



This document is designed to help North Carolina educators teach the Essential Standards (Standard Course of Study). NCDPI staff are continually updating and improving these tools to better serve teachers.

Essential Standards: Physics • Unpacked Content

For the new Essential Standards that will be effective in all North Carolina schools in the 2012-13.

What is the purpose of this document?

To increase student achievement by ensuring educators understand specifically what the new standards mean a student must know, understand and be able to do.

What is in the document?

Descriptions of what each standard means a student will know, understand and be able to do. The “unpacking” of the standards done in this document is an effort to answer a simple question “What does this standard mean that a student must know and be able to do?” and to ensure the description is helpful, specific and comprehensive for educators.

How do I send Feedback?

We intend the explanations and examples in this document to be helpful and specific. That said, we believe that as this document is used, teachers and educators will find ways in which the unpacking can be improved and made ever more useful. Please send feedback to us at feedback@dpi.state.nc.us and we will use your input to refine our unpacking of the standards. Thank You!

Just want the standards alone?

You can find the standards alone at <http://dpi.state.nc.us/acre/standards/new-standards/#science> .

Note on Numbering: **Phy**–Physics

Forces and Motion

Essential Standard and Clarifying Objectives

Phy.1.1 Analyze the motion of objects.

Phy.1.1.1 Analyze motion graphically and numerically using vectors, graphs and calculations.

Phy.1.1.2 Analyze motion in one dimension using time, distance, and displacement, velocity, and acceleration.

Phy.1.1.3 Analyze motion in two dimensions using angle of trajectory, time, distance, displacement, velocity, and acceleration.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.1.1.1

- Identify a frame of reference for measurement of position.
- Compare scalar-vector quantities (distance-displacement and speed-velocity).
- Use vector addition to determine resultant displacement and velocity.
- Describe (conceptually, mathematically and graphically) the velocity of an object as the rate of change of position; distinguish between constant, average and instantaneous velocity.
- Clarify that a positive value for velocity indicates motion in one direction while a negative value indicates motion in the opposite direction.
- Analyze position versus time graphs of an object moving with constant velocity:
 - recognize a linear relationship provided by a best-fit line where velocity is the slope of the line , $\bar{v} = \frac{\Delta x}{\Delta t}$;
 - apply the slope-intercept equation, $y = mx + b$, to derive the relationship for final position, $x_f = x_i + vt$.
- Analyze position versus time graphs of an object moving with constant acceleration:
 - compare to the graph of an object moving at constant velocity;
 - recognize the shape of the curve as parabolic indicating that position is proportional to the square of the time;
 - relate the concept of instantaneous velocity to the slope of the tangent line.
- Describe (conceptually, mathematically and graphically) the acceleration of an object as the rate of change of velocity.
- Clarify that a negative value for acceleration indicates that an object is slowing down when velocity is positive while a negative value for acceleration indicates that an object is speeding up when velocity is negative.

- Analyze velocity versus time graphs of an object moving with constant acceleration:
 - recognize the slope of the line as the acceleration, $a = \frac{\Delta v}{\Delta t}$;
 - recognize that the displacement during any time period is equal to the area under the graph;
 - develop the relationships for objects moving at constant acceleration (such as rolling down an inclined plane or falling toward the Earth), $x_f = x_i + v_i t + \frac{1}{2} a t^2$ and $v_f^2 = v_i^2 + 2a\Delta x$.
- Analyze position vs. time, velocity vs. time, and acceleration vs. time graphs of objects in motion; identify the motion as constant velocity or accelerating based on the shape of the graph; interpret the graph in order to quantitatively describe the motion.

Phy.1.1.2

Analyze situations of motion in one dimension (linear motion) in order to solve problems by applying mathematical relationships for the following:

- constant velocity

$$v = \frac{\Delta x}{\Delta t}$$

$$x_f = x_i + vt$$

- constant acceleration

$$a = \frac{\Delta v}{\Delta t}$$

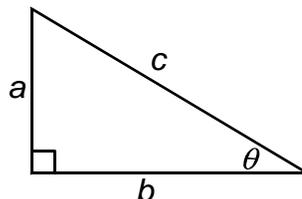
$$x_f = x_i + v_i t + \frac{1}{2} a t^2$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

Phy.1.1.3

- Analyze projectile motion to:
 - determine that horizontal and vertical components are independent of each other;
 - determine that the horizontal component of velocity does not change (neglecting air resistance) and the vertical component of velocity changes due to gravity;
 - determine that for a projectile launched from the ground at an angle, the vertical component of velocity at the maximum height has a value of zero while the horizontal component remains constant;

- resolve vectors into vertical and horizontal components using trigonometric relationships.



$$a^2 + b^2 = c^2$$

$$\sin \theta = \frac{a}{c}$$

$$\cos \theta = \frac{b}{c}$$

$$\tan \theta = \frac{a}{b}$$

- apply conceptual and mathematical relationships for uniform velocity for the horizontal component of velocity and range (horizontal displacement);
- apply conceptual and mathematical relationships for uniform acceleration with the vertical component of velocity and height (vertical displacement).
- Analyze circular motion to:
 - determine that an object may move with constant speed but changing velocity;
 - determine that the directions of velocity and acceleration vectors are perpendicular to each other;
 - determine the relationship between acceleration and velocity (squared), and between acceleration and radius of curvature (inverse), $a_c = \frac{v^2}{r}$.
- Solve problems involving motion of planes and boats due to winds or river currents using vector addition.

