Course Title/ Course #: Physics / 2900

Start day: 1

Meetings: 180 days

**Course Description**

The Physics standards emphasize a more complex understanding of experimentation, the analysis of data, and the use of reasoning and logic to evaluate evidence. The use of mathematics, including algebra and trigonometry, is important, but conceptual understanding of physical systems remains a primary concern. Students build on basic physical science principles by exploring in-depth the nature and characteristics of energy and its dynamic interaction with matter. Key areas covered by the standards include force and motion, energy transformations, wave phenomena and the electromagnetic spectrum, electricity, fields, and non-Newtonian physics. The standards stress the practical application of physics in other areas of science, technology, engineering, and mathematics. The effects of physics on our world are investigated through the study of critical, contemporary global topics.

**Pacing Resources Assessments MP1**

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<thead>
<tr>
<th>Time Frame</th>
<th>Standards of Learning</th>
<th>Units/ Topics/ Concepts</th>
<th>Resources</th>
<th>Assessments</th>
</tr>
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<tbody>
<tr>
<td>1 week</td>
<td>PH.1a-g</td>
<td>Scientific Investigation</td>
<td>Gizmos</td>
<td>Pretest: Physics Baseline Cornerstone Assessment (LENS Project)</td>
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<td>• Free Fall Tower</td>
<td>PALS – Performance Assessments</td>
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<td>• Pendulum Clock</td>
<td>• Friction Force</td>
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<td><strong>Physics Science Fair Project Ideas (Sciencebuddies.com)</strong></td>
<td>• Speed and Collisions</td>
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<td><strong>Physics Science Fair Project Ideas (education.com)</strong></td>
<td>• Electric Energy</td>
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<td><strong>Science Fair Project Guide</strong></td>
<td>• A Cut Above the Rest</td>
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<td>• Radioactive Decay</td>
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<td>• Electric Circuits</td>
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Throughout the course, students should be
participating in every step of the “scientific process,” including:
- proposing scientific questions hypotheses
- designing experiments
- making measurements using appropriate tools and technology safely
- determining and appropriately communicating measurement accuracy and precision
- drawing reasonable conclusions from analyzed data
- Using simulations when necessary to model physical systems

### Practices for Scientific Investigation: Kindergarten-Physics Progression

Students use actual scientific tools (balances, spring scales, graduated cylinders, meter sticks, etc.) to make scientific measurements of “known” quantities (i.e. pre-measured by the teacher). Students are expected to record measurements with appropriate significant figures, complete calculations using appropriate significant figures, and complete error analysis when needed.

<table>
<thead>
<tr>
<th>1 week</th>
<th>PH.1a-g; PH.3a-e</th>
<th>Scientific Reasoning and Logic</th>
<th>NOVA ScienceNOW: Newton’s Dark Secrets (running time: 51:15)</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>• Newton’s Dark Secrets Classroom Guide</td>
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<td>NOVA ScienceNOW: Einstein’s Big Idea (running time: 1:48:58)</td>
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<td>• Einstein’s Big Idea Classroom Guide</td>
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<td>NOVA ScienceNOW: The Fabric of the Cosmos (4 full episodes, each ~50 min.)</td>
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Students may complete a research paper on a specific paradigm shift in physics, including social as well as scientific context and implications.

Students may choose a particular physicist, historical or modern, and complete a biographical project on that person.

Given a series of hypothetical or actual ideas or belief systems, students can be asked to identify whether each fits the “nature of science” or not.
<table>
<thead>
<tr>
<th>Fabric of the Cosmos Worksheets</th>
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<tbody>
<tr>
<td>NOVA ScienceNOW: The Elegant Universe (3 full episodes, each ~50 min.)</td>
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<tr>
<td>The Elegant Universe Classroom Guide</td>
</tr>
<tr>
<td>NOVA ScienceNOW: Big Bang Machine (running time: 53:10)</td>
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</tbody>
</table>

If not, students can explain what aspect(s) of the nature of science is not adhered to by that particular idea.

Given any of the NOVA ScienceNOW videos listed at left, students may write a paper or prepare a presentation why each embodies (or fails to embody) each aspect of the nature of science.
| 3 weeks | PH. 1a-g; PH.2a-d; PH.5a | Data Analysis/Graphing; Linear Motion | Gizmos  
- Unit Conversions  
- Unit Conversions 2 (Sci Notation and Sig Figs)  
- Slope - Activity B  
- Correlation  
- Distance-Time Graphs  
- Distance-Time and Velocity-Time Graphs  
Activities and Labs  
- Motion on a Ramp  
- Seeing Motion  
PhET Simulations  
- The Moving Man  
Physics Lab Online: Introductory Mathematics  
(examples, lab exercises, practice problems, and worksheets)  
Physics Lab Online: Kinematics – Graphs  
Physics Lab Online: Kinematics - Equations  
The Physics Classroom  
- Habits of an Effective Problem Solver  
- Tutorial: 1-D Kinematics  
- Interactives: 1-D Kinematics  
- Problem Set: 1-D Kinematics  
Given a displacement-time or velocity-time graph, students write a story that accurately reflects the motion shown in the graph. Alternatively, they may create a motion-time graph based on a provided story.  
Students may complete a graph-matching exercise using motion detectors and probeware, in which they must move in a certain way in order to reproduce a provided motion graph.  
Given a particular measurement and necessary equivalencies, students can use dimensional analysis methods to convert it to another unit. Skills may include:  
- metric-to-metric conversions  
- standard-to-metric conversions  
- derived-to-base units  
Students can use manual or digital methods to determine a best-fit line from hypothetical or actual data points, and then use the equation for this line to make predictions.  
Solve problems involving displacement, velocity, acceleration, and time in one dimension. |
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<tbody>
<tr>
<td>2 weeks</td>
<td>PH. 1a-g; PH.4a-b; PH.5a</td>
<td>Application/Acceleration, Velocity, Displacement, Time</td>
<td>2 weeks</td>
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| • Vectors  
• Adding Vectors | Students should be able to demonstrate the following skills with fluency:  
• add/subtract vectors in one dimension  
• resolve a vector into its horizontal and vertical components  
• combine horizontal and vertical vectors into one resultant vector |
| Physics Lab Online: Vectors | Given a story, students may represent the motion described in the story using vectors. Alternatively, students may write a story based on a series of motion vectors. |
| The Physics Classroom  
• [Tutorial: Vectors – Motion and Forces in Two Dimensions](http://www.physicsclassroom.com)  
• Interactives: Vectors and Projectiles  
• Problem Set: Vectors and Projectiles  
• Problem Set: Vectors and Forces in 2D | Resolve vector diagrams involving displacement and velocity into their components along perpendicular axes. |
| Khan Academy: Two-Dimensional Motion (1st video) | |

