Principles of Engineering (PoE)

Lesson 1.1

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A.CED.1 - Creating Equations

Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

F.LE.1.b - Linear, Quadratic, and Exponential Models

Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

Principles of Engineering (PoE)

Lesson 1.1

Next Generation Science Standards

DCI - PS3.A - Energy - Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Conserv ation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

Science and Engineering Practice - Analyzing and Interpreting Data

Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

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Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

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Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

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Principles of Engineering (PoE)

Lesson 1.1

Standards for Technological Literacy

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.2

Next Generation Science Standards

HS.PS3.3 - Energy

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

HS.PS3.4 - Energy

Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

HS.ESS3.1 - Earth and Human Activity

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS.ESS3.2 - Earth and Human Activity

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

DCI - PS3.A - Energy - Definitions of Energy

"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

DCI - PS3.A - Energy - Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2)

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DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy. (secondary to HS-PS4-5)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis. (secondary to HS-LS2-5)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

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)

DCI - ETS1.B - Engineering Design - 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)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.A - Earth and Human Activity - Natural Resources

Resource availability has guided the development of human society. (HS-ESS3-1)

DCI - ESS3.A - Earth and Human Activity - Natural Resources

All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosy stem degradation. (HS-ESS3-4)

DCI - ESS3.D - Earth and Human Activity - Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Science and Engineering Practice - Developing and Using Models

Design a test of a model to ascertain its reliability.

Science and Engineering Practice - Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Science and Engineering Practice - Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

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Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - 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.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

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Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Energy drives the cycling of matter within and between systems.

Crosscutting Concepts - 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.

Principles of Engineering (PoE)

Lesson 1.2

Standards for Technological Literacy

4.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.

4.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. Ethical considerations are important in the development, selection, and use of technologies.

4.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

5.9-12.G Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

5.9-12.H Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

5.9-12.I Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> I. With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.

5.9-12.J Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> J. The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

5.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. Humans devise technologies to reduce the negative consequences of other technologies.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.3

Next Generation Science Standards

HS.PS3.3 - Energy

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HS.ESS3.1 - Earth and Human Activity

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS.ESS3.2 - Earth and Human Activity

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

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DCI - ETS1.A - Engineering Design - 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. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

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.

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DCI - ETS1.B - Engineering Design - Developing Possible Solutions

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Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

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Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

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Principles of Engineering (PoE)

Lesson 1.3

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> K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

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> G. Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.

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> H. When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.

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> I. With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making.

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> J. The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.

5.9-12.K Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> K. Humans devise technologies to reduce the negative consequences of other technologies.

5.9-12.L Students will develop an understanding of the cultural, social, economic, and political effects of technology.

> L. Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

> J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

> K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

> L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

> M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

> N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 1.4

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Principles of Engineering (PoE)

Lesson 1.4

Next Generation Science Standards

HS.PS3.3 - Energy

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

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.1 - Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS.ETS1.2 - Engineering Design

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.ETS1.3 - Engineering Design

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.ETS1.4 - Engineering Design

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.

DCI - PS3.A - Energy - Definitions of Energy

“Electrical energy” may mean energy stored in a battery or energy transmitted by electric currents. (secondary to HS-PS2-5)

DCI - PS3.A - Energy - Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system’s total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HSPS3-1), (HS-PS3-2)

DCI - PS3.A - Energy - Definitions of Energy

At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HSPS3-2), (HS-PS3-3)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Conserv ation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between sy stems. (HS-PS3-1), (HS-PS3-4)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)

DCI - PS3.B - Energy - Conservation of Energy and Energy Transfer

The availability of energy limits what can occur in any system. (HS-PS3-1)

DCI - PS3.D - Energy - Energy in Chemical Processes and Everyday Life

Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4)

DCI - ETS1.A - Engineering Design - 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. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

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)

DCI - ETS1.B - Engineering Design - 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)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

DCI - ESS3.C - Earth and Human Activity - Human Impacts on Earth Systems

Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation. (HS-ESS3-4)

DCI - ESS3.D - Earth and Human Activity - Global Climate Change

Though the magnitudes of human impacts are greater than they have ever been, so too are human abilities to model, predict, and manage current and future impacts. (HS-ESS3-5)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Asking questions and defining problems

Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.

