TRUMBULL PUBLIC SCHOOLS

Trumbull, Connecticut

CP Physics
Grade 12

2022

(Last revision date: 2012)

Curriculum Writing Team

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CP Physics

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CORE VALUES AND BELIEFS

The Trumbull High School community engages in an environment conducive to learning which believes that all students will **read** and **write effectively**, therefore communicating in an articulate and coherent manner. All students will participate in activities **that present problem-solving through critical thinking**. Students will use technology as a tool applying it to decision making. We believe that by fostering self-confidence, self-directed and student-centered activities, we will promote **independent thinkers and learners**. We believe **ethical conduct** to be paramount in sustaining the welcoming school climate that we presently enjoy.
Approved 8/26/2011

INTRODUCTION & PHILOSOPHY

In Grade 12 Physics, students will explore many of the systems and processes of the physical world by investigating the macroscopic interactions of matter through the topics of general physics. By focusing on the changes in matter and energy, scientifically literate students can use this deeper understanding to make predictions, analyze scientific data, and contribute to the greater scientific community. Students in this course will typically have completed CP Chemistry with a focus on the microscopic interactions of matter.

This curriculum has been modified most recently (2021) to remain consistent in the continued development of scientifically literate students, with a concentration on matter, energy, and changes. Authentic scientific and engineering experiences build on one another and increase in complexity throughout students' K-12 education. In 2015, the Connecticut State Board of Education adopted the Next-Generation Science Standards (NGSS), which embody the National Research Council's *Framework for K-12 Science Education* (2012). Both the *Framework* and the NGSS stress the importance of teaching classroom scientific inquiry as practiced by scientists and engineers. The *Framework* provides a vision for American science education in the 21st century, while the NGSS provides grade-level student performance expectations, disciplinary core ideas, and crosscutting concepts. The *Framework* and NGSS indicated a paradigm shift in science education, one in which teachers are to incorporate authentic learning experiences for students that reflect the nature of doing science and engineering.

The *Framework* and NGSS provide clarity to classroom scientific inquiry by stressing the importance of eight practices of science and engineering. The practices were designed to help students understand how scientific knowledge develops, and to stimulate students' interest in and continued study of science. Three-dimensional learning facilitates student engagement with Science and Engineering Practices and Crosscutting Concepts to deepen their understanding of Disciplinary Core Ideas in order to explain phenomena and solve problems. Three-dimensional learning promotes development of student skills in the following areas:

- Knowing, using, and interpreting scientific explanations of the natural world (Disciplinary Core Ideas, and Crosscutting Concepts)
- Generating and evaluating scientific evidence and explanations (Science and Engineering Practices)
- Participating productively in scientific practices and discourse (Science and Engineering Practices)

- Understanding the nature and development of scientific knowledge (Science and Engineering Practices, and Crosscutting Concepts)

The shift of science education reflects the interconnected nature of science as it is practiced in the real world and builds coherently across grades K-12. The NGSS focus on deeper understanding of content as well as application of content with an alignment to the Connecticut Core Standards. A deeper understanding and application of science and engineering practices prepare students for postsecondary success and citizenship in a world fueled by innovations in science and technology. In accordance with the NGSS Science and Engineering Practices, students will be asked to . . .

- ask questions (for science) and define problems (for engineering).
- develop and use models.
- plan and carry out investigations.
- analyze and interpret data.
- use mathematics and computational thinking.
- construct explanations (for science) and design solutions (for engineering).
- engage in arguments from evidence.
- obtain, evaluate, and communicate information.

Grade 12 Physics is offered at two separate course levels: College Preparatory (CP) and Advanced College Preparatory (ACP). Both levels will explore each unit of study. The courses are differentiated by pacing of curriculum, rigor of exploration, depth of content knowledge, and the application of quantitative reasoning. The ACP course will explore topics with the greatest depth, most rigorous exploration, deepest study of content, and furthest application of quantitative reasoning. More support will be offered at the CP course level. In addition, study of physics principles is offered through an early college experience collaborative (UCONN Physics) and two Advanced Placement courses: Physics C (AP-C) and Physics 1 (AP-1). These advanced courses follow a different curriculum, and demand a much higher rigor of exploration, depth of content knowledge, and the application of quantitative reasoning.

COURSE GOALS

The following course goals derive from the 2021 Next Generation Science Standards.

HS-PS2-1. 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-PS2-2. 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.

HS-PS2-3. Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

HS-PS2-5. 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.

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-PS3-1 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) and energy flows in and out of the system are known.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

HS-PS3-3. 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.	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-PS3-5.	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.
HS-PS4-1.	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-5.	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.

The following course goals derive from the 2010 Connecticut Common Core State Standards for English Language Arts and Literacy in History/Social Studies, Science and Technical Subjects

CCSS.ELA-LITERACY.RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
CCSS.ELA-LITERACY.RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
CCSS.ELA-LITERACY.RST.11-12.3	Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
CCSS.ELA-LITERACY.RST.11-12.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

CCSS.ELA-LITERACY.RST.11-12.5	Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.
CCSS.ELA-LITERACY.RST.11-12.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.
CCSS.ELA-LITERACY.RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.
CCSS.ELA-LITERACY.RST.11-12.8	Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
CCSS.ELA-LITERACY.RST.11-12.9	Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible
CCSS.ELA-LITERACY.RST.11-12.10	By the end of grade 12, read and comprehend science/technical texts in the grades 11-CCR text complexity band independently and proficiently.