The following are additional resources for vector operations and problem-solving:

- [Gizmos](#) provides interactive simulations for vectors.
- [Physics Lab Online: Vectors](http://www.physicslabonline.com) offers tutorials and practice problems.
- [The Physics Classroom](http://www.physicsclassroom.com) features tutorials and problem sets on vectors and forces in two dimensions.
- [Khan Academy: Two-Dimensional Motion](http://www.khanacademy.org) offers video lessons and practice exercises.
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<thead>
<tr>
<th>Time Frame</th>
<th>Standards of Learning</th>
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<th>Resources</th>
<th>Assessments</th>
</tr>
</thead>
</table>
| 2 weeks    | **PH. 1 a-g; PH.5b-c** | Circular Motion/ Projectile Motion | Gizmos  
• Uniform Circular Motion  
• Shoot the Monkey  
• Golf Range  
PhET Simulations  
• Gravity and Orbits  
• Ladybug Revolution  
• Projectile Motion  
• Ladybug Motion 2D  
• Motion in 2D  
Physics Lab Online: Projectiles  
Physics Lab Online: Uniform Circular Motion  
The Physics Classroom:  
• Tutorial: Circular Motion and Satellite Motion  
• Tutorial: Vectors – Motion and Forces in Two Dimensions  
• Interactives: Vectors and Projectiles  
• Interactives: Circular and Satellite Motion  
• Problem Set: Vectors and Projectiles  
• Problem Set: Circular Motion and Gravitation  
Khan Academy: Two-Dimensional Motion  
Khan Academy: Optimal Angle for a Projectile  
Students may explain, verbally or in writing, the role of centripetal force and acceleration in circular motion, including an explanation of the invalidity of “centrifugal” forces.  
Students may explain, verbally or in writing, the independence of horizontal and vertical components of motion in a projectile’s trajectory.  
After students have an understanding of Newton’s Laws of Motion, students may explain how these laws, especially the 1<sup>st</sup> and 2<sup>nd</sup>, apply to circular and/or projectile motion.  
Students may complete poster-size diagram of circular motion, including labels for centripetal force, centripetal acceleration, and tangential velocity vectors, radius, the trajectory an object would take if the centripetal force disappeared, and key equations.  
Students may complete a poster-size diagram of projectile motion, including labels for the apex, range, initial velocity vector components, gravity, and velocity...
vectors during flight. Key questions may also be included.

Solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration).

Draw vector diagrams of a projectile’s motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance).

Distinguish between centripetal and centrifugal force.

Solve problems related to free-falling objects, including 2-D motion.

Describe the forces involved in circular motion.

| 3 weeks | PH. 1 a-g; PH.5d-f | Newton’s Laws/ Gravitation/ Planetary Motion | Gizmos
|• Force and Fan Carts
|• Fan Cart Physics
|• Orbital Motion - Kepler’s Laws
|• Gravitational Force
|• Gravity Pitch
|• Weight and Mass
|The Concord Consortium
|• Forces - Equal and Opposite
|PhET Simulations
|• Forces and Motion: Basics
|• Forces and Motion
|• Gravity and Orbits
|• My Solar System
|• Forces in 1 Dimension | Use [http://www.problem-attic.com/](http://www.problem-attic.com/) to create a multiple choice or free response quiz or test.

PALS – Performance Assessments
• Friction Force

In writing, verbally, and/or using vector diagrams, students may explain qualitatively how forces produce the motion of familiar situations or videos of less familiar ones (such as the launching of a rocket).

