Fairfield Public Schools
Science Curriculum

Draft Units

Physics 40

DRAFT July 2016

Course: Description

The study of natural phenomena and interactions between matter and energy using mathematical models and laws to explain and understand them and how they impact our everyday lives.

Standards for this course are taken from the *Next Generation Science Standards* and are of three types:

Disciplinary Core Ideas: Shown as content objectives, these standards define what students should know about the most essential ideas in the major science disciplines. The focus is on a limited number of core ideas in science and engineering both within and across the disciplines to avoid the shallow coverage of a large number of topics and to allow more time for teachers and students to explore each idea in greater depth. Reduction of the sheer sum of details to be mastered is intended to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented.

Science and Engineering Practices: These standards enable students to apply the content in the DCI's and the skills of practicing scientists and engineers to explain phenomena and solve real world problems. Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science.

Cross-cutting Concepts: These standards provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas. These broad concepts tie together the influence of engineering, technology, and science on society and the natural world.

http://www.nextgenscience.org/next-generation-science-standards

CROSS CUTTING CONCEPTS

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Physics 40: Overview

Enduring Understandings

Students will develop and use models, plan and conduct investigations, analyze and interpret data, use mathematical and computational thinking, and construct explanations of the physical world. Students will apply this knowledge and these skills to develop engineering practices including design and evaluation. Students will investigate how and why objects move, and why some objects are attracted to each other while others are not. Students will explain and predict interactions between objects and within systems of objects in the context of the conservation of total momentum of an isolated system.

Students will investigate the transfer and conservation of energy, and the relationship between energy and forces. Energy is understood as quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. The work done in any system is always equal to the total energy transferred into or out of the system. Students develop an understanding that energy at both the macroscopic and the atomic scale can be accounted for as either motions of particles or energy associated with the configuration (relative positions) of particles. In some cases, the energy associated with the configuration of particles can be thought of as stored in fields. Students also demonstrate their understanding of engineering principles when they design, build, and refine devices associated with the conversion of energy.

Wave Properties, Electromagnetic Radiation, and Information Technologies and Instrumentation are addressed. The use of wave properties and the interactions of electromagnetic radiation with matter to transfer information across long distances, store information, and investigate nature on many scales is covered. Models of electromagnetic radiation as either a wave of changing electric and magnetic fields or as particles are developed and used. Students understand that combining waves of different frequencies can make a wide variety of patterns and thereby encode and transmit information. Students also demonstrate their understanding of engineering ideas by presenting information about how technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

The crosscutting concepts of organizing patterns, cause and effect, systems and system models, energy and matter, structure and function, stability and change, and the influence of science, engineering, and technology on society and the natural world will be considered. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and carry out investigations, using computational thinking and designing solutions; and to use these practices to demonstrate understanding of the core ideas. Students will ask questions, engage in argument from evidence, analyze data and using math to support claims, applying scientific ideas to solve design problems, and communicate scientific and technical information.

Course Essential Questions

- **How and why do objects move and what is involved in changes in motion?**
- **What are the roles of energy in changes in matter and how is energy changed from one type to another?**
- **Why can electrical forces and fields cause changes in energy and matter?**
- **How and why is energy transferred through waves? How and why do changes in medium affect waves?**
- **How can knowledge in the field of physics be used with engineering practices to greatly enhance our the world and our lives?**

Course: Year-at-a Glance

Unit	Title	Unit Essential Questions
1	Forces & Interactions: Newton's Laws	• How does data support Newton's second law of motion to describe the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration? • How can we use mathematical representation of forces to describe and predict interactions between objects? • How can we use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system? • How can we minimize the force on a macroscopic object during a collision? • How can we quantify problem-solving requirements? • How can we break down problem-solving criteria into simpler ones, and make decisions about the priority of certain criteria?
2	Energy	• How can we use models to illustrate that energy can be accounted for as a combination of energy associated with the motion of particles and the energy associated with the relative position of particles? • How can we model the change in energy of one component of the system when the change in energy of the other component(s) and of the system are known? • How can energy be converted from one form to another? • How can we use two objects interacting through electric or magnetic fields to illustrate the changes in energy of the objects due to the interaction? • How can we quantify problem-solving requirements?
3	Forces & Interactions: Electricity & Magnetism	• How can we use two objects interacting through electric or magnetic fields to illustrate the forces between objects? • How does Coulomb's Law describe the mathematical relationship between charges? • How does an electric current produce a magnetic field? • How does a changing magnetic field produce an electric current?
4	Waves & Applications	• How are the frequency, wavelength, and speed of a wave related mathematically? • What are some of the advantages to digital storage and transmission? • Is electromagnetic radiation better described using a wave model or particle model? • How valid and reliable are the claims in published materials of the effect of different frequencies of electromagnetic radiation have when absorbed by matter? • How are the principles of wave behavior and interactions with matter used to transmit and capture information and energy?