Science and Engineering Practice - Asking questions and defining problems

Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.

Science and Engineering Practice - Developing and Using Models

Design a test of a model to ascertain its reliability.

Science and Engineering Practice - Developing and Using Models

Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.

Science and Engineering Practice - Developing and Using Models

Develop a complex model that allows for manipulation and testing of a proposed process or system.

Science and Engineering Practice - Developing and Using Models

Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

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.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Changes in systems may have various causes that may not have equal effects.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

The total amount of energy and matter in closed systems is conserved.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

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.

Crosscutting Concepts - Energy and Matter: Flows, Cycles, and Conservation

Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Principles of Engineering (PoE)

Lesson 1.4

Standards for Technological Literacy

2.9-12.Z Students will develop an understanding of the core concepts of technology..

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

16.9-12.J Students will develop an understanding of and be able to select and use energy and power technologies.

J. Energy cannot be created nor destroyed; however, it can be converted from one form to another.

16.9-12.K Students will develop an understanding of and be able to select and use energy and power technologies.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

16.9-12.L Students will develop an understanding of and be able to select and use energy and power technologies.

L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.

16.9-12.M Students will develop an understanding of and be able to select and use energy and power technologies.

M. Energy resources can be renewable or nonrenewable.

16.9-12.N Students will develop an understanding of and be able to select and use energy and power technologies.

N. Power systems must have a source of energy, a process, and loads.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.1

Next Generation Science Standards

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - 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.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - 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.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.1

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

> Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.2

Common Core State Standards for English Language Arts

AS.R.1 - Reading

Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

AS.R.2 - Reading

Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.

AS.R.7 - Reading

Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.

AS.R.9 - Reading

Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.

AS.R.10 - Reading

Read and comprehend complex literary and informational texts independently and proficiently.

AS.W.2 - Writing

Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

AS.W.4 - Writing

Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.SL.4 - Speaking and Listening

Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

AS.SL.5 - Speaking and Listening

Make strategic use of digital media and visual displays of data to express information and enhance understanding of presentations.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Principles of Engineering (PoE)

Lesson 2.2

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

G.GMD.3 - Geometric Measurement and Dimension

Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.

G.GMD.4 - Geometric Measurement and Dimension

Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.

G.MG.1 - Modeling with Geometry

Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).

G.MG.2 - Modeling with Geometry

Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).

Principles of Engineering (PoE)

Lesson 2.2

Next Generation Science Standards

HS.PS1.1 - Matter and Its Interactions

Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

DCI - PS1.A - Matter and Its Interactions - Structure and Properties of Matter

The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1)

DCI - PS1.A - Matter and Its Interactions - 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-PS1-3), (secondary to HS-PS2-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

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Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - 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.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - 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.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.2

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.3

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

Principles of Engineering (PoE)

Lesson 2.3

Next Generation Science Standards

HS.PS1.3 - Matter and Its Interactions

Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

DCI - PS1.A - Matter and Its Interactions - 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-PS1-3), (secondary to HS-PS2-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Crosscutting Concepts - Patterns

Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Crosscutting Concepts - Patterns

Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments.

Crosscutting Concepts - Patterns

Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.

Crosscutting Concepts - Patterns

Mathematical representations are needed to identify some patterns.

Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

Crosscutting Concepts - Systems and System Models

Systems can be designed to do specific tasks.

Crosscutting Concepts - Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Crosscutting Concepts - 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.

Crosscutting Concepts - Systems and System Models

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Crosscutting Concepts - Structure and Function

The way an object is shaped or structured determines many of its properties and functions.

Crosscutting Concepts - 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.

Crosscutting Concepts - Structure and Function

The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.

Crosscutting Concepts - Stability and Change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Crosscutting Concepts - Stability and Change

Much of science deals with constructing explanations of how things change and how they remain stable.

Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.3

Standards for Technological Literacy

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 2.4

Common Core State Standards for Mathematics

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

Principles of Engineering (PoE)

Lesson 2.4

Next Generation Science Standards

HS.ESS3.4 - Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS.ETS1.2 - Engineering Design

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.ETS1.3 - Engineering Design

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.ETS1.4 - Engineering Design

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.

DCI - ETS1.A - Engineering Design - 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. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

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)

DCI - ETS1.B - Engineering Design - 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)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Asking questions and defining problems

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Science and Engineering Practice - Planning and Carrying Out Investigations

Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.

Science and Engineering Practice - Planning and Carrying Out Investigations

Select appropriate tools to collect, record, analyze, and evaluate data. Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

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.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

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Crosscutting Concepts - Patterns

Empirical evidence is needed to identify patterns.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

Systems can be designed to cause a desired effect.

Crosscutting Concepts - Scale, Proportion, and Quantity

The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.

Crosscutting Concepts - Scale, Proportion, and Quantity

Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Crosscutting Concepts - Scale, Proportion, and Quantity

Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Crosscutting Concepts - Scale, Proportion, and Quantity

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Crosscutting Concepts - Stability and Change

Feedback (negative or positive) can stabilize or destabilize a system.

Crosscutting Concepts - Stability and Change

Systems can be designed for greater or lesser stability.

Principles of Engineering (PoE)

Lesson 2.4

Standards for Technological Literacy

2.9-12.W Students will develop an understanding of the core concepts of technology.

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

2.9-12.X Students will develop an understanding of the core concepts of technology.

X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

2.9-12.Z Students will develop an understanding of the core concepts of technology..

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching andgenerating ideas, identifying criteria and specifying constraints, exploring possibilities,selecting an approach, developing a design proposal, making a model or prototype,

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.1

Next Generation Science Standards

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.)

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 3.1

Standards for Technological Literacy

2.9-12.FF Students will develop an understanding of the core concepts of technology.

> FF. Complex systems have many layers of controls and feedback loops to provide information.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.2

Next Generation Science Standards

HS.PS3.3 - Energy

> Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS.ETS1.3 - Engineering Design

> 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.

Science and Engineering Practice - Using Mathematics and Computational Thinking

> Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

> Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

> Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

> Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

> Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 3.2

Standards for Technological Literacy

2.9-12.FF Students will develop an understanding of the core concepts of technology.

> FF. Complex systems have many layers of controls and feedback loops to provide information.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

> L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

> P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

> P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 3.3

Common Core State Standards for Mathematics

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Principles of Engineering (PoE)

Lesson 3.3

Next Generation Science Standards

HS.PS3.3 - Energy

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

HS.ETS1.2 - Engineering Design

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.ETS1.3 - Engineering Design

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.ETS1.4 - Engineering Design

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.

DCI - ETS1.A - Engineering Design - 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. (secondary to HS-PS2-3)

DCI - ETS1.A - Engineering Design - Defining and Delimiting Engineering Problems

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)

DCI - ETS1.B - Engineering Design - 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)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Engaging in Argument from Evidence

Evaluate competing design solutions to a real-world problem based on scientific ideas and principles,empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, ethical considerations).

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 3.3

Standards for Technological Literacy

2.9-12.W Students will develop an understanding of the core concepts of technology.

W. Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.

2.9-12.X Students will develop an understanding of the core concepts of technology.

X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.

2.9-12.Y Students will develop an understanding of the core concepts of technology.

Y. The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.

2.9-12.Z Students will develop an understanding of the core concepts of technology..

Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.

2.9-12.AA Students will develop an understanding of the core concepts of technology.

AA. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.

2.9-12.FF Students will develop an understanding of the core concepts of technology.

FF. Complex systems have many layers of controls and feedback loops to provide information.

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

10.9-12.I Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

I. Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.

10.9-12.J Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

J. Technological problems must be researched before they can be solved.

10.9-12.K Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

K. Not all problems are technological, and not every problem can be solved using technology.

10.9-12.L Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

L. Many technological problems require a multidisciplinary approach.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 4.1

Common Core State Standards for Mathematics

S.ID.1 - Interpreting Categorical and Quantitative Data

Represent data with plots on the real number line (dot plots, histograms, and box plots).