Solve problems involving force (F), mass (m), and acceleration (a).
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<tr>
<th>2 weeks</th>
<th><strong>PH. 1 a-g; PH.5g</strong></th>
<th><strong>Energy, Work, Power</strong></th>
<th><strong>Physics Lab Online: Dynamics</strong></th>
<th><strong>Physics Lab Online: Gravitation</strong></th>
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<tr>
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<td><strong>Lunar Lander</strong></td>
<td><strong>Gravity Force Lab</strong></td>
<td><strong>The Physics Classroom</strong></td>
<td><strong>Khan Academy: Forces and Newton’s Laws of Motion</strong></td>
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<td><strong>Friction</strong></td>
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<td><strong>Tutorial: Newton's Laws</strong></td>
<td><strong>Khan Academy: Newton’s Law of Gravitation</strong></td>
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<td><strong>Physics Lab Online: Dynamics</strong></td>
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<td><strong>Interactives: Newton’s Laws</strong></td>
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<td></td>
<td><strong>Physics Lab Online: Gravitation</strong></td>
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<td><strong>Problem Set: Vectors and Forces in 2D</strong></td>
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<td><strong>The Physics Classroom</strong></td>
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<td><strong>Problem Set: Newton’s Laws of Motion</strong></td>
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<td></td>
<td><strong>Khan Academy: Forces and Newton’s Laws of Motion</strong></td>
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<td><strong>Problem Set: Circular Motion and Gravitation</strong></td>
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<td></td>
<td><strong>Gizmos</strong></td>
<td><strong>Energy Conversion in a System</strong></td>
<td><strong>Khan Academy: Work and Energy</strong></td>
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<td><strong>PhET Simulations</strong></td>
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<td><strong>The Physics Classroom</strong></td>
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<td><strong>Pulley Lab</strong></td>
<td><strong>Energy Skate Park: Basics</strong></td>
<td><strong>Tutorial: Work, Energy, and Power</strong></td>
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<td><strong>Energy Skate Park: Basics</strong></td>
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<td><strong>Interactives: Work and Energy</strong></td>
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<td><strong>Physics Lab Online: Work and Energy</strong></td>
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<td><strong>Khan Academy: Work and Energy</strong></td>
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Solve problems involving multiple forces, using free-body diagrams.


In groups, students can complete (and compete in) the Strongman Lab to determine how to accurately measure the force required, work performed, and power generated in a variety of physical activities. Editable versions of the lab handout may be found online by Googling “Strongman Lab.”

Solve problems involving mechanical work, power, and energy.

To demonstrate student growth, students may once again complete the [Physics Baseline Cornerstone Assessment (LENS Project)](http://www.problem-attic.com/). |
### Pacing Resources Assessments MP3

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<tbody>
<tr>
<td>3 weeks</td>
<td>PH. 1 a-g; PH.6a-c; PH.7a-b</td>
<td>Energy (PE and KE, Momentum/ Collisions), Energy Conversion to Work Application</td>
<td>Gizmos</td>
<td>Use <a href="http://www.problem-attic.com/">http://www.problem-attic.com/</a> to create a multiple choice or free response quiz or test.</td>
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<td><strong>Potential Energy on Shelves</strong></td>
<td>PALS – Performance Assessments</td>
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<td><strong>Roller Coaster Physics</strong></td>
<td>• <strong>Speed and Collisions</strong></td>
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<td><strong>Inclined Plane - Sliding Objects</strong></td>
<td>• <strong>A Cut Above the Rest</strong></td>
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<td><strong>Air Track</strong></td>
<td>Solve problems involving mechanical work, power, and energy.</td>
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<td><strong>Pulley Lab</strong></td>
<td>Provide and explain examples of how energy can be converted from potential energy to kinetic energy and the reverse, such as in the case of roller coasters or bouncing objects.</td>
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<td><strong>Energy Conversion in a System</strong></td>
<td>Provide and explain examples showing linear momentum is the product of mass and velocity, and is conserved in a closed system, including during elastic and inelastic collisions.</td>
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<td><strong>Inclined Plane - Simple Machine</strong></td>
<td>Students may explain the significance of Einstein’s famous E=mc² equation qualitatively, as well as use it to calculate the energy contained in any object with a known mass.</td>
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<td><strong>The Concord Consortium</strong></td>
<td>Solve elastic and inelastic collision problems.</td>
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<td>• <strong>Heat and Light from Electricity</strong></td>
<td>Illustrate that energy can be transformed from one form to another, using examples from everyday life and technology. For example, students may write a paragraph, a script, or a poem describing the energy forms and transformations taking place in common objects, such as a flashlight.</td>
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<td>• <strong>Elastic Collisions</strong></td>
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<td>• <strong>Gravity Rules in the Skatepark</strong></td>
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<td><strong>PhET Simulations</strong></td>
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<td>• <strong>Energy Skate Park</strong></td>
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<td>• <strong>Energy Forms and Changes</strong></td>
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<td><strong>Physics Lab Online: Momentum</strong></td>
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<td><strong>The Physics Classroom</strong></td>
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<td>• <strong>Tutorial: Momentum and its Conservation</strong></td>
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<td>• <strong>Tutorial: Work, Energy, and Power</strong></td>
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<td>• <strong>Interactives: Momentum and Collisions</strong></td>
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<td>• <strong>Interactives: Work and Energy</strong></td>
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<td><strong>NOVA ScienceNOW: Einstein’s Big Idea</strong></td>
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<td>• <strong>Einstein’s Big Idea Classroom Guide</strong></td>
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<td><strong>Khan Academy: Work and Energy</strong></td>
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<td><strong>Khan Academy: Momentum</strong></td>
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</table>
Calculate efficiency by identifying the useful energy in a process. For example, students may directly measure the energy input and output of various types of lightbulbs using probeware (or use appropriate specifications from the packaging) to compare efficiencies.

Qualitatively identify the various energy transformations in simple demonstrations.

