STEM Unit 1: Digital Communication (45 Instructional Days)

Overarching Essential Questions	**Overarching Enduring Understandings**
· How can a continuous wave be turned into a discrete signal? · What does converting numbers between bases have to do with the exchange of information? · How is energy harnessed as a means of communication?	· Information can be transmitted as a continuous wave or a discrete pulse of energy, and can take on different forms as it is communicated. · Electrical signals can be used to communicate information by way of a combination of logical operations and written commands.

Student Learning Objectives

What students should be able to do after instruction.	*Evidence Statements*
Evaluate questions about the advantages of using a digital transmission and storage of information. [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]	**HS-PS4-2**

Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]	HS-PS4-5
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-PS4-5) • Communicate technical information or ideas (e.g. about phenomena and/or 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-PS4-5) **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) • Evaluate questions that challenge the premise(s) of an argument, the	**PS4.A: Wave Properties** · Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2) (HS-PS4-5) **PS4.C: Information Technologies and Instrumentation** · Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5) **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)	**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) **Cause and Effect** • Systems can be designed to cause a desired effect. (HS-PS4-5) **Stability and Change** • Systems can be designed for greater or lesser stability. (HS-PS4-2) --- **Connections to Engineering, Technology, and Applications of Science** **Interdependence of Science, Engineering, and Technology** • Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5) **Influence of Engineering, Technology, and Science on Society and the Natural World** • Modern civilization depends on major technological systems. (HS-PS4-5) (HS-PS4-2)

interpretation of a data set, or the suitability of a design. (HS-PS4-2) **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) **Using Mathematics and Computational Thinking** 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	· 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	• New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ETS1-1) (HS-ETS1-3) • Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HSPS4-2)

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.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2)
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-PS4-2)
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-PS4-3) (HS-ETS1-1) (HS-ETS1-3) (HS-PS4-2)
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.11-12.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. (HS-PS4-5)
Mathematics –	
MP.2	Reason abstractly and quantitatively. (HS-ETS1-1) (HS-ETS1-3) (HS-ETS1-4)
MP.4	Model with mathematics. (HS-ETS1-1) (HS-ETS1-2) (HS-ETS1-3) (HS-ETS1-4)

Three-Dimensional Teaching and Learning

Modeling Systems Using Computer Simulations-

Students will use spreadsheets like MS Excel and Google Sheets to model logic circuits and Boolean truth tables. Additionally, they will generate ASCII tables for use in decoding coded messages. Spreadsheets offer an opportunity for students to begin thinking like a programmer without the daunting task of actually programming. To be able to accomplish this while simultaneously learning a new skill will challenge the capacity of the students.

In addition to spreadsheet modeling, students will have an opportunity to generate and evaluate logic truth tables and circuits using an online logic circuit called logic.ly. Using this, students will be able to work back-and-forth between a circuit and a truth table. The concept of validation will be introduced using the simulator. Upon simplifying a given circuit, students should always evaluate its efficacy.

Students will be introduced to computer programming through the use of Arduinos. Some ideas of sketches that can be used include:

§ Complete basic arithmetic operations (+, -, *, /) and print to the serial monitor

§ Organize information upon printing to the serial monitor, such as printing a data table

§ Use the library math.h to perform upper-level mathematical operations

§ Evaluate the law of cosines for a missing side

§ Evaluate the quadratic equation using an 'if' statement, printing the necessary number of roots

§ Using an 'if' statement as a general control element in both the setup and the loop of the sketch

Integration of Engineering-

Students communicate technical information about technological devices that use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. The end of the unit will feature a project where students progress through the design and evaluation process to create a logic circuit that fits a certain real-world scenario. They should be asked to communicate the reasoning behind their design, as well as alternate designs that are inferior to the final design with reasons for not using those.

Prior Learning

Physical Science-

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.
- A sound wave needs a medium through which it is transmitted.
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.

Mathematics-

- A strong command of the base-10 number system, and at least a passing knowledge of binary and hexadecimal.
- Basic logic operations (e.g., and, or, not) can be combined to make complex logic expressions.
- Algebraic expressions can be rearranged according to a set of laws in order to solve for a needed variable.
- All numbers can be expressed according to different bases. A number can be converted between

· **Part A:** How do computers communicate with people, themselves, and each other?

Concepts	Formative Assessment

• Numbers can be represented using different number systems. • Energy comes in many different forms and travels through many different media. By creatively manipulating the waves of certain types of energy, data can be stored, processed, and communicated over long distances. • Digital processing, storing, and communicating of data has taken on many shapes and forms over the years (e.g., from core memory to flash memory, the internet). For the most part, growing capacity and speed needs have driven the changes.	*Students who understand the concepts are able to:* • Evaluate the use of different types of energy as a means of transmitting data. • Decode a message sent in 7- or 8-bit binary using number base conversions. This should be done by hand and include differentiation between 7- and 8- bit binary code. • Use models (e.g., mathematical, computer models) to display the value of numbers in different base systems and their equivalent ASCII or Unicode value. The model can be automated and show the equivalent decimal, binary and hexadecimal values of ASCII characters.

Part B: How are computers used to simulate physical phenomena?	
Concepts	**Formative Assessment**

• Mathematical expressions can be used to represent physical laws. These expressions can be manipulated and evaluated at certain conditions to solve for certain missing variables. • Computers use binary to communicate both internally and externally. Serial communication is repeated communication between devices and can be used to evaluate and model physical phenomena. • Programming microprocessors and, by extension, computers requires acute abilities in logic, structure, organization, and creativity. The	*Students who understand the concepts are able to:* • Use an Arduino to solve mathematical models for the proper variable. • Write a sketch for an Arduino to aid in the evaluation of algebraic and geometric expressions. Expressions should vary and include basic arithmetic and more advanced functions, using the math.h library. • 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 C: How do engineers use logic to create and manipulate data?	
Concepts	**Formative Assessment**
• Boolean algebra is a branch of algebra in which the values of the variables are the binary digits 1 and 0. By manipulating an electric current, engineers have utilized Boolean algebra to perform logical operations. • Logical circuitry can be used in control systems to solve complicated real-world problems. This can be done without the use of a computer or data-based system, rather with a simple set of switches.	*Students who understand the concepts are able to:* • Evaluate a truth table and design a model circuit for a given Boolean algebraic expression. The expression is typically limited to three input variables. Laws of Boolean algebra should be used to simplify the circuit as much as possible. • Analyze a real-world problem that can be solved by using a logic circuit and communicate the results of the analysis. Sum of products and/or product of sums analysis should be used, along with a. Numerous options should be presented and evaluated to determine which is the best.

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 using digital transmission and storage of information. • 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. ***Mathematics-*** • Choose and produce an equivalent form of an expression using Boolean simplification rules. • Use a mathematical model to describe the principles of data transmission using logic circuits and predict the effects of the design on systems and/or interactions between systems. Identify important quantities in the principles of data transmission using logic circuits, 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:
BinHexDec Converter is an online binary-decimal-hexadecimal converter to use to double check the math. Logic.ly is an online logic circuit simulator you can use to build, run and evaluate logic circuits The Logic Lab is another online logic circuit simulator. Arduino.cc is the Arduino website. There you can find free software and a host of information for all levels of user.

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
Intervention & Modification	• 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

ELLs	• 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

21st Century Skills

- Creativity
- Innovation
- Critical Thinking
- Problem Solving
- Communication
- Collaboration

Integrating Technology

- Chromebooks
- Internet research
- Online programs
- Virtual collaboration and projects
- Presentations using presentation hardware and software