S.ID.2 - Interpreting Categorical and Quantitative Data

Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

S.ID.3 - Interpreting Categorical and Quantitative Data

Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).

S.ID.4 - Interpreting Categorical and Quantitative Data

Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.

S.IC.1 - Making Inferences and Justifying Conclusions

Understand statistics as a process for making inferences about population parameters based on a random sample from that population.

S.IC.2 - Making Inferences and Justifying Conclusions

Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability 0.5. Would a result of 5 tails in a row cause you to question the model?

S.IC.4 - Making Inferences and Justifying Conclusions

Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

S.CP.1 - Conditional Probability and the Rules of Probability

Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events (“or,” “and,” “not”).

S.CP.2 - Conditional Probability and the Rules of Probability

Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.

S.CP.3 - Conditional Probability and the Rules of Probability

Understand the conditional probability of A given B as P(A and B)/P(B), and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.

S.CP.4 - Conditional Probability and the Rules of Probability

Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.

S.CP.5 - Conditional Probability and the Rules of Probability

Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.

S.CP.6 - Conditional Probability and the Rules of Probability

Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.

S.CP.7 - Conditional Probability and the Rules of Probability

Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.

S.CP.8 - Conditional Probability and the Rules of Probability

(+) Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B|A) = P(B)P(A|B), and interpret the answer in terms of the model.

S.CP.9 - Conditional Probability and the Rules of Probability

(+) Use permutations and combinations to compute probabilities of compound events and solve problems.

S.MD.7 - Using Probability to Make Decisions

(+) Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).

Principles of Engineering (PoE)

Lesson 4.1

Next Generation Science Standards

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.

Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Principles of Engineering (PoE)

Lesson 4.1

Standards for Technological Literacy

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.

Principles of Engineering (PoE)

Lesson 4.2

Common Core State Standards for English Language Arts

AS.W.5 - Writing

Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.

AS.W.6 - Writing

Use technology, including the Internet, to produce and publish writing and to interact and collaborate with others.

AS.W.7 - Writing

Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation.

AS.W.8 - Writing

Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.

AS.W.9 - Writing

Draw evidence from literary or informational texts to support analysis, reflection, and research.

AS.W.10 - Writing

Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.

AS.SL.2 - Speaking and Listening

Integrate and evaluate information presented in diverse media and formats, including visually, quantitatively, and orally.

AS.L.1 - Language

Demonstrate command of the conventions of standard English grammar and usage when writing or speaking.

AS.L.2 - Language

Demonstrate command of the conventions of standard English capitalization, punctuation, and spelling when writing.

AS.L.6 - Language

Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level; demonstrate independence in gathering vocabulary knowledge when considering a word or phrase important to comprehension or expression.

Principles of Engineering (PoE)

Lesson 4.2

Common Core State Standards for Mathematics

N.RN.2 - The Real Number System

Rewrite expressions involving radicals and rational exponents using the properties of exponents.

N.Q.1 - Quantities

Use units as a way to understand problems and to guide the solution of multistep problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

N.Q.2 - Quantities

Define appropriate quantities for the purpose of descriptive modeling.

N.Q.3 - Quantities

Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

N.VM.1 - Vector and Matrix Quantities

(+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).

N.VM.2 - Vector and Matrix Quantities

(+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point.

N.VM.3 - Vector and Matrix Quantities

(+) Solve problems involving velocity and other quantities that can be represented by vectors.

A.SSE.1 - Seeing Structure in Expressions

Interpret expressions that represent a quantity in terms of its context.

A.SSE.1.a - Seeing Structure in Expressions

Interpret parts of an expression, such as terms, factors, and coefficients.

A.SSE.1.b - Seeing Structure in Expressions

Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1+r)n as the product of P and a factor not depending on P.

A.CED.3 - Creating Equations

Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non- viable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.

