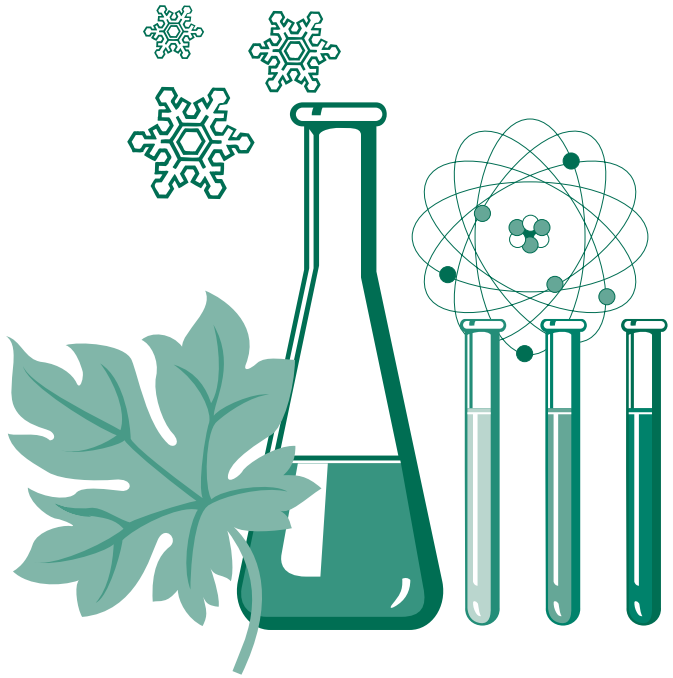

Science Standards of Learning Curriculum Framework

Physics

Commonwealth of Virginia
Board of Education
Richmond, Virginia

Standard PH.1 a, b, e

The student will plan and conduct investigations in which

a) the components of a system are defined;
b) instruments are selected and used to extend observations and measurements of mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge; and
e) the limitations of the experimental apparatus and design are recognized.

Essential Understandings	Essential Knowledge and Skills
• Appropriate instruments are used to measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, fields, and electric charge. • No measurement is complete without a statement about its exactness.	<u>Knowledge</u> • The difference between the accepted value and the measured value is the uncertainty or error. <u>Skills</u> • Determine percent error from experimental and theoretical values. • Measure displacement, time, mass, volume, temperature, heat exchange, energy transformations, motion, and electric charge. • Follow safe practices in all laboratory procedures.

Standard PH.1 c, d, f, g, h

The student will plan and conduct investigations in which

c) information is recorded and presented in an organized format;
d) metric units are used in all measurements and calculations;
f) the limitations of measured quantities are recognized through the appropriate use of significant figures or error ranges;
g) data gathered from non-SI instruments are incorporated through appropriate conversions; and
h) appropriate technology including computers, graphing calculators, and probeware, is used for gathering and analyzing data and communicating results.

Essential Understandings	Essential Knowledge and Skills
• Experimental records, including experimental diagrams, data, and procedures, are kept concurrently with experimentation. • Tables and graphs are used to interpret, organize, and clarify experimental observations, possible explanations, and models for phenomena being observed. • The average for a set of data is a valid way to estimate the true value of the set. • The spread in a set of data is an indication of the error in the measurement: a large spread indicates a large error, and a small spread indicates a small error.	<u>Knowledge</u> • Measurements are always recorded with appropriate SI units. • Calculations are made using appropriate SI units. • 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. <u>Skills</u> • Calculate average values, and compare to theoretical values.

Standard PH.2 a, b, c, d

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; and
d) interpolated, extrapolated, and analyzed trends are used to make predictions.

Essential Understandings	Essential Knowledge and Skills
• Mathematics is a tool used to explain and describe phenomena. • Dimensional analysis is the verification of the appropriateness of the units. (This can be used as a consistency check in calculations as well as in experiments.) • Graphing is used to reveal relationships and other important features of data. • Predictions are made from trends based on the data. • All experimental data do not follow a linear relationship.	<u>Knowledge</u> • The shape of the curve passing through experimentally obtained data is used to determine the relationship of the plotted quantities. • A physical phenomena or events can often be described in mathematical terms (as an equation or inequality). <u>Skills</u> • Recognize linear and nonlinear relationships from graphed data. • Draw the appropriate straight line through a set of experimental data points and determine the slope, using appropriate SI units. • Use dimensional analysis to solve problems.