The following course goals derive from the 2010 Connecticut Core Standards for Literacy.

CCSS.ELA-LITERACY.RI.11-12.1	Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.
CCSS.ELA-LITERACY.RI.11-12.2	Determine two or more central ideas of a text and analyze their development over the course of the text, including how they interact and build on one

	another to provide a complex analysis; provide an objective summary of the text.
CCSS.ELA-LITERACY.RI.11-12.5	Analyze and evaluate the effectiveness of the structure an author uses in his or her exposition or argument, including whether the structure makes points clear, convincing, and engaging.
CCSS.ELA-LITERACY.RI.11-12.6	Determine an author's point of view or purpose in a text in which the rhetoric is particularly effective, analyzing how style and content contribute to the power, persuasiveness or beauty of the text.
CCSS.ELA-LITERACY.W.11-12.1.B	Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant evidence for each while pointing out the strengths and limitations of both in a manner that anticipates the audience's knowledge level, concerns, values, and possible biases.
CCSS.ELA-LITERACY.W.11-12.1.D	Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
CCSS.ELA-LITERACY.W.11-12.2.B	Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
CCSS.ELA-LITERACY.W.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
CCSS.ELA-LITERACY.W.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.
CCSS.ELA-LITERACY.W.11-12.10	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.
CCSS.ELA-LITERACY.SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data
CCSS.ELA-LITERACY.SL.11-12.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.
CCSS.ELA-LITERACY.L.11-12.3	Apply knowledge of language to understand how language functions in different contexts, to make effective choices for meaning or style, and to comprehend more fully when reading or listening.
CCSS.ELA-LITERACY.L.11-12.6	Acquire and use accurately 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

The following course goals derive from the 2016 International Society for Technology in Education (ISTE) Technology Standards

ISTE Standard 1 - Empowered Learner	Students leverage technology to take an active role in choosing, achieving, and demonstrating competency in their learning goals, informed by the learning sciences.
ISTE Standard 2 - Digital Citizen	Students recognize the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, and they act and model in ways that are safe, legal and ethical.
ISTE Standard 3 - Knowledge Constructor	Students critically curate a variety of resources using digital tools to construct knowledge, produce

	creative artifacts and make meaningful learning experiences for themselves and others.
ISTE Standard 4 - Innovative Designer	Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.
ISTE Standard 5 - Computational Thinker	Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.
ISTE Standard 6 - Creative Communicator	Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.
ISTE Standard 7 - Global Collaborator	Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.

COURSE ENDURING UNDERSTANDINGS

Students will understand that…

- scientific knowledge is acquired through inquiry, experimentation, data analysis, and interpretation.
- scientific conclusions and explanations are based on research data, and scientific results may be assessed based on the design of the investigation.
- scientific ideas and concepts evolve over time.
- the credibility of scientific information found in various media can vary.
- mathematical operations and procedures may be used to calculate, analyze, and present data and ideas.
- science and technology affect the quality of our lives.

Also, in accordance with the NGSS Cross-Cutting Concepts, students will work to understand . . .

- how observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them.
- events have causes, sometimes simple, sometimes multifaceted and that 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.
- that 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.
- that the tracking of fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
- structure and function, in such that the way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
- that 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.

COURSE ESSENTIAL QUESTIONS

- How are graphical and mathematical models created from experimental data?
- How are fields used to model physics phenomena?
- How can rules and relationships be used to predict what happens in a physical situation?
- How can physics be applied to understanding everyday life?
- How can abstract mathematics be used to describe phenomena?
- How can abstract mathematics be used to represent relationships between variables?
- To what extent does physics explain phenomena at the wide variety of scales?
- How can physics be used to solve problems?
- How does physics explain change and constancy in the universe?
- What is the value in separating the universe into systems when trying to explain it?
- Why are system boundaries important to define?
- Why are assumptions and approximations important in physics? To what extent does this limit the usefulness of your results?
- To what extent does physics explain cause and effect?
- How can scientific ideas be used to solve problems?
- How are matter and energy related?
- How is the universe constructed from the tiny scales to the largest?
- How can physics be used to create models and simulations?
- Why is correlation and causation not the same thing?
- How are physics and engineering related?
- How can scientific knowledge be communicated?
- How can scientific arguments be evaluated?
- How should scientific investigations be designed?
- How can one explain and predict interactions of objects and systems of objects?
- How can one predict an object's continued motion, change in motion, or stability?
- What underlying forces explain the variety of interactions observed?
- Why are some physical systems more stable than others?
- How is energy transferred and conserved?
- What is meant by conservation of energy?
- How is energy transferred between objects or systems?
- How are forces related to energy?
- How do food and fuel provide energy?
- If energy is conserved, why do people say it is produced or used?
- How are waves used to transfer energy and information?
- What are the characteristic properties and behaviors of waves?
- What is light?
- How can one explain the varied effects that involve light?
- What other forms of electromagnetic radiation are there?
- How are instruments that transmit and detect waves used to expand human senses?

COURSE KNOWLEDGE & SKILLS

The following core knowledge and skills will be developed through students' work in this course:

Students will know . . .