Essential Standard and Clarifying Objectives

Phy.1.2 Analyze systems of forces and their interaction with matter.

Phy.1.2.1 Analyze forces and systems of forces graphically and numerically using vectors, graphs, and calculations.

Phy.1.2.2 Analyze systems of forces in one dimension and two dimensions using free body diagrams.

Phy.1.2.3 Explain forces using Newton's laws of motion as well as the universal law of gravitation.

Phy.1.2.4 Explain the effects of forces (including weight, normal, tension and friction) on objects.

Phy.1.2.5 Analyze basic forces related to rotation in a circular path (centripetal force).

Unpacking

What does this standards mean a child will know and be able to do?

Phy.1.2.1

- From a free body diagram, assess the interdependence of vector components of forces; resolve forces into perpendicular components.
- Apply Newton's second law as the sum of all forces in a given direction so that the net force acting on an object in static equilibrium is zero and in a dynamic situation equal to ma .

Phy.1.2.2

- Analyze systems of forces involving
 - objects at rest (on a surface or suspended),
 - objects pulled or pushed along a horizontal surface by an applied force that is either parallel to the surface or applied at an angle,
 - objects sliding or rolling down an inclined plane,
- Distinguish forces on objects based on interactions including contact and forces at a distance (normal force, weight, friction, tension, applied force).

Phy.1.2.3

- Conclude that an object will continue in a state of motion (rest or constant velocity) unless acted upon by a net outside force (Newton's first law of motion – the law of inertia).
- Explain the law of inertia as a cause and effect relationship between an observed change in motion and the presence of an unbalanced or net force.

- Conceptually and mathematically describe the acceleration of an object in terms of its mass and the net force applied (Newton's second law- the law of acceleration), $a = \frac{F_{net}}{m}$ or $F_{net} = ma$.
- Apply proportional reasoning to determine the effect of changing one quantity while another is held constant – if the force on a mass is doubled, the resulting acceleration would be doubled (direct proportion); if an equal force is applied to an object with double the mass, its acceleration would be half that of the first object (inverse proportion).
- Conclude that while Newton's second law describes a single object, forces always come in equal and opposite pairs due to interaction between objects. Give examples of interaction between objects describing Newton's third law – whenever one object exerts a force on another, an equal and opposite force is exerted by the second on the first. The third law can be written mathematically as $F_{A \rightarrow B} = -F_{B \rightarrow A}$.
- Explain gravity as a force of attraction between objects due to their mass that decreases with the distance between them; develop the mathematical relationship given by the universal law of gravitation, $F_G = \frac{Gm_1m_2}{r^2}$.

Phy.1.2.4

Construct a cause and effect relationship for interactions between objects that include

- weight as the force of gravity directed toward the Earth,
- normal force as a support force when an object is in contact with another stable object (always acts perpendicular to the surface),
- tension as a force transmitted through and directed along the length of a string, rope, cable or wire due to forces acting at opposite ends,
- friction as a force opposing motion of an object due to contact between surfaces (static or kinetic),
- air resistance as a frictional force acting on objects traveling through the air.

Phy.1.2.5

- Recognize the cause and effect relationship between centripetal force and the change in velocity due to change in direction (centripetal acceleration) of an object as an example of Newton's second law, $F_c = ma_c$;
- Recognize that a centripetal force is *not* the result of circular motion but is provided by interaction with another object.

Essential Standard and Clarifying Objectives

Phy.1.3 Analyze the motion of objects based on the principles of conservation of momentum, conservation of energy and impulse.

Phy.1.3.1 Analyze the motion of objects in completely elastic and completely inelastic collisions by using the principles of conservation of momentum and conservation of energy.

Phy.1.3.2 Analyze the motion of objects based on the relationship between momentum and impulse.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.1.3.1

- Conclude that the total momentum before an interaction is equal to the total momentum after the interaction as long as there are no external forces – the law of conservation of momentum.
- Analyze conservation of momentum and conservation of kinetic energy in the following instances:
 - two objects initially at rest push each other apart,
 - a moving object collides with a stationary object and the two objects stick together,
 - a moving object collides with a stationary object and the two objects move off separately,
 - two moving objects collide and either stick together or move off separately.
- Distinguish between elastic and inelastic collisions – both kinetic energy and momentum are conserved in elastic collisions while objects are deformed and kinetic energy is converted to other forms (generally heat) in inelastic collisions.
- Relate the concept of completely elastic collisions to molecules of an ideal gas.
- Solve problems involving conservation of momentum in collisions.

