the desired outcome of changing the situation.	
Student questions are based on observations and information gathered about scientific phenomenon that are important to the situation.	
Identifies a simple problem that can be solved with the development of a new or improved object or tool.	
^^^Does this using the information they gathered, including answers to questions, personal observations, and scientific information.	
Describes the desired features of the tool or object that would solve the problem.	

Student performance engineering design k - 2

Name: ______________________________________

Engineering Skills - ETS1 - 2 - Developing and Using models	Color the face that describes you best.
Develop a representation of an object and the problem it is intended to solve.	
Student identifies the object/model/solution.	
Student identifies the relevant shape (s) of the object.	
Student identifies the function of the object.	
Student uses sketches, drawings, or physical models to convey their representation.	
Student identifies relationships between the shape(s) of the object and the object's function.	
Student identifies relationships between the object and the problem it is designed to solve.	
Students use their representation to communicate the connections between the shape(s) of an object, and how the object could solve the problem.	

Student performance engineering design k - 2

Name: ______________________________

Engineering Skills - ETS1 - 3 - Analyzing and Interpreting data	**Color the face that describes you best.**
Uses graphical displays (tables, pictographs, line plots) to organize given data from tests of two objects.	
Data has information about features and relative performance of each solution.	
Students use organization of data to find patterns of data.	
Student uses data to see how each object performed.	
Student uses data to compare performance to another object.	
Student uses data to compare how object performed relative to its intended performance.	
Students use performance patterns to describe the physical process of how each object will solve the problem.	
Students use performance patterns to describe strengths and weaknesses of each design.	
Students use performance patterns to describe which object is better suited to the desired function, if both solve the problem.	

Student performance engineering design 3- 5

Name: ______________________________

Engineering Skills - ETS1 - 1 - Identifying the problem to be solved	Color the face that describes you best.
Student used scientific information.	
Student used situation or phenomenon info.	
Defined a simple design problem.	
Defined problem responds to a need/want.	
The problem can be solved with the development of a new or improved object, tool, process, or system.	
Student describes* people's needs/wants change over time.	
Student defined limits to a problem.	
The limits include addressing something people want and need at the current time.	
Students specify criteria of a successful solution.	
Students describe the constraints or limitations on their design, which may include: cost, materials, time.	

Student performance engineering 3 - 5

Name: ______________________________

Engineering Skills - ETS1 - 2 - Generating Design Solutions	Color the face that describes you best.
Student used scientific information from research.	
Student included causes and effects of the problem.	
Generated at least two possible solutions.	
Solutions based on scientific info and understanding the problem.	
Student specifies how design solves the problem.	
Shares ideas and findings with others.	
Generates a variety of possible solutions with others.	
Researched and communicated with others throughout the design process to improve the design.	
Describe the criteria and constraints for the solutions.	
Described increasing benefits of solutions.	
Described decreasing risks/costs.	
Described meeting societal demands.	
Described how criteria and constraints are used to test solutions.	
Test each solution under a range of conditions.	
Gathered data from testing.	
Determined how well the solutions meet the criteria and constraints using testing data.	
Compared solutions using collected data.	

Student performance engineering 3 - 5

Name: ______________________________

Engineering Skills - ETS1 - 3 - Planning and Carrying out fair tests	Color the face that describes you best.
Describes* possible failures that can be improved.	
Describes* difficulties to identify what can be improved.	
Describes* the evidence to be collected.	
Student tests how well the model performs against the given criteria/constraints.	
Identify what evidence reveals failure points/difficulties.	
Identify what evidence will show how model can be improved to better meet the criteria and constraints.	
Describes how evidence is relevant to the purpose of the investigation.	
Creates a plan for the investigation.	
The plan has different tests for criteria and constraints.	
The plan describes specific criteria or constraint.	
The plan identifies the independent variable.	
The plan identifies a outcome/dependent variable.	
The plan identifies tools and methods for collecting data.	
The plan identifies what is kept the same.	
Students collect and record data.	
Students follow the plan they developed.	

Glossary

AC-DC Converter
- An electronic device used to change alternating current into direct current by using diodes and/or other circuit components. Also known as a rectifier. This component differs from a DC-AC converter, also known as an inverter.

Alternating Current
- A current that changes direction over time. This process is due to the voltage changing polarity periodically. Commonly written as “AC.”

Ampere
- The unit of measure for current. It is equal to a flow of one coulomb per second. Symbolized by “A.” Often referred to as amps.

Ammeter
- A tool used to measure the current in a series connected circuit. The device can measure a wide range of current values in amperes (amps).

Anion
- An ion with a negative charge. Anions are atoms that have gained electrons.