- the appropriate techniques and procedures to use in a laboratory setting.
- the difference between scalar and vector quantities.
- the difference between distance and displacement.
- the difference between speed and velocity.
- the definition of the term acceleration.
- Newton's Laws of Motion.
- the various types of forces.
- the definitions of momentum and momentum conservation.
- the definition of impulse and its relationship to momentum change.
- the relationship between momentum conservation and Newton's laws of motion.
- the differences between various types of energy (kinetic, gravitational potential, elastic potential, thermal).
- the relationship between work and the change in energy of a system.
- that power is calculated as the rate at which work is done (rate of energy conversion).
- that charging of an object is the separation, not the creation, of electrical charges.
- that electrically charged objects exert forces, both attractive and repulsive.
- the ways objects become charged.
- the definition of electrical force as it relates to the charges on objects and the distance between them.
- the definitions of electric current, potential difference, resistance, and power, and their relationships to each other.
- the properties of magnets and the origin of magnetism in materials.
- the relationship between magnetic induction and the direction of force on a current-carrying wire in a magnetic field.
- the design and operation of an electric motor.
- how changing magnetic fields can generate electric current and potential difference.
- the differences among temperature, heat and thermal energy.
- how the transfer of thermal energy can change the state (phase) of a substance.
- how increasing the temperature of an object will make it expand.
- Archimedes' and Pascal's Principles.
- how wave phenomena are described, using the following terms: amplitude, wave pulse, periodic wave, wavelength, frequency, period, and wave speed.
- the differences between transverse and longitudinal waves, and provide examples of each.
- what happens when two or more waves attempt to occupy the same location in a medium.
- the definition of wave resonance and its relation to an object's natural frequency.
- how light travels.
- that light is part of the electromagnetic spectrum.

- that when light strikes an object, it is absorbed, reflected from or transmitted through the substance, and what happens when these occur.
- the dual nature of light.

Students will be able to . . .

- abide by the safety rules and regulations set forth by the safety contract.
- use appropriate tools and techniques to make observations and gather data.
- articulate conclusions and explanations based on research data, and assess results based on the design of the investigation.
- describe the motion of an object with constant velocity vs. constant acceleration.
- use the kinematic equations to complete one-dimensional motion problems.
- create and interpret position vs. time graphs.
- create and interpret velocity vs. time graphs.
- describe the motion of a freely-falling object.
- use the kinematic equations to complete free fall motion problems.
- describe the motion of a projectile.
- use the kinematic equations to complete two-dimensional motion problems.
- describe how friction affects the motion of two objects that are in contact with each other.
- draw free body diagrams of objects with arrows identifying the forces acting on the object.
- use a free body diagram and vector addition to determine the net force acting on an object.
- use Newton's Second Law to predict the acceleration of an object given its mass and the net force acting upon it.
- solve problems relating an object's mass, forces acting on it and its motion.
- calculate the gravitational force acting between two objects based upon their masses and separation distance.
- solve collision and explosion problems using the conservation of momentum.
- quantify the amount of each type of energy a system possesses.
- quantify the amount of work done by a force.
- use the work-energy theorem to solve problems.
- use conservation of energy to solve problems.
- solve electrostatics problems using the conservation of charge.
- describe the requirements for electric current flow in circuits.
- diagram simple electric circuits.
- solve problems involving current, potential difference, resistance, power, and the use and cost of electric energy.
- compare various magnetic fields.
- solve problems involving magnetic field strength and forces on current-carrying wires, and on moving, charged particles in magnetic fields.
- solve problems involving magnetic field strength and forces and induced EMF in moving wires.
- apply the phenomenon of induced EMF to the construction of generators and transformers.

- solve problems relating the specific heats of substances to their temperature and state changes.
- solve thermal expansion problems.
- solve buoyancy and hydraulic problems.
- calculate the intensity (in W/m2 and decibels) of a sound wave.
- explain and draw how standing waves can form on a string.
- explain and draw how standing waves can form in a closed pipe.

COURSE SYLLABUS

Course Name

CP Physics

Level

College Prep

Prerequisites

CP Prerequisite: Successful completion of CP Chemistry or ACP Chemistry

General Description of the Course

This course stresses a practical study of mechanics, heat, sound, electricity, magnetism, light, atomic physics and astrophysics, and their technological application. The CP level is similar to ACP Physics except that there is less of a need for mathematical skills. It is designed to acquaint the student with physics, as it is applicable in everyday life. Recommended for students planning to attend college, but who are not planning to major in science. Although less rigorous than the ACP Physics course, the CP level includes a quantitative study of physics concepts, demonstrates the mathematical relationships in these concepts and applies these relationships to problem solving situations.

Assured Assessments

Formative assessments can include, but are not limited to:

- Individual and group lists of safety lessons learned (Unit 1)
- Construction of models (Unit 2)
- Lab activities (Units 2, 3, 4, 5, 6, 7, 8, 9, 10)
- Data collection and analysis (Units 2, 3, 4, 5, 6, 7, 8, 9, 10)

Summative Assessments:

- End-of-unit assessment with multiple-choice questions (Unit 1)
- End-of-unit assessment with multiple-choice questions, free-response questions, and interpreting and analyzing data (Units 2, 3, 4, 5, 6, 7, 8, 9, 10)
- Midyear examination
- End-of-year examination

UNIT 1
Mathematical Tools

Unit Goals

At the completion of this unit, students will:

- know how to conduct experiments safely with a variety of physics-related equipment and technologies in accordance with the Connecticut State Department of Education (SDE) guidance document which can be found at the following link: https://portal.ct.gov/SDE/Publications/Connecticut-High-School-Science-Safety/Physics-Laboratory-Safety-Specifications

- collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making (ISTE Technology Standards – Computational Thinking – Standard 5b)

Unit Essential Questions

- How do scientists experiment safely?
- How are tools selected and utilized to gather valid data in science?