<table>
<thead>
<tr>
<th>3 weeks</th>
<th><strong>PH. 1 a-g; PH.8a-c</strong></th>
<th><strong>Waves (Light and Sound), Characteristics &amp; Fundamentals</strong></th>
<th><strong>Gizmos</strong></th>
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<td>Pendulum Clock</td>
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<td>Energy of a Pendulum</td>
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<td>Period of a Pendulum</td>
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<td>Longitudinal Waves</td>
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<td>Ripple Tank</td>
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<td>Laser Reflection</td>
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<td>Sound Beats and Sine Waves</td>
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<td>Simple Harmonic Motion</td>
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<td>The Concord Consortium</td>
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<td>Complex Sounds and Instruments (link to application is near the bottom of the right-hand list of activities)</td>
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<td>Ripple Tank</td>
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<td>The Shape of Sound Waves (link to application is at the bottom of the right-hand list of activities)</td>
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<td>PhET Simulations</td>
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<td>Pendulum Lab</td>
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<td>Wave Interference</td>
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<td>Sound</td>
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<td>Refraction</td>
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<td>Wave on a String</td>
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<td>Identify examples of and differentiate between transverse and longitudinal waves, using simulations and/or models.</td>
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<td>Illustrate period, wavelength, and amplitude on a graphic representation of a wave, possibly on a poster or flyer.</td>
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<td>Solve problems involving frequency, period, wavelength, and velocity.</td>
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<td>Distinguish between superimposed waves that are in-phase and those that are out-of-phase.</td>
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<td>Graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary.</td>
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<td>Graphically illustrate constructive and destructive interference.</td>
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<td>Identify a standing wave, using a string.</td>
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<td>2 weeks</td>
<td><strong>PH. 1 a-g; PH.9a-c</strong></td>
<td><strong>Light Waves/ Frequencies and Wavelengths</strong></td>
<td><strong>Gizmos</strong>&lt;br&gt;• Doppler Shift&lt;br&gt;• Herschel Experiment&lt;br&gt;• Photoelectric Effect</td>
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<tr>
<td>Time Frame</td>
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<td>Units/ Topics/ Concepts</td>
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<tr>
<td>2 weeks</td>
<td>PH. 1 a-g; PH.10a-b</td>
<td>Forces/ Coulomb’s Law/Newton’s Universal Gravitation, Technological Applications</td>
<td>Gizmos</td>
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<td>PhET Simulations</td>
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<td></td>
<td>• My Solar System</td>
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<td>User: Static Electricity</td>
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<td>• Gravity Force Lab</td>
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<td>• Faraday's Electromagnetic Lab</td>
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| 2 weeks | PH. 1 a-g; PH.11a-d | Circuits/ Ohm’s Law, Series and Parallel Circuits, AC and DC | Khan Academy: Newton’s Law of Gravitation  
Khan Academy: Charge and Electric Field  
Khan Academy: Magnetism  

| 2 weeks | PH. 1 a-g; PH.12a-j | Nanotechnology & Modern Physics | Use [http://www.problem-attic.com/](http://www.problem-attic.com/) to create a multiple choice or free response quiz or test.  

**PH.11a-d**

- **Gizmos**
  - Circuits
  - Advanced Circuits
  - Circuit Builder

- The Concord Consortium
  - Current in a Simple Circuit
  - Voltage in a Simple Circuit

- PhET Simulations
  - Circuit Construction Kit (DC Only)
  - Circuit Construction Kit (AC & DC)
  - Ohm’s Law
  - Battery-Resistor Circuit
  - Battery Voltage

- Physics Lab Online: DC Circuits

- The Physics Classroom
  - Tutorial: Current Electricity
  - Interactives: Electric Circuits
  - Problem Set: Electric Circuits

- Khan Academy: Circuits

**PH.12a-j**

- **Gizmos**
  - Photoelectric Effect
  - Nuclear Decay

- PhET Simulations
  - Nuclear Fission
  - Photoelectric Effect
  - Quantum Wave Interference

**PH.12a-j**

- **Gizmos**
  - Photoelectric Effect
  - Nuclear Decay

- PhET Simulations
  - Nuclear Fission
  - Photoelectric Effect
  - Quantum Wave Interference

- Physics Lab Online: DC Circuits

- The Physics Classroom
  - Tutorial: Current Electricity
  - Interactives: Electric Circuits
  - Problem Set: Electric Circuits

**Khan Academy: Circuits**

**Recognize a series and a parallel circuit and assemble simple circuits composed of batteries and resistors in series and in parallel.**

**Apply Ohm’s law to a series and a parallel circuit and solve simple circuits using Ohm’s law.**

**Calculate the dissipated power of a circuit element.**

**Recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets.**

**Use** [http://www.problem-attic.com/](http://www.problem-attic.com/) **to create a multiple choice or free response quiz or test.**

**Explain that the motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be**
Blackbody Spectrum

Physics Lab Online: Modern Physics

NOVA ScienceNOW: The Fabric of the Cosmos (4 full episodes, each ~50 min.)
  • Fabric of the Cosmos Worksheets

NOVA ScienceNOW: The Elegant Universe (3 full episodes, each ~50 min.)
  • The Elegant Universe Classroom Guide

NOVA ScienceNOW: Big Bang Machine (running time: 53:10)

National Nanotechnology Infrastructure Network: Classroom Activities and Curriculum Materials

treated within the theory of relativity.

Describe the relationship between the Big Bang theory timeline and particle physics.

Describe the structure of the atomic nucleus, including quarks.

Provide examples of technologies used to explore the nanoscale through research projects and presentations.

PALS – Performance Assessments
  • Radioactive Decay

2 weeks **PH.1-12**

Review and Final Exam

Bozeman Science Review Videos (Units 1 – 10)

60 Questions Physics Students Should Know (Conceptual, by Paul Hewitt)
The *Science Standards of Learning* Curriculum Framework amplifies the *Science Standards of Learning for Virginia Public Schools* and defines the content knowledge, skills, and understandings that are measured by the Standards of Learning tests. The Science Curriculum Framework provides additional guidance to school divisions and their teachers as they develop an instructional program appropriate for their students. It assists teachers as they plan their lessons by identifying essential understandings and defining the essential content knowledge, skills, and processes students need to master. This supplemental framework delineates in greater specificity the minimum content that all teachers should teach and all students should learn.