UNIT 1 - Forces and Interactions: Newton's Laws

Overview

Classical mechanics describes the relationship between the motion of objects found in our world and the forces acting upon them. This unit involves Newton's three laws of motion and his law of gravity. Newton's three laws opened avenues of inquiry and discovery that are used routinely today in virtually all areas of mathematics, science, engineering, and technology. Newton's theory of universal gravitation had a similar impact, starting a revolution in celestial mechanics and astronomy that continues to this day. Newton's three laws of motion, together with his law of gravitation, are considered among the greatest achievements of the human mind.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- 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
- Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
- Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
- Use mathematical representations of Newton's Law of Gravitation to describe and predict the gravitational forces between objects.
- Students will be able to solve problems satisfying any requirements set by society, such as taking issues of risk mitigation into account, and quantifying them to the extent possible.
- Break down problem-solving criteria into simpler ones that can be approached systematically, and make decisions about the priority of certain criteria over others.

Unit Essential Questions

- How does data support Newton's second law of motion to describe the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration?
- How can we use mathematical representation of forces to describe and predict interactions between objects?
- How can we use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system?
- How can we minimize the force on a macroscopic object during a collision?
- How can we quantify problem-solving requirements?
- How can we break down problem-solving criteria into simpler ones, and make decisions about the priority of certain criteria?

Crosscutting Concepts
Patterns Cause and Effect Systems and System Models

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS2.A: Forces and Motion
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)

PS2.B: Types of Interactions
- Newton's law of universal gravitation ... provide(s) the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)
- Forces at a distance are explained by fields (gravitational...) permeating space that can transfer energy (HS-PS2-4)

SCIENCE AND ENGINEERING PRACTICES (SEP):

ETS1.A: Defining and Delimiting an Engineering Problem
- 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)

ETS1.C: Optimizing the Design Solution
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3)

Corresponding CT Core Standards:

Common Core State Standards Connections:
ELA/Literacy - RST.11-12.1, RST.11-12.7, WHST.11-12.2, WHST.11-12.7, WHST.11-12.8, WHST.11-12.9
Mathematics - MP.2; MP.4; HSN.Q.A.1; HSN.Q.A.2; HSN.Q.A.3; HSA.SSE.A.1; HSA.SSE.B.3; HSA.CED.A.1; HSA.CED.A.2; HSA.CED.A.4; HSF-IF.C.7; HSS-IS.A.1

UNIT 2 - Energy

Overview

Energy is present in the universe in a variety of forms, including mechanical, chemical, electromagnetic, and nuclear energy. Even the inert mass of everyday matter contains a very large amount of energy. Although energy can be transformed from one kind to another, all observations and experiments suggest that the total amount of energy in an isolated system remains the same. The focus of this unit is mainly on *mechanical energy*, which is the sum of *kinetic energy* (energy of motion) and *potential energy* (energy of position). This unit is linked to Newtonian Mechanics through the concept of *work*.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) (energy flowing in and out of the system) is known
- Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- Design, build, and refine a device that works within given constraints to convert one form of energy into another form of 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)
- Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.
- Students will be able to solve problems satisfying any requirements set by society, such as taking issues of risk mitigation into account, and quantifying them to the extent possible.

Unit Essential Questions

- How can we use models to illustrate that energy can be accounted for as a combination of energy associated with the motion of particles and the energy associated with the relative position of particles?
- How can we model the change in energy of one component of the system when the change in energy of the other component(s) and of the system are known?
- How can energy be converted from one form to another?
- How can we use two objects interacting through electric or magnetic fields to illustrate the changes in energy of the objects due to the interaction?
- How can we break down problem-solving criteria into simpler ones, and make decisions about the priority of certain criteria?

Crosscutting Concepts
Cause and Effect **Systems and System Models** **Energy and Matter**
Corresponding CT Core Standards: ***ELA/Literacy - RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5,*** ***Mathematics - MP.2, MP.4, HSN.Q.A.1, HSN.Q.A.2, HSN.Q.A.3***

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS3.A: 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.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

PS3.B: Conservation of Energy and Energy Transfer

- Conservation 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.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- 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.
- The availability of energy limits what can occur in any system.

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem

- 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)*

PS3.C: Relationship Between Energy and Forces

- When two objects interacting through a field change relative position, the energy stored in the field is changed.