Unit Scope and Sequence

- Scientists develop models based on observation and data to explain natural phenomena and predict the results of actions.
- Data is collected through observation and measurement, using human senses or measuring devices.
- Measuring devices are calibrated to agree with each other or agree with an accepted value.
- The accuracy of a measurement or calculation refers to its agreement with other measurements or calculations, or to an accepted value for that quantity.
- The precision of a measurement refers to the "exactness" of the quantity, and is determined by the measuring device used.
- Data trends are best conveyed and communicated through the creation of a graph.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of scientific measurement.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments: Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to mathematical scientific tools.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
- Flinn Scientific's Student Safety Contract

Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 1-2 Weeks

UNIT 2
Kinematics

Unit Goals

At the completion of this unit, students will:

NGSS Crosscutting Concepts
Patterns: recognize that 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. Example: As gravity affects a ball's motion both on its way up as well as on its way back down, students discover that a ball's downward motion is just a 'mirror image' of its upward motion. This symmetry becomes clear in the ball's dot diagram, the position vs. time graph, and in the velocity vs. time graph. Such patterns are not only helpful in solving kinematics problems, they speak to gravity's constant effect on any object in free fall.

NGSS Practices
Analyzing and Interpreting Data: analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. Example: With pictorial and graphical data representations of a ball's motion, students are asked to analyze data and make meaning of the patterns that emerge from the data sets. Students also use information from one graph in combination with data from another to determine an unknown quantity or relationship.

Developing and Using Models: Develop and/or use a model to generate data to support explanations, analyze systems, or solve problems. Example: A ball's motion is represented using graphical and pictorial models. Students are required to use one or more of these models to analyze the ball's motion, to give explanations, and to solve problems

ISTE Technology Standards

ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How is motion quantified?
- How is motion predictable?

Unit Scope and Sequence

- Scalar quantities can be described completely with magnitude alone; vector quantities are described
- completely with magnitude and direction.
- Position is a vector quantity that describes where an object is at some moment in time.
- Displacement is a vector quantity that describes how far and in what direction an object has moved; distance is a scalar quantity that describes how far an object traveled in total to get from its starting to ending location.
- Velocity is a vector quantity that describes the direction and rate at which an object changes position, usually measured in "meters per second" (m/s). Speed is a scalar quantity that is either (1) the rate at which distance traveled changes, or (2) the magnitude of the velocity.
- Instantaneous velocity refers to the velocity at one particular moment in time, regardless of previous or future moments. Average velocity refers to the average rate of change in position over a given time interval.
- Acceleration is a vector quantity that describes the direction and rate at which an object's velocity changes, usually measured in "(meters per second) per second" (or m/s^2). Instantaneous acceleration refers to the acceleration at one particular moment in time, regardless of previous or future moments; average acceleration refers to the average rate of change in velocity over a given time interval.
- A ticker tape diagram (or oil drop diagram) can be used to visually represent the motion of an object. Concepts such as displacement, velocity, and acceleration can be inferred from these diagrams.
- A position vs. time graph displays the location of an object as a function of time. The slope of this graph represents the average velocity of the object.
- A velocity vs. time graph displays the velocity of an object as a function of time. The slope of this graph represents the average acceleration of the object. The area bounded by this graph and the time axis represents the displacement of the object.
- An object is said to be in free fall any time the force of gravity is the only force acting on the object. This includes objects dropped, objects through up or down, and projectiles (always assuming air resistance is negligible). While in free fall near the surface of the Earth, all objects experience a constant downward acceleration of approximately 9.8 m/s^2.
- The kinematic equations are a set of four mathematical equations that can be used to describe the one-dimensional motion of any object experiencing constant acceleration. The equations relate the object's acceleration, initial velocity, velocity at some time t, displacement at some time t, and time.
- Vector quantities can be added visually using either the tail-to-tip method or the parallelogram method. These methods are especially useful when the vectors are not collinear.
- An object's measured velocity and displacement are dependent on both the object's motion and the relative motion of the object and observer. The observed acceleration of the object, however, is independent of the observer's motion (as long as the observer is not accelerating).

- The two-dimensional motion of an object can be described as two independent one-dimensional motions. Commonly these two dimensions are either (1) horizontal and vertical, or (2) north-south and east-west.
- A projectile in two-dimensional motion near the surface of the Earth experiences constant velocity in the horizontal direction and a constant acceleration of 9.8 m/s^2 downward in the vertical direction.
- The kinematic equations can be used to describe two-dimensional motion by treating the motion in each dimension separately.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of constant speed, constant velocity and uniformly accelerated motion, including the acceleration of free-fall. Experimental work with projectile motion will also occur. Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to the kinematics of moving objects in one and two dimensions.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 3-5 weeks

UNIT 3
Forces

Unit Goals

At the completion of this unit, students will:

HS-PS2-1.	**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-PS2-4.	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS2-6.	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How do Newton's Motion Laws predict the effect of forces on an object's motion?