Applied Force
- A force applied by an object onto another object.

Arduino
- An open-source electronics platform and the software that programs it.

Atom
- The smallest unit of matter that has the properties of a single chemical element. Every atom is composed of protons, neutrons, and electrons. Protons and neutrons are bound within the nucleus, while electrons may orbit the nucleus.

Atomic Properties
- Chemical elements have specific measurable properties exuded on an atomic scale. These properties include atomic mass, electronegativity, first ionization energy, atomic radii, number of valence electrons, etc. We use our knowledge of atomic properties as the fundamental basis of electromagnetics.

Atomic Structure
- The theorized internal structure of an atom, including the positively charged nucleus and the negatively charged electrons orbiting it.

Capacitance
- An object or system’s ability to store an electric charge. Symbolized by “C.” The SI unit of capacitance is the farad (F).

Capacitor
- A circuit component composed of at least two metal plates (conductors) separated by a dielectric (insulator) used to add a desired capacitance, which occurs as a voltage difference develops between the two plates. The effect of a capacitor is known as its capacitance.

Cation
- An ion with a positive charge. Cations are atoms that have lost electrons.

Centralized Power Generation
- Large-scale power generation at centralized facilities including coal, nuclear, hydro, natural gas, wind and solar farms. The majority of electricity used in the US comes from centralized generation that is distributed through the power grid.

Glossary

Charge
- The physical property that causes matter to experience a force when placed in an electromagnetic field. Charges can be positive, negative, or neutral. This fundamental property of matter is neither created nor destroyed.

Charge Carrier
- See electron.

Chemical Energy
- Energy that is stored within the bonds of chemical compounds. This potential energy is released when a chemical substance undergoes a transformation (chemical reaction) to transform other chemical substances.

Circuit
- Electrical components that provide a complete pathway that an electric current flows or may flow.

Circuit Diagram
- A representation of an electrical circuit. Also referred to as circuit schematic, electrical diagram, or electronic schematic.

Closed Circuit
- A circuit through which there is a continuous path that allows current to flow.

Coal
- A nonrenewable resource known as a fossil fuel. The sedimentary rock is primarily composed of carbon. The chemical energy stored in coal is released through combustion to produce heat and electricity.

Coal Plant
- Uses coal to produce steam to turn a
- propeller-like mechanism called a turbine to produce energy.

Concentrated Solar Power
- Type of solar power that uses a system of mirrors or lenses to reflect and concentrate a large area of solar thermal energy (radiant and thermal energy) onto a small area. This energy is then used to power turbines or heat engines that transform the solar thermal energy into electrical energy. Also known as CSP.

Conductor
- Any material or object through which free electrons can flow with the application of voltage. Good conductors give little resistance. Typically metallic.

Conductivity
- The degree to which a material conducts electricity. The opposite of resistivity. Also known as specific conductance.

Consumption
- The act of individuals or groups to use electrical energy over a certain period of time.

Conventional Current
- The flow of positive charge.

Copper
- A metal chemical element that is soft, malleable, and ductile with a very high thermal and electrical conductivity. It is one of the most commonly used conductors.

Coulomb
- The unit of measure for electric charge. Symbolized by “C.”

Glossary

Crystal Lattice
- The ordered arrangement of atoms, ions or molecules. These repetitive groups are usually patterned in symmetrical arrangements bound closely together with few free electrons.

Current
- The flow of charged particles through any medium. Symbolically written as "I" and measured in Amperes (A).

Dam
- A barrier constructed across a stream or river to restrict the flow of water and contain it. The resulting reservoir may be used to generate electricity or to provide water for an area.

DC-AC Converter
- An electronic device used to convert direct current to alternating current by using switches and other circuit components. Also known as an inverter.

Decentralized Generation
- Small-scale distributed generation where most or all of the power generated is used by the residents or owner of the property. Micro-grids are an example of decentralized generation.

Diamagnetic Elements
- Elements with unpaired electrons that experience a repulsive force that weakly repels magnets.

Dielectric
- An insulator placed between conductors used to keep them separated and to keep charge from moving between them.

Diode
- An electrical component that passes current in one direction and blocks current in the opposite direction.

Direct Current
- Constant current that doesn't change direction. Commonly written as "DC."

Dish Stirling Systems
- Use mirrors to focus solar rays on a desired area, but are attached to a heat engine to generate power.

Distribution
- The substations at the end of the transmission lines will then lower the voltage to be between 2.3kV to 34.5kV using step-down transformers.

Ductility
- A material's ability of being easily stretched and shaped because they are soft.

