STEM Unit 2: Electric Circuits (45 Instructional Days)

Overarching Essential Questions	**Overarching Enduring Understandings**
· When does 30,000 Volts tickle? · Is there a correct answer to the AC/DC debate? · What can electricity do? · How can words be used to control current?	· Certain types of materials have atomic properties such that electrons can be coaxed to move through the material and transfer energy. This form of energy is known as electrical energy. · The flow of electric energy is called current. There are two types of current – alternating current and direct current – in wide use today. · Managing current is essentially at the heart of modern computing, allowing us to control the conversion of electrical energy to other forms.

Student Learning Objectives	
What students should be able to do after instruction.	*Evidence Statements*

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.* [Clarification Statement: Emphasis is on both qualitative and quantitative evaluations of devices. Examples of devices could include Rube Goldberg devices, wind turbines, solar cells, solar ovens, and generators. Examples of constraints could include use of renewable energy forms and efficiency.] [*Assessment Boundary: Assessment for quantitative evaluations is limited to total output for a given input. Assessment is limited to devices constructed with materials provided to students.*]	**HS-PS3-3**
Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]	**HS-PS2-6**
Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	**HS-ETS1-1**
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	**HS-ETS1-2**
Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.	**HS-ETS1-3**
Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.	**HS-ETS1-4**

The Student Learning Objectives above were developed using [the following elements from the NRC document *A Framework for K-12 Science Education*]:		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concepts**

Obtaining, Evaluating, and Communicating Information

Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. (HS-PS2-6)

- Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6)

Asking Questions and Defining Problems

Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

- Analyze complex real-world problems by specifying criteria and constraints for successful solutions. (HS-ETS1-1)

PS1.A: Structure and Properties of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS2-6)

PS2.B: Types of Interactions

- Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS2-6)

PS3.A: Definitions of Energy

- At the macroscopic scale, energy manifests itself in multiple ways, such as motion, sound, light, and thermal energy. (HS-PS3-3)

ETS1.A: Defining and Delimiting Engineering Problems

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1) (secondary to HS-PS3-3)

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-ETS1-4)

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)

Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. (HS-PS2-6)

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including

Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-2) • Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-ETS1-3) • Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS3-3) **Using Mathematics and Computational Thinking**	· Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1) **ETS1.B: Developing Possible Solutions** · When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3) · Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet their needs. (HS-ETS1-4) **ETS1.C: Optimizing the Design Solution** · Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the	some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) • Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. · Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4)	priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)	

Embedded English Language Arts/Literacy and Mathematics

English Language Arts/Literacy -

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-6)
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-ETS1-1) (HS-ETS1-3)
RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. (HS-ETS1-1) (HS-ETS1-3)
RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. (HS-ETS1-1) (HS-ETS1-3)
WHST.9-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)
WHST.9-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-ETS1-1) (HS-ETS1-3) (HS-ETS1-4) (HS-PS3-3)
MP.4	Model with mathematics. (HS-ETS1-1) (HS-ETS1-2) (HS-ETS1-3) (HS-ETS1-4) (HS-PS3-3)

HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-6) (HS-PS3-3)
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. (HS-PS2-6) (HS-PS3-3)
HSN.Q.A.2	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-6) (HS-PS3-3)

Three-Dimensional Teaching and Learning

Coherence with the Digital Communication unit-

Students continue their investigation of communication in the 21st Century with a look at how a society that continues to increase energy demands will power itself. Global population continues to rise, as does the technology and power demands of the current population. The previous unit looked specifically at communication and how it has evolved from an analog to digital signal. This unit takes a step back and looks more generally at how we are going to meet the needs of a much more energy-dependent and connected world.

Modeling Systems Using Computer Simulations-

Students will model simple electrical circuits using the PhET simulation. This allows for control and reading of various elements of an electrical circuit, including resistance, voltage, and current. In additional PhET simulations, students can use sliders to view a visual model of the relationships in Ohm's Law and how resistance is found in wires.

Students will be introduced to computer programming through the use of Arduinos. The files that are used to program an Arduino are called 'sketches'. Some ideas of sketches that can be used are:

§ Expand the use of 'if' statements

§ Introduce new control elements, such as while and for loops, to further develop logical capabilities

§ Blink a light according to morse code to send a message

§ Send a blinking signal through a series of LED lights

§ Blend colors using an RGB-led and hex colors

§ Create a function to be called in the setup or loop

Integration of Engineering-

The unit asks students to argue for alternating or direct current as a means of powering an increasingly energy-dependent world. Through research into the costs associated, the environmental and societal impacts, and the benefits and challenges of using a particular type, students will conclude which is optimal. This is after student-driven investigations into the nature of each type using computer simulations.

Prior Learning
Physical science- • Atoms have two distinct parts: the nucleus, which contains protons and neutrons, and the electron cloud, which contains electrons. • Electrons are negatively charged and are electrostatically attracted to protons, which are positively charged. • Different atoms have different numbers of protons and electrons. The arrangement of electrons dictates certain properties of that atom. • Energy can be converted to different forms (e.g., kinetic, chemical, thermal) and, in doing so, is conserved. ***Mathematics-*** • Mathematical expressions can be arranged to model certain physical phenomena. • Mathematical expressions can be rearranged to isolate a certain variable.