Unit Scope and Sequence

- Forces are defined as pushes or pulls on an object.
- Forces are classified as contact versus field forces. These are further categorized as gravitational, electromagnetic, strong nuclear and weak nuclear.
- Forces are expressed as vectors having magnitude and direction.
- Friction force acts between objects that contact each other. Friction acts parallel to the contacting surface in a direction that opposes the objects' sliding relative to each other.

- Normal force between objects that contact each other. Normal force acts perpendicular to the contacting surface.
- Friction force is directly proportional to normal force.
- The proportionality constant between friction and normal force is the friction coefficient, which is a property of any two contacting surfaces.
- Static (objects not sliding past each other) friction coefficients are generally greater than kinetic (objects sliding past each other) friction coefficients.
- Forces acting on an object combine to exert a net force.
- Net force is quantified through the use of a free body diagram of an isolated object with arrows indicating the forces exerted on the object.
- A net force is necessary to change the motion state of an object. (Newton's First Law of Motion)
- All objects have mass, the measurement of the object's inertia, its tendency to maintain its motion state.
- Acceleration, the change of an object's motion, is directly proportional to the net force acting on an object and inversely proportional to the mass of an object. (Newton's Second Law of Motion)
- Forces act in pairs between two objects. The paired forces are equal in magnitude and opposite in direction. (Newton's Third Law of Motion)
- A centripetal force acts perpendicular to an object's velocity and causes a circular motion.
- A gravitational force is shared between two objects that exerts in an attractive direction.
- The gravitational force is proportional to the product of the objects' masses and inversely proportional to the square of the distance separating the objects. (Newton's Universal Gravitation Law)

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of force (including weight, tension, friction and normal force) and Newton's Laws, including linear and centripetal accelerations. Experimental work on vector force addition will also occur.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to force and Newton's Laws of mechanics.

Resources

<u>Core</u>
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental

Online resources

- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 3-4 weeks

UNIT 4
Momentum

Unit Goals

At the completion of this unit, students will:

HS-PS2-2.	**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.**
HS-PS2-3.	Apply science and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

ISTE Technology Standards ISTE Empowered Learner (Standard 1c)	technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- What is momentum?
- How does momentum conservation determine the motion of objects interacting with each other?

Unit Scope and Sequence

- Impulse is defined as a force exerted on an objects over a period of time
- Impulse causes a change in an object's momentum. An object's momentum change is equal in magnitude and direction to the impulse exerted on it.
- The impulse/momentum change equation is the original expression of Newton's Second Law.
- Momentum is always conserved. This means that the total momentum of an isolated system of objects remains constant.
- Momentum conservation results from Newton's Third Law of Motion.
- Momentum conservation is applied to collision and explosion problems to determine objects' motion before or after a collision or explosion.
- Rotational momentum involves the mass distribution of a rotating object. This causes a rotating object to speed up as mass is moved towards its center.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of impulse and conservation of momentum.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to momentum, its transfer and its conservation.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

UNIT 5
Energy

Unit Goals

At the completion of this unit, students will:

HS-PS3-1	**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) and energy flows in and out of the system are known.**
HS-PS3-2.	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).
HS-PS3-3.	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How will the increasing demand for energy be met in the future?

Unit Scope and Sequence

- Energy is an abstract, scalar quantity possessed by an object (or system of objects) that comes in a variety of forms. The SI unit for energy is the joule (J), named after James Prescott Joule, and is equivalent to N•m or $kg•m^2/s^2$. Energy is also commonly measured in calories
- Energy can be converted from one form to another through the process of work, but it can neither be created nor destroyed. The total amount of energy in the universe is constant.
- Kinetic energy is energy associated with the translational motion of an object/system. A faster moving object has more kinetic energy than an identical slower moving object. A massive object has more kinetic energy than a less massive object moving at the same speed.

- Gravitational potential or interaction energy is energy associated with the interaction (attraction) between objects with mass. The farther apart two masses are the more gravitational potential/interaction energy there is.
- Elastic potential/interaction energy is energy associated with the stretching or compressing of a spring (or other elastic substance). The more stretched/compressed a spring, the more elastic potential energy it has stored. A stiffer spring will possess more elastic potential energy than a looser spring for the same amount of stretching or compression.
- The Law of Conservation of Energy states that energy can neither be created nor destroyed, but it can be converted between the different energy types.
- Power is the rate at which work is done (or the rate at which energy is converted from one form to another).

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of work, power and conservation of energy.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to energy, its transfer and its conservation.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

UNIT 6
Electrostatics

Unit Goals

At the completion of this unit, students will:

HS-PS2-4.	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS2-6.	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3-5.	**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.**

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How does electrical charge interact with matter?
- What rules govern how charge pushes and pulls on the world?