SCIENCE AND ENGINEERING PRACTICES (SEP):

ETS1.A: Defining and Delimiting an Engineering Problem

- 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)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3)

Corresponding CT Core Standards:

ELA/Literacy - RST.11-12.1, RST.11-12.7, WHST.11-12.2, WHST.11-12.7, WHST.11-12.8, WHST.11-12.9,
Mathematics - MP.2, MP.4, HSN.Q.A.1, HSN.Q.A.2, HSN.Q.A.3, HSA.SSE.A.1, HSA.SSE.B.3, HSA.CED.A.1, HSA.CED.A.2, HSA.CED.A.4, HSF-IF.C.7, HSS-IS.A.1

UNIT 3 - Forces and Interactions: Electricity

Overview

Electricity is the lifeblood of technological civilization and modern society. With the discovery and harnessing of electric forces and fields,we can view arrangements of atoms, probe the inner workings of the cell, and send spacecraft beyond the limits of the solar system. In this unit, we use the effect of charging by friction to begin an investigation of electric forces. We then discuss Coulomb's law, which is the fundamental law of force between charged particles. The unit then continues on to discuss the connection between electric currents and magnetic fields (and vice versa).

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Use mathematical representations of Coulomb’s Law to describe and predict the electrostatic forces between objects.
- Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Unit Essential Questions

- How can we use two objects interacting through electric or magnetic fields to illustrate the forces between objects?
- How does Coulomb’s Law describe the mathematical relationship between charges?
- How does an electric current produce a magnetic field?
- How does a changing magnetic field produce an electric current?
- Use mathematical representations of Coulomb’s Law to describe and predict the electrostatic forces between objects.
- Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
- How can we break down problem-solving criteria into simpler ones, and make decisions about the priority of certain criteria?

Crosscutting Concepts
Patterns **Cause and Effect** **Systems and System Models**

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS2.B: Types of Interactions

- Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4)
- Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. (HS-PS2-4),(HS-PS2-5)

PS3.A: Definitions of Energy

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

SCIENCE AND ENGINEERING PRACTICES (SEP):

ETS1.A: Defining and Delimiting an Engineering Problem

- 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)

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3)

Corresponding CT Core Standards:

ELA/Literacy - RST.11-12.1, RST.11-12.7, WHST.11-12.2, WHST.11-12.7, WHST.11-12.8, WHST.11-12.9,
Mathematics - MP.2, MP.4, HSN.Q.A.1, HSN.Q.A.2, HSN.Q.A.3, HSA.SSE.A.1, HSA.SSE.B.3, HSA.CED.A.1, HSA.CED.A.2, HSA.CED.A.4, HSF-IF.C.7, HSS-IS.A.1

UNIT 4 - Waves and Electromagnetic Radiation

Overview

Periodic vibrations can cause disturbances that move through a medium in the form of waves. Many kinds of waves occur in nature, such as sound waves, water waves, and electromagnetic waves. These very different physics phenomena are described by common terms and concepts introduced here. In this unit, uses of waves in everyday life in technological tools and information storage and transfer will be analyzed.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
- Evaluate questions about the advantages of using a digital transmission and storage of information.
- Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.
- Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
- Describe how modern society depends on major technological systems, and use those systems to solve original problems.

Unit Essential Questions

- How are the frequency, wavelength, and speed of a wave related mathematically?
- What are some of the advantages to digital storage and transmission?
- Is electromagnetic radiation better described using a wave model or particle model?
- How valid and reliable are the claims in published materials of the effect of different frequencies of electromagnetic radiation have when absorbed by matter?
- How are the principles of wave behavior and interactions with matter used to transmit and capture information and energy?
- How does modern society depend on major technological systems?

Crosscutting Concepts
Cause and Effect **Systems and System Models** **Stability and Change**

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS3.D: Energy in Chemical Processes

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

PS4.A: Wave Properties

- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2),(HS-PS4-5)
- [From the 3–5 grade band endpoints] Waves can add or cancel one another as they cross, depending on their relative phase (i.e., relative position of peaks and troughs of the waves), but they emerge unaffected by each other. (Boundary: The discussion at this grade level is qualitative only; it can be based on the fact that two different sounds can pass a location in different directions without getting mixed up.) (HS-PS4-3)

PS4.B: Electromagnetic Radiation

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)

SCIENCE AND ENGINEERING PRACTICES (SEP):

Interdependence of Science, Engineering, and Technology

- Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)

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

- Modern civilization depends on major technological systems. (HS-PS4-2),(HS-PS4-5)
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS4-2)

Corresponding CT Core Standards:

ELA/Literacy - RST.9-10.8, RST.11-12.1, RST.11-12.7, RST.11-12.8, WHST.9-12.2, WHST.11-12.8,
Mathematics - MP.2, MP.4, HSA-SSE.A.1, HSA-SSE.B.3, HSA.CED.A.4