Standard PH.2 e

The student will investigate and understand how to analyze and interpret data. Key concepts include

e) analysis of systems employs vector quantities utilizing trigonometric and graphical methods.

Essential Understandings	Essential Knowledge and Skills
• Not all quantities add algebraically. Some must be combined using trigonometry. These quantities are known as vectors.	Skills • Combine vectors and resolve vectors into components, using graphical methods that place scaled vectors head-to-tail. • Sketch a vector diagram, and trigonometrically solve for the components. • Sketch the components of a vector, and trigonometrically solve for the resultant.

Standard PH.3 a, b, c, d, e

The student will investigate and understand how to demonstrate 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 nature of science).

Essential Understandings	Essential Knowledge and Skills
• 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.	<u>Knowledge</u> • Relativity and quantum mechanics are recent examples of paradigm shifts in theoretical physics. • The change from an earth-centered to a sun-centered model of the solar system is an example of a paradigm shift. <u>Skills</u> • Identify and explain the interaction between human nature and the scientific process.

Standard PH.4 a, b

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.

Essential Understandings	Essential Knowledge and Skills
• Physics discoveries, both theoretical and experimental, result in advancements in communication, medicine, transportation, commerce, exploration, and technology.	<u>Knowledge</u> • 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.

Standard PH.5 a, b, c

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; and
c) projectile motion.

Essential Understandings	Essential Knowledge and Skills
• 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. • The concept of motion is described in terms of position, displacement, velocity, acceleration, and their dependence on time. • Graphical analysis is used as a representation of motion. • Horizontal and vertical components of the motion of a projectile are independent of one another. • In a uniform vertical gravitational field with negligible air resistance, a projectile moves with constant horizontal velocity and constant vertical acceleration.	<u>Knowledge</u> • *Velocity* is the change in distance divided by the change in time. • A straight-line, position-time graph indicates constant velocity. • A straight-line, velocity-time graph indicates constant acceleration. • A horizontal-line, velocity-time graph indicates zero acceleration. • The slope of a distance-time graph is the velocity. • The slope of a velocity-time graph is the acceleration. • *Acceleration* is the change in velocity divided by the change in time.

Standard PH.5 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
• An object moving uniformly along a circle moves with a constant speed and with acceleration directed toward the center of the circle. • Centripetal force is a "true" force acting on a body in circular motion while centrifugal force is a "false" force that describes the feeling experienced in centripetal acceleration.	<u>Skills</u> • 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 distance and velocity. • Draw vector diagrams of a projectile's motion. Find range, trajectory, height of the projectile, and time of flight (uniform field, no air resistance). • Distinguish between centripetal and centrifugal force.

Standard PH.5 d, e, f

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

d) Newton's laws of motion;
e) gravitation; and
f) planetary motion.

Essential Understandings	Essential Knowledge and Skills
• Newton's three laws of motion are the basis for understanding the mechanical universe. • Newton's Law of Universal Gravitation 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.	<u>Knowledge</u> • An object with no force acting on it moves with constant velocity. • The acceleration of a body is directly proportional to the net force on it and inversely proportional to its mass. • 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. • *Weight* is the gravitational force acting on a body. • ($F_w = mg$) • *Friction* is a force that acts in a direction opposite the velocity. • For small angles of oscillation, a pendulum exhibits simple harmonic motion.

Standard PH.5 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	• Newton's Law of Universal Gravitation can be used to determine the force between objects separated by a known distance, and the distance between objects with a known gravitational attraction. <u>Skills</u> • Qualitatively explain motion in terms of Newton's Laws. • Solve problems involving force (F), mass (m), and acceleration (a). • Solve problems related to free-falling objects, including 2-D motion. • Solve problems using Newton's Law of Universal Gravitation • Solve problems using the coefficient of friction. • Solve problems involving multiple forces, using free-body diagrams.