Unit Scope and Sequence

- There are two kinds of electrical charge, positive and negative
- Electrical charge is not created or destroyed; it is conserved.
- Objects can be charged by the transfer of electrons.
- Charges added to one part of an insulator remain on that part.
- Charges added to a conductor quickly spread over the surface of the object.
- Charged objects exert forces on other charged objects. Like charges repel; unlike charges attract
- An object can be charged by conduction by touching a charged object to it

- To charge an object by induction, a charged object is first brought nearby, causing a separation of charges. Then the object to be charged is separated, trapping opposite charges on the two halves.
- Coulomb's law states that force between two charged objects varies directly with the product of their charges and inversely with the square of the distance between them.
- A charged object of either sign can produce separation of charge in a neutral body. Thus a charged object attracts a neutral one.
- An electric field exists around any charged object. The field produces forces on other charged objects.
- Electric potential difference is the change in potential energy per unit charge in an electric field, and is measured in volts.
- A charged object can have its excess charge removed by touching it to Earth or to an object touching Earth. This is called grounding.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of electrostatics.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to electrostatic interactions.

Resources
Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

UNIT 7
Electric Current

Unit Goals

At the completion of this unit, students will:

HS-PS2-6.	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3-1	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) and energy flows in and out of the system are known.
HS-PS3-3.	**Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.**

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How is energy transferred in electric circuits?

Unit Scope and Sequence

- Batteries, generators, and solar cells convert various forms of energy to electric energy
- In an electric circuit, electric energy is transmitted from a device that produces electric energy to a resistor or other device that converts electrical energy to the form needed.
- As a charge moves through resistors in a circuit, its potential energy is reduced. The energy released when the charge moves around the remainder of the circuit equals the work done to give the charge its initial potential energy.
- The SI unit for electric current is the ampere (A). One ampere is one coulomb per second.

- Ohm's law states that the resistance (R) of a device is the ratio of the voltage (V) across it divided by the current (I) through it, or R = V/I.
- In a device that obeys Ohm's law, the resistance remains constant as the voltage and current change.
- The current in a circuit can be varied by changing either the voltage or the resistance, or both.
- In a circuit diagram, conventional current is used. This is the direction in which a positive charge would move.
- In long-distance transmission, current is reduced without power being reduced by increasing voltage.
- Current is the same everywhere in a series circuit.
- The equivalent resistance of a series circuit is the sum of the resistances of its parts.
- The sum of the voltage drops across resistors in series is equal to the potential difference applied across the combination.
- The voltage drops across all branches of a parallel circuit are the same.
- In a parallel circuit, the total current is equal to the sum of the currents in the branches.
- The reciprocal of the equivalent resistance of parallel resistors is equal to the sum of the reciprocals of the individual resistances.
- If any branch of a parallel circuit is opened, there is no current in that branch. The current in the other branches is unchanged.
- A fuse or circuit breaker, placed in series with appliances, creates an open circuit when dangerously high currents flow.
- An ammeter is used to measure current in a branch or part of a circuit. An ammeter always has a low resistance and is connected in series.
- A voltmeter is used to measure a potential difference (voltage) across any part or combination of parts of a circuit. A voltmeter always has high resistance and is connected in parallel with the part of the circuit being measured.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of electrical circuitry, including Ohm's Law and series and parallel circuits.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to electrical current and its control.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 3-4 weeks

UNIT 8
Magnetism

Unit Goals

At the completion of this unit, students will:

HS-PS2-5.	**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.**
HS-PS2-6.	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
HS-PS3-1	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) and energy flows in and out of the system are known.
HS-PS3-3.	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-PS3-5.	**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.**

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How are magnetism, electric charge and electricity related?
- How is electromagnetism harnessed to produce mechanical work?

Unit Scope and Sequence

- Like magnetic poles repel; unlike magnetic poles attract
- Magnetic fields exit from the north pole of a magnet and enter its south pole.
- Magnetic field lines always form closed loops.
- A magnetic field exists around any wire that carries current.
- A coil of wire that carries a current has a magnetic field. The field about the coil is like the field about a permanent magnet.
- When a current-carrying wire is placed in a magnetic field, there exists a force on the wire that is perpendicular to both the field and the wire.
- An electric motor consists of a coil of wire placed in a magnetic field. When there is current in the coil, the coil rotates as the result of the force on the wire in the magnetic field.
- A generator and a motor are similar devices. A generator converts mechanical energy to electrical energy; a motor converts electrical energy to mechanical energy.
- A transformer has two coils wound about the same core. An AC current through the primary coil induces an alternating EMF in the secondary coil. The voltages in alternating-current circuits may be increased or decreased by transformers.

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of magnetism, including electro-magnetic induction.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to magnetic interactions.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

UNIT 9
Waves and Sound

Unit Goals

At the completion of this unit, students will:

HS-PS4-1.	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.**
HS-PS4-5.	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.

ISTE Technology Standards ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- How does our understanding of wave phenomena affect human society?

Unit Scope and Sequence

- A wave is a disturbance or vibration in matter that results in the transfer of energy between locations without the bulk transfer of matter.
- Most waves require a medium (matter) to travel through; energy is transmitted from particle to particle in the medium. Electromagnetic waves (light) are an exception to this as they can travel through a vacuum.
- Transverse waves are waves in which the individual particles in the medium vibrate perpendicularly to the direction the energy is travelling. Examples include light and “the wave” done during sporting events.
- Longitudinal waves are waves in which the individual particles in the medium vibrate parallel to the direction the energy is travelling, resulting in compressions and expansions of the particles. Sound is an example of a longitudinal wave.
- The amplitude of a wave is measured based on the maximum distance the particles are displaced from their rest position. Amplitude is related to the amount of energy being

transmitted; a wave with a greater amplitude transmits more energy than a wave with a smaller amplitude.