School divisions should use the *Science Curriculum Framework* as a resource for developing sound curricular and instructional programs. This framework should not limit the scope of instructional programs. Additional knowledge and skills that can enrich instruction and enhance students’ understanding of the content identified in the Standards of Learning should be included as part of quality learning experiences.

The Curriculum Framework serves as a guide for Standards of Learning assessment development. Assessment items may not and should not be a verbatim reflection of the information presented in the Curriculum Framework. Students are expected to continue to apply knowledge and skills from Standards of Learning presented in previous grades as they build scientific expertise.

The Board of Education recognizes that school divisions will adopt a K–12 instructional sequence that best serves their students. The design of the Standards of Learning assessment program, however, requires that all Virginia school divisions prepare students to demonstrate achievement of the standards for elementary and middle school by the time they complete the grade levels tested. The high school end-of-course Standards of Learning tests, for which students may earn verified units of credit, are administered in a locally determined sequence.

Each topic in the *Science Standards of Learning* Curriculum Framework is developed around the Standards of Learning. The format of the Curriculum Framework facilitates teacher planning by identifying the key concepts, knowledge and skills that should be the focus of instruction for each standard. The Curriculum Framework is divided into two columns: Understanding the Standard (K-5); Essential Understandings (middle and high school); and Essential Knowledge, Skills, and Processes. The purpose of each column is explained below.

**Understanding the Standard (K-5)**
This section includes background information for the teacher. It contains content that may extend the teachers’ knowledge of the standard beyond the current grade level. This section may also contain suggestions and resources that will help teachers plan instruction focusing on the standard.

**Essential Understandings (middle and high school)**
This section delineates the key concepts, ideas and scientific relationships that all students should grasp to demonstrate an understanding of the Standards of Learning.

**Essential Knowledge, Skills and Processes (K-12)**
Each standard is expanded in the Essential Knowledge, Skills, and Processes column. What each student should know and be able to do in each standard is outlined. This is not meant to be an exhaustive list nor a list that limits what is taught in the classroom. It is meant to be the key knowledge and skills that define the standard.
Standard PH.1

The student will plan and conduct investigations using experimental design and product design processes. Key concepts include:

a) the components of a system are defined;
b) instruments are selected and used to extend observations and measurements;
c) information is recorded and presented in an organized format;
d) the limitations of the experimental apparatus and design are recognized;
e) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;
f) models and simulations are used to visualize and explain phenomena, to make predictions from hypotheses, and to interpret data; and
g) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

Essential Understandings

- Appropriate instruments are used to measure position, time, mass, force, volume, temperature, motion, fields, electric current, and potential.
- No measurement is complete without a statement about its uncertainty.
- Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation.
- Tables, spreadsheets, and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed.
- Accuracy is the difference between the accepted value and the measured value.
- Precision is the spread of repeated measurements.
- Results of calculations or analyses of data are reported in appropriate numbers of significant digits.
- Data are organized into tables and graphed when involving dependent and independent variables.

Essential Knowledge and Skills

In order to meet this standard, it is expected that students will:

- measure and record position, time, mass, force, volume, temperature, motion, fields, and electric current and potential, using appropriate technology.
- determine accuracy of measurement by comparing the experimental averages and the theoretical value.
- determine precision of measurement using range or standard deviation.
- follow safe practices in all laboratory procedures.
- use simulations to model physical phenomena.
- draw conclusions and provide reasoning using supporting data.
Standard PH.2

PH.2 The student will investigate and understand how to analyze and interpret data. Key concepts include
a) a description of a physical problem is translated into a mathematical statement in order to find a solution;
b) relationships between physical quantities are determined using the shape of a curve passing through experimentally obtained data;
c) the slope of a linear relationship is calculated and includes appropriate units;
d) interpolated, extrapolated, and analyzed trends are used to make predictions; and
e) situations with vector quantities are analyzed utilizing trigonometric or graphical methods.

Essential Understandings

The concepts developed in this standard include the following:
- Mathematics is a tool used to model and describe phenomena.
- Graphing and dimensional analysis are used to reveal relationships and other important features of data.
- Predictions are made from trends based on the data.
- The shape of the curve fit to experimentally obtained data is used to determine the relationship of the plotted quantities.
- All experimental data do not follow a linear relationship.
- The area under the curve of experimentally obtained data is used to determine related physical quantities.
- Not all quantities add arithmetically. Some must be combined using trigonometry. These quantities are known as vectors.
- Physical phenomena or events can often be described in mathematical terms (as an equation or inequality).

Essential Knowledge and Skills

In order to meet this standard, it is expected that students will
- recognize linear and nonlinear relationships from graphed data.
- where appropriate, draw a straight line through a set of experimental data points and determine the slope and/or area under the curve.
- use dimensional analysis to verify appropriate units.
- combine vectors into resultants utilizing trigonometric or graphical methods.
- resolve vectors into components utilizing trigonometric or graphical methods.
The student will investigate and demonstrate an understanding of the nature of science, scientific reasoning, and logic. Key concepts include:

- a) analysis of scientific sources to develop and refine research hypotheses;
- b) analysis of how science explains and predicts relationships;
- c) evaluation of evidence for scientific theories;
- d) examination of how new discoveries result in modification of existing theories or establishment of new paradigms; and
- e) construction and defense of a scientific viewpoint.