Electric Field
- The area around a charged particle that exerts a force on other charges by attracting or repelling.

Electric Potential Energy
- A form of potential energy that is derived from Coulomb forces and the relation between point charges.

Electrical Energy
- A type of energy dealing with the flow of electrons.

Electrical Potential Difference
- The difference in electric potential from initial to final point.

Electrical Power
- The rate at which electrical energy is used or generated. See also: power.

Electromagnetic Field
- A field caused by electrically charged objects affecting the behavior of other

Glossary

- charged objects. Also known as EMF.

Electromotive Force
- The energy required to move charge between two points. Also known as voltage or the electrical potential.

Electron
- A subatomic particle with a negative electric charge that orbits around an atom. Electrons can be freed from the atom if given the right type of force. Also referred to as charge carrier.

Electron Orbital
- A mathematical function that specifies the shape, position, and area that electrons are most likely to occupy in an atom.

Elementary Charge
- The electrical charge carried by a single electron.

Energy
- A measure of how much work a system is able to do. Measured in Joules (J).

Energy Poverty
- The disparity in access to electrical power and modern energy services that much of the world faces. Most of the affected population is from developing countries, but energy poverty occurs in developed countries as well.

Energy Source
- Categorized as either renewable or nonrenewable energy.

Energy Transformations
- The process that occurs when one form of energy is changed to another.

Engineer
- A person trained and skilled in the design, construction, and use of engines
- or machines, or in any of various branches of engineering.

Engineering Design Process
- The series of steps by which engineers solve a problem. It typically begins with recognizing a need, developing requirements for a solution, implementing those requirements through a design and reviewing, and testing that design until the need is met. Also referred to as EDP or simply the design process.

Equivalent Resistance
- The amount of resistance that a single resistor would need in order to model the overall effect of all the resistors in a circuit.

Farad
- The unit of measure for capacitance. Symbolized by "F." Named in honor of Michael Faraday.

Force
- The push or pull of an object with a mass that can cause a change in velocity. Force is equal to mass times acceleration. It is a characteristic of interaction between any set of objects.

Free Electron
- An electron that is not attached to an atom.

Frequency
- The number of complete oscillations per second of energy in the form of waves. It is the number of waves passing a point in a certain amount of time. Symbolically written as "f" and measured in Hertz (Hz), which is the number of changes per second.

Glossary

Gallium Arsenide
- Crystalline compound made from the elements Gallium (Ga) and Arsenic that is used in the synthesizing of solar cells. Gallium Arsenide is a semiconductor material.

Generation
- Refers to the methods of electricity generation. During Generation, power sources like coal plants, solar fields, and wind farms harness the earth's resources and turn them into electric power. There are two types of generation in the power grid: centralized and decentralized.

Germanium
- The chemical element is a metalloid in the carbon group with properties similar to silicon. Germanium was once commonly used in the creation of semiconductor devices and transistors.

Generator
- There are many different types of generators. When we refer to a "generator" we are referring to an electric generator which is a device that transforms mechanical energy into electrical energy.

Global Climate Change
- Climate change is the long term (i.e. ranging from decades to millions of years) change in the Earth's climate, this includes changing temperatures but also weather patterns and other factors of climate. Global climate change is driven by natural processes (such as plate tectonics) or events (such as the earth's orbit) and anthropogenic
- influence (such as increased carbon emissions).

Gold
- The chemical element is a metal that exhibits properties that make it a great conductor.

Gravitational Energy
- Potential energy held by an object due to its high position compared to a lower position.

The Grid
- All of the generation, transmission and consumption of electrical power in the country, and how it is all connected.

Henry
- The unit of measure for inductance. Symbolized by "H." Named after Joseph Henry.

Horizontal Axis Wind Turbine
- Must have the wind flowing in a certain direction in order for the blades to turn.

Hydroelectricity
- The name for electricity produced by water power.

Hydroelectric Plant
- Uses falling water to turn a propeller-like mechanism called a turbine to produce energy.

Hydroelectric Power
- Electric power generated by turbines that are spun by the flow of water.

Hydroelectric Turbine
- Converts the flowing water's mechanical energy.

Inductance
- An object's ability to change current over time. The voltage of an object is dependant on how fast the current

Glossary

- through the object changes and the natural properties.

Inductor
- A circuit component made of a wire wound around a dielectric to add a desired inductance, which occurs as a current develops through the wire due to a changing magnetic field.

Ion
- Chemical elements with a net charge.

Insulator
- Any material through which electrons cannot flow. Typically nonmetallic.

Inverter
- An electronic device or circuit component that converts direct current (DC) to alternating current (AC).