Standard PH.5 g

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

g) work, power, and energy.

Essential Understandings	Essential Knowledge and Skills
• *Energy* is the capacity to do work. Work and energy are expressed in the same units, but are not identical. • When work is done, energy converts from one form to another and energy is conserved.	Knowledge • *Work* is the product of the force exerted on an object and the distance the object moves in the direction of the force. • *Power* is the rate of doing work. • Work and energy are measured in Joules, which is a derived unit equal to a Nm or kgm^2/s^2. • Power is measured in Watts, which is a derived unit equal to a J/s. Skills • Solve problems involving work, power, and energy.

Standard PH.6 a, b

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

a) kinetic and potential energy; and
b) elastic and inelastic collisions.

Essential Understandings	Essential Knowledge and Skills
• *Kinetic energy* is energy of motion. • *Potential energy* is energy due to an object's position or state. • 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, such as heat. • Quantities such as energy and momentum are conserved when they are exchanged or transformed, and their total quantity remains the same.	<u>Skills</u> • Calculate potential and kinetic energy from theoretical and experimental situations. • Model conservation of energy and momentum, using elastic and inelastic collisions.

Standard PH.6 c

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

c) electric power.

Essential Understandings	Essential Knowledge and Skills
• Electrical charge moves through electrical circuits and is conserved.	Knowledge • *Electric power* (watt) is change in electrical energy divided by corresponding change in time. • *Current* (ampere) is the amount of charge that moves through a circuit element divided by the elapsed time. • *Electric potential difference* (voltage) is change in electric potential energy per unit charge. • In any system of electrical charge, electrical movement, or electrical interaction, both charge and energy are conserved.

Standard PH.7 a, b, c, d, e, f

The student will investigate and understand properties of fluids. Key concepts include

a) density and pressure;
b) variation of pressure with depth;
c) Archimedes' principle of buoyancy;
d) Pascal's principle;
e) fluids in motion; and
f) Bernoulli's principle.

Essential Understandings	Essential Knowledge and Skills
• Density of solids and liquids is measured using the same units. • The pressure of a fluid depends on the depth of the fluid and not on the shape or size of the container. • In a moving fluid, internal pressure and speed are inversely related. • Floating objects displace a volume of fluid that has a weight equal to the floating object. • Submerged objects displace a volume of fluid equal to the volume of the submerged object. • The buoyant force on an object is equal to the weight of the fluid displaced by that object.	<u>Skills</u> • Determine if a given object will float or sink in water, given its mass and volume or dimensions. • Explain phenomenon applying the appropriate principle. - the flight of a curve ball - the flight of a golf ball - the factors that allow airplanes to fly - the fact that humans sink in water as they exhale.

Standard PH.8 a, b

The student will investigate and understand that energy can be transferred and transformed to provide usable work. Key concepts include

a) transformation of energy among forms including mechanical, thermal, electrical, gravitational, chemical, and nuclear; and
b) efficiency of systems.

Essential Understandings	Essential Knowledge and Skills
• Energy can be transformed from one form to another. (Example: Falling water turns a turbine that generates electricity and produces heat and light in a classroom.) • *Efficiency* of a machine is the ratio of output work to input work.	Skills • 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 forms of energy transformations in simple demonstrations.

Standard PH.9 a

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

a) wave characteristics (period, wavelength, frequency, amplitude, and phase).

Essential Understandings	Essential Knowledge and Skills
• Mechanical waves transport energy as a traveling disturbance in a medium. • In a transverse wave, particles of the medium move in a direction perpendicular to the direction the wave travels. • In a longitudinal wave, particles of the medium move in a direction parallel to the direction the wave travels. • For harmonic waves, velocity equals the product of the frequency and the wavelength. • Frequency and period are reciprocals of each other.	<u>Knowledge</u> • Period, wavelength, and frequency are measured in seconds, meters, and Hertz. <u>Skills</u> • Identify examples of longitudinal and transverse waves. • Differentiate between transverse and longitudinal waves, using simple models (slinky, stadium waves). • Illustrate period, wavelength, and amplitude on a graphic representation of a harmonic wave. • Solve problems involving frequency, period, wavelength, and velocity. • Distinguish between waves that are in-phase and those that are out-of-phase.