- A wave pulse is a single disturbance or vibration. A periodic wave results when wave pulses occur at a regular interval/rate.
- Wave speed is the rate at which the disturbance moves through the medium. As with any speed, it is often measured in meters per second. Wave speed is determined by the properties of the medium (for example sound travels faster in water than in air due to the different properties of those media).
- Frequency is a measurement associated with a periodic wave, and it is the rate at which wave pulses are created (how many waves per second). Frequency is measured in hertz (Hz), and is determined by the source of the disturbance.
- Period is a measurement associated with a periodic wave, and it is the number of seconds between wave pulses. Period and frequency are thus inversely related to one another (seconds per wave vs. waves per second).
- Wavelength is a measurement associated with a periodic wave, and it is the distance between successive wave pulses. Wavelength is measured in meters, and is dependent upon the wave speed and frequency.
- Wave speed, wavelength, and frequency are related to each other through the wave equation: $v = \lambda f$. This equation can be used to describe any type of wave phenomena.
- Intensity is a measurement of the rate of energy delivered by a wave per unit area.
- The lowest intensity perceptible to the human ear is approximately 10^{-12} W/m^2, and the greatest intensity (when sound starts to be painful) is 1 W/m^2. Due to this huge range of values, the Decibel scale is often used.
- The Decibel scale is a logarithmic scale, where 0 dB is the threshold of hearing and 120 dB is the threshold of pain.
- When more than one wave occupies the same location in a medium, superposition occurs and the amplitudes of the waves combine. Constructive interference occurs when the overall amplitude is greater than the individual amplitudes; destructive interference occurs when the overall amplitude is smaller than the individual amplitudes.
- Standing waves can be formed in a medium under the right conditions of constructive and destructive interference. A standing wave appears to oscillate in place as the individual wave pulses travel back and forth. Certain locations in the medium (called nodes) always have destructive interference occurring, resulting in minimal vibration of the medium. Other locations in the medium (called antinodes) alternate between destructive interference and constructive interference, resulting in maximum vibration of the medium.
- The speed of waves on a string, wire, or spring is dependent on the tension and linear mass density of the medium. Standing waves can be formed on a string, wire, or spring when the length of the medium is a multiple of half wavelengths of the periodic wave (with a node existing at each end).
- The speed of sound in air is directly related to the temperature of the air. At room temperature, the speed of sound is approximately 343 m/s.
- Standing sound waves can be created in an open pipe (open to the atmosphere at both ends) when the length of the pipe is a multiple of half wavelengths of the sound waves (with an antinode existing at each end).

- Standing sound waves can be created in a closed pipe (open to the atmosphere at only one end) when the length of the pipe is an odd multiple of quarter wavelengths of the sound waves (with a node at the closed end and an antinode at the open end).

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of waves and sound, including resonance and standing waves.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to waves and sound.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

UNIT 10
Light

Unit Goals

At the completion of this unit, students will:

HS-PS4-1.	**Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.**
HS-PS4-5.	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.

ISTE Technology Standards	
ISTE Empowered Learner (Standard 1c)	use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
ISTE Knowledge Constructor (Standard 3d)	build knowledge by actively exploring real-world (Standard 3d) issues and problems, including the anchoring event of the unit, developing ideas and theories and pursuing answers and solutions.

Unit Essential Questions

- What is the nature of light?
- How does light interact with substances?
- How can light properties be used?

Unit Scope and Sequence

- Light is part of the electromagnetic spectrum of waves that travel through space in essentially straight lines at 3×10^8 meters per second.
- Light also exhibits properties of particles. These particles are called photons which contain a certain amount of energy and momentum as indicated by their frequency.
- Reflected light leaves an object's surface at the same angle it hit the object's surface.
- Refraction index of a substance indicates the degree to which the light is slowed down when it is transmitted through the substance.

- When light enters an object at an angle, its direction is changed according to Snell's law and the refraction index.
- Light striking the surface can experience total internal reflection if the incident angle is greater than the critical angle.
- Light reflected off the surface of an object can be directed to form an image.
- Light refracted through an object can be directed to form an image.
- These images can be real (projectable) or virtual (not projectable)

Unit Assured Assessments

Formative Assessments:
Students will complete laboratory data collection and graphical analysis through experimental processes on the topics of light optics, including image formation.
Students will have the opportunity to assess comprehension of concepts and mastery of skills through applied quiz work.

Summative Assessments:
Students will complete an assessment consisting of multiple-choice questions, free response questions and problem solving, and/or the interpretation and analysis of data, related to light and optics.

Resources

Core
- Conceptual Physics textbook
- Use of traditional data collection tools and electronic data collection probes: e.g. Pasco

Supplemental
Online resources
- The Physics Classroom. https://www.physicsclassroom.com/. Web.
- Pivot Interactives. https://www.pivotinteractives.com/. Web.
- Flipping Physics. https://www.flippingphysics.com/. Web.
- Khan Academy. https://www.youtube.com/user/khanacademy. Web.
- University of Colorado Boulder. PhET Interactive Simulations. https://phet.colorado.edu/en/simulations/category/new. Web.