The concepts developed in this standard include the following:

- The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts:
  - a) the natural world is understandable;
  - b) science is based on evidence - both observational and experimental;
  - c) science is a blend of logic and innovation;
  - d) scientific ideas are durable yet subject to change as new data are collected;
  - e) science is a complex social endeavor; and
  - f) scientists try to remain objective and engage in peer review to help avoid bias.

- Experimentation may support a hypothesis, falsify it, or lead to new discoveries.
- The hypothesis may be modified based upon data and analysis.
- A careful study of prior reported research is a basis for the formation of a research hypothesis.
- A theory is a comprehensive and effective explanation, which is well supported by experimentation and observation, of a set of phenomena.
- Science is a human endeavor relying on human qualities, such as reasoning, insight, energy, skill, and creativity as well as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

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<th>Essential Understandings</th>
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<tr>
<td>• The nature of science refers to the foundational concepts that govern the way scientists formulate explanations about the natural world. The nature of science includes the following concepts:</td>
<td>• identify and explain the interaction between human nature and the scientific process.</td>
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<tr>
<td>a) the natural world is understandable;</td>
<td>• identify examples of a paradigm shift (e.g., quantum mechanics).</td>
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<tr>
<td>b) science is based on evidence - both observational and experimental;</td>
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<tr>
<td>c) science is a blend of logic and innovation;</td>
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<td>d) scientific ideas are durable yet subject to change as new data are collected;</td>
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<td>e) science is a complex social endeavor; and</td>
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<tr>
<td>f) scientists try to remain objective and engage in peer review to help avoid bias.</td>
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### Standard PH.4

The student will investigate and understand how applications of physics affect the world. Key concepts include:

- a) examples from the real world; and
- b) exploration of the roles and contributions of science and technology.

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<td>The concepts developed in this standard include the following:</td>
<td>In order to meet this standard, it is expected that students will</td>
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<tr>
<td>- Discoveries in physics, both theoretical and experimental, have resulted in advancements in communication, medicine, engineering, transportation, commerce, exploration, and technology.</td>
<td>- be aware of real-world applications of physics, and the importance of physics in the advancement of various fields, such as medicine, engineering, technology, etc.</td>
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<tr>
<td>- Journals, books, the Internet, and other sources are used in order to identify key contributors and their contributions to physics as well as their impact on the real world.</td>
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Standard PH.5

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include:

- linear motion;
- uniform circular motion;
- projectile motion;
- Newton’s laws of motion;
- gravitation;
- planetary motion; and
- work, power, and energy.

### Essential Understandings

The concepts developed in this standard include the following:

- Newton’s three laws of motion are the basis for understanding the mechanical universe.
- Linear motion graphs include:
  - displacement (d) vs. time (t)
  - velocity (v) vs. time (t)
  - acceleration (a) vs. time (t)
- Position, displacement, velocity, and acceleration are vector quantities.
- Motion is described in terms of position, displacement, time, velocity, and acceleration.
- Velocity is the change in displacement divided by the change in time. A straight-line, position-time graph indicates constant velocity. The slope of a displacement-time graph is the velocity.
- Forces are interactions that can cause objects to accelerate. When one object exerts a force on a second object, the second exerts a force on the first that is equal in magnitude but opposite in direction.
- An object with no net force acting on it is stationary or moves with constant velocity.
- Acceleration is the change in velocity divided by the change in time. A straight-line, velocity-time graph indicates constant acceleration. A horizontal-line, velocity-time graph indicates zero acceleration. The slope of a velocity-time graph is the acceleration.

### Essential Knowledge and Skills

In order to meet this standard, it is expected that students will:

- qualitatively explain motion in terms of Newton’s Laws.
- solve problems involving force (F), mass (m), and acceleration (a).
- construct and analyze displacement (d) vs. time (t), velocity (v) vs. time (t), and acceleration (a) vs. time (t) graphs.
- solve problems involving displacement, velocity, acceleration, and time in one and two dimensions (only constant acceleration).
- resolve vector diagrams involving displacement and velocity into their components along perpendicular axes.
- draw vector diagrams of a projectile’s motion. Find range, trajectory, height of the projectile, and time of flight (uniform gravitational field, no air resistance).
- distinguish between centripetal and centrifugal force.
- solve problems related to free-falling objects, including 2-D motion.
- solve problems involving multiple forces, using free-body diagrams.
- solve problems involving mechanical work, power, and energy.
- describe the forces involved in circular motion.
PH.5 The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

a) linear motion;
b) uniform circular motion;
c) projectile motion;
d) Newton’s laws of motion;
e) gravitation;
f) planetary motion; and
g) work, power, and energy.

Essential Understandings

- The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass.
- In a uniform vertical gravitational field with negligible air resistance, horizontal and vertical components of the motion of a projectile are independent of one another with constant horizontal velocity and constant vertical acceleration.
- An object moving along a circular path with a constant speed experiences an acceleration directed toward the center of the circle.
- The force that causes an object to move in a circular path is directed centripetally, toward the center of the circle. The object’s inertia is sometimes falsely characterized as a centrifugal or outward-directed force.
- Weight is the gravitational force acting on a body.
- Newton’s Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and describes the force that determines the motion of celestial objects. The total force on a body can be represented as a vector sum of constituent forces.
- For a constant force acting on an object, the impulse by that force is the product of the force and the time the object experiences the force. The impulse also equals the change in momentum of the object.
- Work is the mechanical transfer of energy to or from a system and is the product of a force at the point of application and the parallel component of the object’s displacement. The net work on a system equals its
Standard PH.5

The student will investigate and understand the interrelationships among mass, distance, force, and time through mathematical and experimental processes. Key concepts include

a) linear motion;
b) uniform circular motion;
c) projectile motion;
d) Newton’s laws of motion;
e) gravitation;
f) planetary motion; and
g) work, power, and energy.