Standard PH.9 b, c

The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include

b) fundamental wave processes (reflection, refraction, diffraction, interference, polarization, Doppler effect); and
c) light and sound in terms of wave models.

Essential Understandings	Essential Knowledge and Skills
• Waves are reflected and refracted when they encounter a change in medium or a boundary. • The overlapping of two or more waves results in constructive or destructive interference. • Polarizing filters can transmit one direction of polarized light and block the other. • When source and observer are in relative motion, a shift in frequency occurs (Doppler effect). • Sound is a longitudinal wave that travels through matter. • Light is an electromagnetic wave (transverse) that can travel through matter as well as a vacuum.	<u>Knowledge</u> • *Reflection* is the change of direction of the wave in the original medium. • *Refraction* is the change of direction (bending) of the wave in the new medium. • *Diffraction* is the spreading of a wave around a barrier or an aperture. • The pitch of a note is determined by the frequency of the sound wave. • The color of light is determined by the frequency of the light wave. • As the amplitude of a sound wave increases, the loudness of the sound increases. • As the amplitude of a light wave increases, the brightness of the light increases.

Standard PH.9 b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	Skills • Graphically illustrate reflection and refraction of a wave when it encounters a change in medium or a boundary. • Graphically illustrate constructive and destructive interference. • Identify a standing wave, using a string.

Standard PH.10 a, b

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 and behaviors of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays; and
b) current applications based on the wave properties of each band.

Essential Understandings	Essential Knowledge and Skills
• Frequency, wavelength, and energy vary across the entire electromagnetic spectrum.	<u>Knowledge</u> • The long wavelength, low frequency portion of the electromagnetic spectrum is used for communication (e.g., radio, TV, cellular phone). • Medium wavelengths (infrared) are used for heating and night-vision-enhancing devices. • Visible light comprises a very narrow portion of the electromagnetic spectrum. • Ultraviolet wavelengths (shorter than the visible spectrum) are responsible for sunburn. • X-rays and gamma rays are the highest frequency and shortest wavelength and are used primarily for medical purposes.

Standard PH.11 a, b

The student will investigate and understand, in describing optical systems, how light behaves in the fundamental processes of reflection, refraction, and image formation. Key concepts include

a) application of the laws of reflection and refraction; and
b) construction and interpretation of ray diagrams.

Essential Understandings	Essential Knowledge and Skills
• The ray model of light can be used to understand the behavior of optical systems. • Light incident on a smooth plane surface is reflected such that the angle of incidence equals the angle of reflection. • Light incident on a smooth surface is refracted (transmitted) in such a manner that the ratio of the sine of the angle of incidence and the sine of the angle of refraction equals a constant.	<u>Knowledge</u> • For a converging lens, the focal point is the point at which a beam of light parallel to the principal axis converges. • For a diverging lens, the focal point is the point from which a beam of light parallel to the principal axis appears to originate. • A real image is formed by converging lights rays and can be displayed on a screen. • A virtual image can be seen by an observer but cannot be projected on a screen because the light does not actually emanate from the image. • The focal point is the point at which rays converge or from which they appear to diverge in a lens or mirror. • The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium.

Standard PH.11 a, b (continued)

Essential Understandings	Essential Knowledge and Skills
	Skills • Investigate propagation, refraction, and reflection, using the ray model of light. • Construct ray diagrams to verify the laws of reflection and refraction.

Standard PH.11 c, d

The student will investigate and understand, in describing optical systems, how light behaves in the fundamental processes of reflection, refraction, and image formation. Key concepts include

c) development and use of mirror and lens equations; and
d) predictions of types, size, and position of real and virtual images.