Joule
- The unit of measure for energy. Symbolized by “J.”

Law of Conservation of Energy
- Energy cannot be created or destroyed but can only be transformed from one form to another.

Load
- Anything that produces or consumes power. A load can be a resistor, capacitor, inductor, or a combination of these. In the power grid, athe electric power being used by users.

Kinetic Energy The energy an object has when being in motion.

Magnet
- An object/material that has a magnetic field.

Magnetic Field
- Generated when an electron is in motion.

Matter
- A physical substance that has a mass and volume.

Malleability
- A material’s ability of being easily stretched or shaped because they are soft.

Melting Point
- A temperature in which a solid will transform to its liquid state of matter.

Mechanical Energy
- Includes both the kinetic energy of an object and the potential energy of the object.

Mechanism
- A system of parts working together in a machine; a piece of machinery.

Metals
- A material that is typically a good conductor, ductile, malleable, and fusible.

Metallic
- Consisting of similar properties to metal.

Multimeter
- A tool that can be used to measure many different electrical parameters in parallel circuits such as voltage, current and resistance.

Negative Charge
- Occurs when the number of electrons surpasses the number of protons in an object.

Glossary

Negative Pole
- The pole on a magnet that seeks out south when hanging freely.

Negative Terminal
- The side of a voltage source that carries more electrons.

Net Charge
- Calculated by adding up the charges of the particles within the system. A net charge is maintained within an isolated system, it is neither created or destroyed.

Neutral Charge
- Net charge of zero.

Neutron
- Subatomic particle with no charge.

Newton
- The SI unit of force. (N)

Node
- Functions as an electrical point where two or more components meet in a circuit.

Nonmetallic
- Not consisting of similar properties to metal.

Nonrenewable Energy
- See nonrenewable resource.

Nonrenewable Resource
- Resources that do not quickly replenish and exist in limited amounts. Examples include coal, oil, and natural gas. Also referred to as nonrenewable energy.

Nuclear Energy
- Energy produced by splitting atoms and harnessing the heat to produce steam which in turn rotates a turbine.

Nuclei
- Plural of nucleus. See nucleus.

Nucleus
- The core of an atom, which is positively charged because it consists of neutrons and protons.

Ohm
- The unit of measure for resistance. Symbolized by "Ω."

Ohm's Law
- The relationship between Voltage, Current and Resistance ($V = I \bullet R$).

Open Circuit
- A circuit through which there is not a continuous path allowing current to flow.

Oscilloscope
- A measuring instrument used to view varying voltage signals over time.

Parabolic Trough
- Thermal energy is created by having the sun rays reflect off of mirrors onto a focal point.

Parallel Circuit
- When all resistors in a circuit are connected in parallel.

Penstock
- A channel that directs water flow to a turbine.

Photovoltaic
- Solar panels that are made up of individual solar cells connected together.

Polarity
- Exhibiting the property of possessing poles.

Glossary

Pole
- Where the magnetic flux produced, emerge and enter on a magnet.

Positive Charge
- Occurs when the number of protons surpasses the number of electrons in an object.

Positive Net Charge
- Occurs when a point has lost electrons.

Positive Pole
- The pole on a magnet that seeks out north when hanging freely.

Positive Terminal
- The side of a voltage source that current begins to flow.

Potential Difference
- The displacement of electric potential energy from two different points.

Potential Energy
- Energy stored within a system. It is classified depending on the specific applied restoring force.

Power
- The rate at which electrical energy is consumed. Symbolically written as "P" and measured in Watts (W).

Power Distribution Line
- A part of the electrical grid containing wires transmitting electricity at long distances within a city at high voltages. Carries electric power from a substation to homes, businesses and other electrical consumers nearby. Voltages can range from as low as 2.3 kiloVolts up to 34.5 kiloVolts.

Power Grid
- An interconnected network for delivering electricity from producers to consumers.

Power Outage
- Loss of electric power in a given area.

Power Transmission Line
- A part of the electrical grid containing wires transmitting electricity extremely long distances at extremely high voltages. Carries electric power from the generation plant to the substations in a city in need of power at voltages that can range from 69 kiloVolts to over 700 kiloVolts.

Primary Source
- Sources of energy that can be used directly.

Proton
- Subatomic particle with a positive charge.

Radiant Energy
- Energy that travels by waves.

Raspberry Pi
- A simple computer that is held on a single circuit board.

Rectifier
- Converts AC to DC.

Glossary

Renewable Resource

- ➢ Any resource that does not deplete due to being used or harnessed and is replaced quickly and naturally. Examples include wind and solar power. Also referred to as renewable energy.