Essential Understandings

- For a constant force acting on an object, the work done by that force is the product of the force and the distance the object moves in the direction of the force. The net work performed on an object equals its change in kinetic energy.
- Power is the rate of doing work.

Essential Knowledge and Skills
## Standard PH.6

The student will investigate and understand that quantities including mass, energy, momentum, and charge are conserved. Key concepts include:

1. kinetic and potential energy;
2. elastic and inelastic collisions; and
3. mass/energy equivalence.

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<tr>
<td>The concepts developed in this standard include the following:</td>
<td>In order to meet this standard, it is expected that students will:</td>
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<tr>
<td>• Kinetic energy is the energy of motion. Potential energy is the energy due to an object’s position or state.</td>
<td>• provide and explain examples of how energy can be converted from potential energy to kinetic energy and the reverse.</td>
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<tr>
<td>• Total energy and momentum are conserved.</td>
<td>• provide and explain examples showing linear momentum is the product of mass and velocity, and is conserved in a closed system.</td>
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<tr>
<td>• For elastic collisions, total momentum and total kinetic energy are conserved. For inelastic collisions, total momentum is conserved and some kinetic energy is transformed to other forms of energy.</td>
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<td>• Electrical charge moves through electrical circuits and is conserved.</td>
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<td>• In some systems the conservation of mass and energy must take into account the principle of mass/energy equivalence.</td>
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**Standard PH.7**

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<tr>
<th>PH.7</th>
<th>The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include a) transfer and storage of energy among systems including mechanical, thermal, gravitational, electromagnetic, chemical, and nuclear systems; and b) efficiency of systems.</th>
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<tbody>
<tr>
<td><strong>Essential Understandings</strong></td>
<td><strong>Essential Knowledge and Skills</strong></td>
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<tr>
<td>The concepts developed in this standard include the following: • Energy can be transformed from one form to another. • Efficiency is the ratio of output work to input work.</td>
<td>In order to meet this standard, it is expected that students will • illustrate that energy can be transformed from one form to another, using examples from everyday life and technology. • calculate efficiency by identifying the useful energy in a process. • qualitatively identify the various energy transformations in simple demonstrations.</td>
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Standard PH.8

PH.8  The student will investigate and understand wave phenomena. Key concepts include
a) wave characteristics;
b) fundamental wave processes; and
c) light and sound in terms of wave models.

### Essential Understandings

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<td>• Mechanical waves transport energy as a traveling disturbance in a medium.</td>
<td>• identify examples of and differentiate between transverse and longitudinal waves, using simulations and/or models.</td>
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<tr>
<td>• In a transverse wave, particles of the medium oscillate in a direction perpendicular to the direction the wave travels.</td>
<td>• illustrate period, wavelength, and amplitude on a graphic representation of a wave.</td>
</tr>
<tr>
<td>• In a longitudinal wave, particles of the medium oscillate in a direction parallel to the direction the wave travels.</td>
<td>• solve problems involving frequency, period, wavelength, and velocity.</td>
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<tr>
<td>• Wave velocity equals the product of the frequency and the wavelength.</td>
<td>• distinguish between superimposed waves that are in-phase and those that are out-of-phase.</td>
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<tr>
<td>• For small angles of oscillation, a pendulum exhibits simple harmonic motion.</td>
<td>• graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary.</td>
</tr>
<tr>
<td>• Frequency and period are reciprocals of each other.</td>
<td>• graphically illustrate constructive and destructive interference.</td>
</tr>
<tr>
<td>• Waves are reflected and transmitted when they encounter a change in medium or a boundary.</td>
<td>• identify a standing wave, using a string.</td>
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<tr>
<td>• The overlapping of two or more waves results in constructive or destructive interference.</td>
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**Standard PH.8**

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<tr>
<td>• The pitch of a note is determined by the frequency of the sound wave.</td>
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<tr>
<td>• The color of light is determined by the frequency of the light wave.</td>
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<tr>
<td>• As the amplitude of a sound wave increases, the loudness of the sound increases.</td>
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<tr>
<td>• As the amplitude of a light wave increases, the intensity of the light increases.</td>
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<tr>
<td>• Electromagnetic waves can be polarized by reflection or transmission.</td>
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<tr>
<td>• Polarizing filters allow light oriented in one direction (or component of) to pass through.</td>
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Back to CPR MP1  Back to CPR MP3
Standard PH.9

The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include:

- a) the properties, behaviors, and relative size of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays;
- b) wave/particle dual nature of light; and
- c) current applications based on the respective wavelengths.

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<td>The concepts developed in this standard include the following:</td>
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<td>• Frequency, wavelength, and energy vary across the entire electromagnetic spectrum.</td>
<td>• describe the change in observed frequency of waves due to the motion of a source or a receiver (the Doppler effect).</td>
</tr>
<tr>
<td>• The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone).</td>
<td>• identify common uses for radio waves, microwaves, X-rays and gamma rays.</td>
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<tr>
<td>• Medium wavelengths (infrared) are used for heating and remote control devices.</td>
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<tr>
<td>• Visible light comprises a relatively narrow portion of the electromagnetic spectrum.</td>
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<tr>
<td>• Ultraviolet (UV) wavelengths (shorter than the visible spectrum) are ionizing radiation and can cause damage to humans. UV is responsible for sunburn, and can be used for sterilization and fluorescence.</td>
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<tr>
<td>• X-rays and gamma rays are the highest frequency (shortest wavelength) and are used primarily for medical purposes. These wavelengths are also ionizing radiation and can cause damage to humans.</td>
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</table>
Standard PH.10

PH.10 The student will investigate and understand how to use the field concept to describe the effects of gravitational, electric, and magnetic forces.