Essential Understandings	Essential Knowledge and Skills
• The mirror and thin lens equation can be used to calculate the position of the object or image based on the focal length of the mirror or lens.	<u>Skills</u> • Solve problems dealing with object and image distance, object and image size, and focal length, using the lens and mirror equations. • Illustrate characteristics of real and virtual images, using examples (lens and mirror). • Identify the type (real and virtual) and size of image formed by concave lenses and by convex lenses when the object is located at various locations including inside the focal point, at the focal point, at twice the focal point, and beyond twice the focal point.

Standard PH.12 a, b

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) operating principles of motors, generators, transformers, and cathode ray tubes.

Essential Understandings	Essential Knowledge and Skills
• The force found from Newton's law and Coulomb's law is dependent on the inverse square of the distance between two objects. • 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) is always an attractive force. • The interaction of two particles can be described as a two-step process: the creation of a field by one of the particles and the interaction of the field with the second particle.	<u>Knowledge</u> • Newton's Law of Universal Gravitation states that every particle in the universe attracts every other particle in the universe. $F = G (m_1m_2)/r^2$. (F is the force, G is the universal gravitation constant, m is the mass of the two particles, and r is the distance between them.) • Coulomb's law states that the magnitude F of the electrostatic force exerted by one point charge on another point charge is directly proportional to the magnitudes of q1 and q2 of the charges and inversely proportional to the square of the distance r between them: $F = k (q_1q_2)/r^2$. • The rotation of the coil of a motor or a generator through a magnetic field is used to transfer energy.

Standard PH.13 a, b, c

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

a) Ohm's law;
b) series, parallel, and combined circuits; and
c) circuit components including resistors, batteries, generators, fuses, switches, and capacitors.

Essential Understandings	Essential Knowledge and Skills
• Current is the flow of electrical charge. • Voltage in a circuit provides the energy that drives the current. • Elements in a circuit are positioned relative to other elements either in series or parallel.	<u>Knowledge</u> • According to Ohm's law, the resistance equals the voltage divided by the current. • Voltage difference is change in electrical potential energy per unit charge. <u>Skills</u> • Recognize a series and a parallel circuit. • Apply Ohm's law to a series and a parallel circuit. • Assemble simple circuits composed of batteries and resistors in series and in parallel. • Solve simple circuits using Ohm's law.

Standard PH.14 a, b, c, d

The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied by Newtonian physics. Key concepts include

a) wave/particle duality;
b) wave properties of matter;
c) matter/energy equivalence; and
d) quantum mechanics and uncertainty.

Essential Understandings	Essential Knowledge and Skills
• 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). • The special theory of relativity predicts that energy and matter can be converted into each other.	<u>Knowledge</u> • Electrons rotating around the nucleus of an atom can be treated as standing waves in order to model the atomic spectrum. • The dramatic examples of the mass-energy transformation are the fusion of hydrogen in the sun, which provides light and heat for the earth, and the fission process in nuclear reactors that provide electricity. • 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.

Standard PH.14 e, f, g, h. i

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 include

e) relativity;
f) nuclear physics;
g) solid state physics;
h) superconductivity; and
i) radioactivity.

Essential Understandings	Essential Knowledge and Skills
• 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. • Nuclear physics is the study of the interaction of the protons and neutrons in the atom's nucleus. • Natural radioactivity is the spontaneous disintegration of unstable nuclei. • Atoms and molecules bind together in regular arrays to form crystals. The structure of these crystals is important in determining the properties of these materials (appearance, hardness, etc.). • Certain materials at very low temperatures exhibit the property of zero resistance called *superconductivity*.	<u>Knowledge</u> • Objects cannot travel faster than the speed of light. • The nuclear force binds protons and neutrons in the nucleus. • Alpha, beta, and gamma are different emissions associated with radioactive decay. • *Fission* is the breakup of heavier nuclei to lighter nuclei. • *Fusion* is the combination of lighter nuclei to heavier nuclei. • Many substances in the natural world have a crystal structure, including most metals and minerals.