A.CED.4 - Creating Equations

Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law V = IR to highlight resistance R.

A.REI.3 - Reasoning with Equations and Inequalities

Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

A.REI.4 - Reasoning with Equations and Inequalities

Solve quadratic equations in one variable.

F.TF.7 - Trigonometric Functions

(+) Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.

G.SRT.6 - Similarity, Right Triangles, and Trigonometry

Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

G.SRT.8 - Similarity, Right Triangles, and Trigonometry

Use trigonometric ratios and the Pythagorean theorem to solve right triangles in applied problems.

G.MG.3 - Modeling with Geometry

Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).

S.ID.2 - Interpreting Categorical and Quantitative Data

Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.

Principles of Engineering (PoE)

Lesson 4.2

Next Generation Science Standards

HS.PS2.1 - Motion and Stability: Forces and Interactions

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS.PS3.3 - Energy

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

DCI - ETS1.A - Engineering Design - 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. (secondary to HS-PS2-3)

DCI - ETS1.B - Engineering Design - 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)

DCI - ETS1.C - Engineering Design - Optimizing the Design Solution

Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

Science and Engineering Practice - Asking questions and defining problems

Ask questions

- o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
- o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- o to determine relationships, including quantitative relationships, between independent and dependent variables.
- o to clarify and refine a model, an explanation, or an engineering problem.

Science and Engineering Practice - Asking questions and defining problems

Evaluate a question to determine if it is testable and relevant.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Science and Engineering Practice - Using Mathematics and Computational Thinking

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m3, acre-feet, etc.).

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Science and Engineering Practice - Constructing Explanations and Designing Solutions

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.

Science and Engineering Practice - Engaging in Argument from Evidence

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Science and Engineering Practice - Obtaining, Evaluating, and Communicating Information

> Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible.
> Communicate scientific and/or 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 (i.e., orally, graphically, textually, mathematically).

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

> Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Crosscutting Concepts - Cause and Effect: Mechanism and Prediction

> Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Crosscutting Concepts - Scale, Proportion, and Quantity

> Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

Crosscutting Concepts - Systems and System Models

> Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Principles of Engineering (PoE)

Lesson 4.2

Standards for Technological Literacy

8.9-12.H Students will develop an understanding of the attributes of design.

H. The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.

8.9-12.I Students will develop an understanding of the attributes of design.

I. Design problems are seldom presented in a clearly defined form.

8.9-12.J Students will develop an understanding of the attributes of design.

J. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.

8.9-12.K Students will develop an understanding of the attributes of design.

K. Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

9.9-12.I Students will develop an understanding of engineering design.

I. Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.

9.9-12.J Students will develop an understanding of engineering design.

J. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.

9.9-12.K Students will develop an understanding of engineering design.

K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

9.9-12.L Students will develop an understanding of engineering design.

L. The process of engineering design takes into account a number of factors.

11.9-12.M Students will develop the abilities to apply the design process.

M. Identify the design problem to solve and decide whether or not to address it.

11.9-12.N Students will develop the abilities to apply the design process.

N. Identify criteria and constraints and determine how these will affect the design process.

11.9-12.O Students will develop the abilities to apply the design process.

O. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.

11.9-12.P Students will develop the abilities to apply the design process.

P. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.

11.9-12.Q Students will develop the abilities to apply the design process.

Q. Develop and produce a product or system using a design process.

11.9-12.R Students will develop the abilities to apply the design process.

R. Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

12.9-12.L Students will develop the abilities to use and maintain technological products and systems.

L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.

12.9-12.M Students will develop the abilities to use and maintain technological products and systems.

M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.

12.9-12.N Students will develop the abilities to use and maintain technological products and systems.

N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.

12.9-12.O Students will develop the abilities to use and maintain technological products and systems.

O. Operate systems so that they function in the way they were designed.

12.9-12.P Students will develop the abilities to use and maintain technological products and systems.

P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

17.9-12.P Students will develop an understanding of and be able to select and use information and communication technologies.

P. There are many ways to communicate information, such as graphic and electronic means.