Key concepts include

a) inverse square laws (Newton’s law of universal gravitation and Coulomb’s law); and
b) technological applications.

Essential Understandings

The concepts developed in this standard include the following:

- The electrostatic force (Coulomb’s law) can be either repulsive or attractive, depending on the sign of the charges.
- The gravitational force (Newton’s Law of Gravitation) is always an attractive force.
- The force found from Newton’s Law of Gravitation and in Coulomb’s law is dependent on the inverse square of the distance between two objects.
- The interaction of two particles at a distance can be described as a two-step process that occur simultaneously: the creation of a field by one of the particles and the interaction of the field with the second particle.
- The force a magnetic field exerts on a moving electrical charge has a direction perpendicular to both the velocity and field directions. Its magnitude is dependent on the velocity of the charge, the magnitude of the charge, and the strength of the magnetic field.

Essential Knowledge and Skills

In order to meet this standard, it is expected that students will

- describe the attractive or repulsive forces between objects relative to their forces and distance between them (Coulomb’s law).
- describe the attraction of particles (Newton’s Law of Universal Gravitation).
- describe the effect of a uniform magnetic field on a moving electrical charge.
Standard PH.11

The student will investigate and understand how to diagram, construct, and analyze basic electrical circuits and explain the function of various circuit components. Key concepts include

a) Ohm’s law;
b) series, parallel, and combined circuits;
c) electrical power; and
d) alternating and direct currents.

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<td>• Current is the rate at which charge moves through a circuit element.</td>
<td>• recognize a series and a parallel circuit.</td>
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<td>• Electric potential difference (voltage) in a circuit provides the energy that drives the current.</td>
<td>• apply Ohm’s law to a series and a parallel circuit.</td>
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<tr>
<td>• Elements in a circuit are positioned relative to other elements either in series or parallel.</td>
<td>• assemble simple circuits composed of batteries and resistors in series and in parallel.</td>
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<tr>
<td>• According to Ohm’s law, the resistance of an element equals the voltage across the element divided by the current through the element.</td>
<td>• solve simple circuits using Ohm’s law.</td>
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<tr>
<td>• Potential difference (voltage) is the change in electrical potential energy per unit charge across that element.</td>
<td>• calculate the dissipated power of a circuit element.</td>
</tr>
<tr>
<td>• The dissipated power of a circuit element equals the product of the voltage across that element and the current through that element.</td>
<td>• recognize that DC power is supplied by batteries and that AC power is supplied by electrical wall sockets.</td>
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<tr>
<td>• In a DC (direct current) circuit, the current flows in one direction, whereas in an AC (alternating current) circuit, the current switches direction several times per second (60Hz in the U.S.).</td>
<td></td>
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</tbody>
</table>
PH.12: The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts may include:
  a) wave/particle duality;
  b) wave properties of matter;
  c) matter/energy equivalence;
  d) quantum mechanics and uncertainty;
  e) relativity;
  f) nuclear physics;
  g) solid state physics;
  h) nanotechnology;
  i) superconductivity; and
  j) radioactivity.

Essential Understandings

The concepts developed in this standard include the following:

- For processes that are important on the atomic scale, objects exhibit both wave characteristics (e.g., interference) as well as particle characteristics (e.g., discrete amounts and a fixed definite number of electrons per atom).
- Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus.
- The nuclear force binds protons and neutrons in the nucleus. Fission is the breakup of heavier nuclei to lighter nuclei. Fusion is the combination of lighter nuclei to heavier nuclei.
- Dramatic examples of mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for Earth, and the fission process in nuclear reactors that provide electricity.
- Natural radioactivity is the spontaneous disintegration of unstable nuclei. Alpha, beta, and gamma rays are different emissions associated with radioactive decay.
- The special theory of relativity predicts that energy and matter can be converted into each other.
- Objects cannot travel faster than the speed of light.
- The atoms and molecules of many substances in the natural world, including most metals and minerals, bind together in regular arrays to

Essential Knowledge and Skills

In order to meet this standard, it is expected that students will:

- explain that the motion of objects traveling near or approaching the speed of light does not follow Newtonian mechanics but must be treated within the theory of relativity.
- describe the relationship between the Big Bang theory timeline and particle physics.
- describe the structure of the atomic nucleus, including quarks.
- provide examples of technologies used to explore the nanoscale.
The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts may include:

a) wave/particle duality;
b) wave properties of matter;
c) matter/energy equivalence;
d) quantum mechanics and uncertainty;
e) relativity;
f) nuclear physics;
g) solid state physics;
h) nanotechnology;
i) superconductivity; and
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**Essential Understandings**

- Certain materials at very low temperatures exhibit the property of zero resistance called superconductivity.
- Electrons in orbitals can be treated as standing waves in order to model the atomic spectrum.
- Quantum mechanics requires an inverse relationship between the measurable location and the measurable momentum of a particle. The more accurately one determines the position of a particle, the less accurately the momentum can be known, and vice versa. This is known as the Heisenberg uncertainty principle.
- Matter behaves differently at nanometer scale (size and distance) than at macroscopic scale.

**Essential Knowledge and Skills**

form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.).