Reservoir

- ➢ Acts like a battery, storing energy to use later.

Resistance

- ➢ Measurement of how much an object or component opposes the flow of current. Symbolically written as "R" and measured in Ohms (Ω).

Resistivity

- ➢ The property that measures how strong an insulator can be.

Resistor

- ➢ A circuit component that provides a desired resistance to a circuit. Typically made of metal, metal-oxide or carbon film.

Rubber

- ➢ One of the most commonly used insulators.

Semiconductor

- ➢ Any material that does not strictly act as a conductor or insulator, but can act as either. It is often metallic but not always.

Sensors

- ➢ Detect fluctuations and disturbances, signaling for certain areas to be isolated.

Series Circuit

- ➢ A connection or circuit in which there is only one pathway for the current to flow. Components in this circuit share a common node.

Silicon

- ➢ The most commonly used semiconductor material.

Simple Circuit

- ➢ The most basic type of circuit, consists of very few components a voltage source connected to a single resistor.

Sine Wave

- ➢ A wave that represents accurate oscillations like that of a sine function.

Sinusoid

- ➢ Wave-like pattern.

Smart Appliances

- ➢ Shut off in response to frequency fluctuations and can be shifted to off-peak times to save money.

Smart Grid

- ➢ An electricity network that can intelligently manipulate the actions of all users connected to it--generators, consumers, and those that do both--in order to efficiently deliver sustainable, economic and secure electricity supplies.

Smart Grid Processors

- ➢ Execute special protection schemes in microseconds.

Glossary

Solar Power
- ➢ Electric power generated by collecting radiant (light) or thermal (heat) energy from the sun and converting it into electrical energy.

Solar Towers
- ➢ Use mirrors to focus solar rays on a desired area.

Sound
- ➢ Form of kinetic energy traveling through a medium by vibrations.

Stable
- ➢ Having an uninterrupted, secure signal or flow of power.

Step-down Transformer
- ➢ Substations at the end of transmission lines will then lower the voltage using step-down transformers.

Step-up Transformer
- ➢ Increases voltage from primary to secondary.

Storage
- ➢ Can use energy generated at off-peak times to be stored in batteries for later use.

Substation
- ➢ A part of the electrical grid where high voltage transmission lines are transformed and sent out as lower voltage distribution lines.

Sustainability
- ➢ The process of maintaining balance amongst change in technology, energy resources, and society.

Temperature
- ➢ A measure of the warmth or coldness of an object or substance with reference to some standard value.

Thermal Energy
- ➢ Heat

Three-Blade Tower
- ➢ Wind turbine.

Transformer
- ➢ An electrical component that transforms voltage to be higher or lower.

Transistor
- ➢ The fundamental component to computers and most modern technology.

Transmission
- ➢ The movement of bulk energy from generating sites to substations.

Turbine
- ➢ A mechanical device found in generators that is rotated to convert one form of energy into a more useful one.

Vertical Axis Wind Turbine
- ➢ Turbine that works regardless of the direction of the wind.

Volt
- ➢ The unit of measure for voltage. Symbolized by "V."

Voltage
- ➢ The difference in electrical potential between any two points. It is also known as electromotive force. Symbolically written as "V" and measured in Volts (V).

Glossary

Voltage Source
- A two terminal device that maintains a fixed voltage.

Voltmeter
- A tool used to measure voltage between two points.

Watt
- The unit of measure for power. Symbolized by "W."

Wind Energy
- Harnessed by using a mechanism called a turbine connected to blades that are moved by the wind.

Wind Farm
- Harness the earth's resources and turn them into electric power.

Wind Power
- Electric power generated by wind.

Work
- A measure of energy transfer. The SI unit of work is the joule (J).

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Abbreviations

Abbreviation	Explanation
A; amps	Amperes
AC	Alternating Current
AC/DC	Alternating Current/Direct Current
C	Coulombs
CO_2	Carbon dioxide
CSP	Concentrated Solar Power
DC	Direct Current
DOE	Department of Energy
e-	Electron
EDP	Engineering Design Process
EMF	Electromotive force
ERC	Engineering Research Center
I	Current
I + direction of flow	Pathway for current (ex. wires)
J	Joules
LED	Light Emitting Diode
N	Newton
NGSS	Next Generation Science Standards

Abbreviation	Explanation
NSF	National Science Foundation
P	Power
p. or pp.	Page(s)
PV	Photovoltaic
R	Resistance
R_{eq}	Equivalent resistance
RET	Research Experience for Teachers
s	Seconds
STEM	Science, Tech., Engineering, Math
V	Voltage
W	Watts
Ω	Ohm