Part A: How is electricity like plumbing?	
Concepts	**Formative Assessment**

• Electrons travel to move electrical energy. Properties of the material that carries the current can have a drastic effect on the quality and safety of the circuit. • Voltage, resistance, and current are related by Ohm's Law: V = I * R. • Power is calculated using the Power Law: P = I * V. • Resistors can be arranged in series or parallel. Different arrangements of resistors will produce circuits with different properties. • Kirchoff's laws can be used to analyze multiple-resistor circuits. • Resistors are labeled according to a system of colored bands which display their resistance in ohms. • Multiple resistors can be combined to act as a single resistor. • Electrical energy can be utilized to do work by being converted into some other form (e.g., thermal, mechanical)	*Students who understand the concepts are able to:* • Evaluate different materials to determine if they would be ideal in electronic circuitry. Cost, material properties, commercial application, and commercial availability are factors to be analyzed. • Use computer models to design and build a circuit given certain constraints on resistance, voltage, current, power, or some combination of those. • Design and build a circuit that is powered by an Arduino sketch. Test the sketch using the circuit. Calculations should justify the need for certain resistors. Resistors should be identified by their color bands. • Use comments to annotate a sketch and optimize a sketch by using the most efficient code possible. Sketches should be double checked to ensure efficiency.

Part B: Are personal batteries the answer to our energy problems?	
Concepts	**Formative Assessment**

• Batteries can be used to store energy for later use. By collecting energy in sustainable ways and storing it in batteries, fossil fuel consumption could be reduced. • Continuous power generation is messy but allows for the extremely large capacity of demand globally. • Alternating current and direct current both have benefits and drawbacks alike. A hybrid system is the best solution for highly functioning and reliable large-scale energy infrastructure.	*Students who understand the concepts are able to:* • Evaluate the different types of electrical delivery and storage (alternating and direct current) to propose a long-term energy solution. • Use multiple lines of evidence to support an argument for or against a certain type of current. • Communicate scientific ideas in multiple formats (including orally, graphically, textually, and mathematically) comparing alternating current and direct current.

Modifications: *Teachers identify the modifications that they will use in the unit. The unneeded modifications can then be deleted from the list.(See NGSS Appendix D)*

- *Restructure lesson using UDL principles (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)*
- *Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.*
- *Provide students with multiple choices for how they can represent their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).*
- *Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).*
- *Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).*
- *Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.*
- *Use project-based science learning to connect science with observable phenomena.*
- *Structure the learning around explaining or solving a social or community-based issue.*
- *Provide ELL students with multiple literacy strategies.*
- *Collaborate with after-school programs or clubs to extend learning opportunities.*

Leveraging English Language Arts/Literacy and Mathematics

English Language Arts/Literacy-

- Assess the extent to which the reasoning and evidence in a text support the advantages of storing and moving electricity using alternating current or direct current.
- Cite specific textual evidence to support the advantages of using digital transmission and storage of information, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- Conduct short as well as more sustained research projects to describe energy conversions as energy flows into, out of, and within systems.
- Integrate and evaluate multiple sources of information presented in diverse formats and media to describe energy conversions as energy flows into, out of, and within systems.
- Evaluate scientific text regarding energy conversions to determine the validity of the claim that although energy cannot be destroyed, it can be converted into less useful forms.
- Compare different sources of information describing energy conversions to create a coherent understanding of energy flows into, out of, within, and between systems.

Mathematics-

- Define appropriate quantities for the purpose of descriptive modeling of how the quantitative change in energy of one component in a system can be calculated when the change in energy of the other component(s) and energy flows in and out of the system are known.
- Represent symbolically that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects), and manipulate the representing symbols. Make sense of quantities and relationships between the energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).
- Represent the conversion of one form of energy into another symbolically, considering criteria and constraints, and manipulate the representing symbols. Make sense of quantities and relationships in the conversion of one form of energy into another.
- Use a mathematical model of how energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects). Identify important quantities representing how the energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and

energy associated with the relative position of particles (objects), and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

- Use a mathematical model to describe the conversion of one form of energy into another and to predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the conversion of one form of energy into another and map their relationships using tools. Analyze those relationships mathematically to draw conclusions, reflecting on the results and improving the model if it has not served its purpose.

Samples of Open Education Resources for this unit: *These are student sense-making experiences that can be used after being modified to be three dimensional.*
PhET Circuit Construction Kit (DC only)is online simulation software to model DC circuits. PhET Circuit Construction Kit (AC and DC) is online simulation software to model AC and DC circuits. PhET Simulation – Ohm's Law is online simulation software to model the relationship described by Ohm's Law. PhET Simulation – Resistance in a Wire is online simulation software to model the relationship to calculate a wire's resistance. Arduino.cc is the Arduino website. There you can find free software and a host of information for all levels of user. Edison v. Westinghouse is an article on The Smithsonian that tells of the "Battle of Currents" between Thomas Edison and George Westinghouse/Nikola Tesla.

Appendix

Differentiation	
Enrichment	• Utilize collaborative media tools • Provide differentiated feedback • Opportunities for reflection • Encourage student voice and input • Model close reading • Distinguish long term and short term goals

<table>
<tr><td>Intervention & Modification</td><td>Utilize “skeleton notes” where some required information is already filled in for the student
Provide access to a variety of tools for responses
Provide opportunities to build familiarity and to practice with multiple media tools
Leveled text and activities that adapt as students build skills
Provide multiple means of action and expression
Consider learning styles and interests
Provide differentiated mentors
Graphic organizers</td></tr>
<tr><td>ELLs</td><td>Pre-teach new vocabulary and meaning of symbols
Embed glossaries or definitions
Provide translations
Connect new vocabulary to background knowledge
Provide flash cards
Incorporate as many learning senses as possible
Portray structure, relationships, and associations through concept webs
Graphic organizers</td></tr>
<tr><td colspan="2">21st Century Skills</td></tr>
<tr><td colspan="2">Creativity
Innovation
Critical Thinking
Problem Solving
Communication
Collaboration</td></tr>
</table>

Integrating Technology
• Chromebooks • Internet research • Online programs • Virtual collaboration and projects • Presentations using presentation hardware and software