Time Allotment

- Approximately 2-3 weeks

CREDIT

1 credit in science
One class period daily, for a full year

PREREQUISITES

Successful completion of CP Chemistry or ACP Chemistry

ASSURED STUDENT PERFORMANCE RUBRICS

- Trumbull High School School-Wide Problem Solving Through Critical Thinking Rubric
- Trumbull High School School-Wide Writing Rubric
- Trumbull High School School-Wide Independent Learning and Thinking Rubric

Trumbull High School School-Wide Problem Solving Through Critical Thinking Rubric

Category/ Weight	Exemplary 4	Goal 3	Working Toward Goal 2	Needs Support 1-0
Understanding X_____	• Student demonstrates clear understanding of the problem and the complexities of the task	• Student demonstrates sufficient understanding of the problem and most of the complexities of the task	• Student demonstrates some understanding of the problem but requires assistance to complete the task	• Student demonstrates limited or no understanding of the fundamental problem after assistance with the task
Research X_____	• Student gathers compelling information from multiple sources including digital, print, and interpersonal	• Student gathers sufficient information from multiple sources including digital, print, and interpersonal	• Student gathers some information from few sources including digital, print, and interpersonal	• Student gathers limited or no information
Reasoning and Strategies X_____	• Student demonstrates strong critical thinking skills to develop a comprehensive plan integrating multiple strategies	• Student demonstrates sufficient critical thinking skills to develop a cohesive plan integrating strategies	• Student demonstrates some critical thinking skills to develop a plan integrating some strategies	• Student demonstrates limited or no critical thinking skills and no plan
Final Product and/or Presentation X_____	• Solution shows deep understanding of the problem and its components • Solution shows extensive use of 21st-century technology skills	• Solution shows sufficient understanding of the problem and its components • Solution shows sufficient use of 21st-century technology skills	• Solution shows some understanding of the problem and its components • Solution shows some use of 21st-century technology skills	• Solution shows limited or no understanding of the problem and its components • Solution shows limited or no use of 21st-century technology skills

Trumbull High School School-Wide Writing Rubric

Category/ Weight	Exemplary 4 Student work:	Goal 3 Student work:	Working Toward Goal 2 Student work:	Needs Support 1-0 Student work:
Purpose X_____	• Establishes and maintains a clear purpose • Demonstrates an insightful understanding of audience and task	• Establishes and maintains a purpose • Demonstrates an accurate awareness of audience and task	• Establishes a purpose • Demonstrates an awareness of audience and task	• Does not establish a clear purpose • Demonstrates limited/no awareness of audience and task
Organization X_____	• Reflects sophisticated organization throughout • Demonstrates logical progression of ideas • Maintains a clear focus • Utilizes effective transitions	• Reflects organization throughout • Demonstrates logical progression of ideas • Maintains a focus • Utilizes transitions	• Reflects some organization throughout • Demonstrates logical progression of ideas at times • Maintains a vague focus • May utilize some ineffective transitions	• Reflects little/no organization • Lacks logical progression of ideas • Maintains little/no focus • Utilizes ineffective or no transitions
Content X_____	• Is accurate, explicit, and vivid • Exhibits ideas that are highly developed and enhanced by specific details and examples	• Is accurate and relevant • Exhibits ideas that are developed and supported by details and examples	• May contain some inaccuracies • Exhibits ideas that are partially supported by details and examples	• Is inaccurate and unclear • Exhibits limited/no ideas supported by specific details and examples
Use of Language X_____	• Demonstrates excellent use of language • Demonstrates a highly effective use of standard writing that enhances communication • Contains few or no errors. Errors do not detract from meaning	• Demonstrates competent use of language • Demonstrates effective use of standard writing conventions • Contains few errors Most errors do not detract from meaning	• Demonstrates use of language • Demonstrates use of standard writing conventions • Contains errors that detract from meaning	• Demonstrates limited competency in use of language • Demonstrates limited use of standard writing conventions • Contains errors that make it difficult to determine meaning

Trumbull High School School-Wide Independent Learning and Thinking Rubric

Category/ Weight	Exemplary 4	Goal 3	Working Toward Goal 2	Needs Support 1-0
Proposal X_____	• Student demonstrates a strong sense of initiative by generating compelling questions, creating uniquely original projects/work	• Student demonstrates initiative by generating appropriate questions, creating original projects/work	• Student demonstrates some initiative by generating questions, creating appropriate projects/work	• Student demonstrates limited or no initiative by generating few questions and creating projects/work
Independent Research & Development X_____	• Student is analytical, insightful, and works independently to reach a solution	• Student is analytical, and works productively to reach a solution	• Student reaches a solution with direction	• Student is unable to reach a solution without consistent assistance
Presentation of Final Product X_____	• Presentation shows compelling evidence of an independent learner and thinker • Solution shows deep understanding of the problem and its components • Solution shows extensive and appropriate application of 21st-century skills	• Presentation shows clear evidence of an independent learner and thinker • Solution shows adequate understanding of the problem and its components • Solution shows adequate application of 21st-century skills	• Presentation shows some evidence of an independent learner and thinker • Solution shows some understanding of the problem and its components • Solution shows some application of 21st-century skills	• Presentation shows limited or no evidence of an independent learner and thinker • Solution shows limited or no understanding of the problem and its components • Solution shows limited or no application of 21st-century skills