Phy.1.3.2

- Define momentum as a vector quantity proportional to the product of mass and velocity, $p = mv$; distinguish momentum from inertia and velocity; develop a conceptual understanding that the same momentum could be associated with a slow-moving massive object and an object moving at high velocity with a very small mass (e.g. - 100 kg object moving 1 m/s has the same momentum as a 1-kg object moving 100m/s).
- Conceptually and mathematically analyze Newton's second law to relate the change in momentum, $\Delta p = m\Delta v$, to acceleration in order to develop the impulse-momentum relationship – the impulse applied to an object is equal to the resulting change in momentum.

$$F_{net} = ma = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} \text{ or } F_{net}\Delta t = m\Delta v$$

- Analyze a force vs. time graph; compare the area under the graph to a calculated change in momentum.
- Analyze real world examples including the use of airbags in cars, time of contact and “follow-through” in throwing, catching, kicking, and hitting objects in sports, and bending your knees when you jump from a height to the ground to prevent injury.

Energy: Conservation and Transfer

Essential Standard and Clarifying Objectives

Phy.2.1 Understand the concepts of work, energy, and power, as well as the relationship among them.

Phy.2.1.1 Interpret data on work and energy presented graphically and numerically.

Phy.2.1.2 Compare the concepts of potential and kinetic energy and conservation of total mechanical energy in the description of the motion of objects.

Phy.2.1.3 Explain the relationship among work, power and energy.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.2.1.1

- Identify work as the transfer of energy by a force acting through a distance, when that force acts in the direction of motion of the object, $W = F\Delta x$.
- Interpret a graph of force vs. distance for the displacement of an object by a constant force; the area under the graph is equal to the work done by the force on the object; work is a scalar quantity.
- Explain the work-energy relationship involving
 - work done in lifting an object vertically to the change in gravitational potential energy, $PE_g = mgh$.
 - work done in setting an object in motion to the change in kinetic energy, $KE = \frac{1}{2}mv^2$.

- work done in stretching or compressing a spring to the change in elastic potential energy, $PE_s = \frac{1}{2}kx^2$.

Phy.2.1.2

- Compare conceptually and mathematically situations involving potential-kinetic energy transformations (pendulum, falling object, roller coaster, inclined plane, block-spring system) indicating the amount of energy at various locations.
- Summarize the concept of energy conservation - energy can be stored and transferred, but cannot be created or destroyed.
- Conclude that in all situations, energy tends to dissipate throughout the environment generally due to friction resulting in heat transfer.

Phy.2.1.3

- Define power as the rate of doing work (transferring energy), $P = \frac{W}{\Delta t} = F\bar{v}$.
- Explain that while it takes the same amount of energy (same amount of work) to walk or run up a flight of stairs, the power is different.

Essential Standard and Clarifying Objectives

Phy.2.2 Analyze the behavior of waves.

Phy.2.2.1 Analyze how energy is transmitted through waves, using the fundamental characteristics of waves: wavelength, period, frequency, amplitude, and wave velocity.

Phy.2.2.2 Analyze wave behaviors in terms of transmission, reflection, refraction and interference.

Phy.2.2.3 Compare mechanical and electromagnetic waves in terms of wave characteristics and behavior (specifically sound and light).

Unpacking

What does this standards mean a child will know and be able to do?

Phy.2.2.1

- Analyze basic properties of waves in pendulums, mass-spring system, ropes, tuning forks, large coil (Slinky®) springs, and ripple tanks connecting prior knowledge of work-energy theorem and vibratory motion to the transfer of energy through a medium.
- Conceptually, graphically and mathematically define and organize the characteristics of wavelength, period, frequency, amplitude and wave speed to these varied situations to include

- an inverse relationship between period and frequency, $T = \frac{1}{f}$,
- the relationship between wave speed, frequency and wavelength, $v = f\lambda$,
- that amplitude is related to wave energy,
- that wave speed in a mechanical wave is determined by the medium (density and elasticity) and is independent of frequency or amplitude(energy).
- Analyze the change in frequency due to motion of a wave source or receiver – the Doppler effect; identify pitch as an interpretation of the frequency of sound and color as the perception of visible light frequency.

Phy.2.2.2

- Analyze transmission, refraction, and reflection of waves to conclude the following:
 - Mechanical waves require a medium while electromagnetic waves can travel in a vacuum;
 - When waves encounter a new medium the energy may be absorbed by the molecules of the material, transmitted changing speed (refracted) or reflected from the surface.
 - Electromagnetic waves travel at the speed of light, c , in air or a vacuum and slow down as they enter other transparent materials according to the mathematical relationships relating wave speed, v , index of refraction, n , and angle of light measured from the normal: $n = \frac{c}{v}$, $n_1v_1 = n_2v_2$, $n_1 \sin \theta_1 = n_2 \sin \theta_2$ (Snell's Law);
 - The angle that light strikes a boundary determines if it is transmitted into another transparent material or reflected;
 - The angle beyond which all light is reflected (total internal reflection) is called the critical angle and can be found from the relationship $\sin \theta_c = \frac{n_2}{n_1}$;
 - Light waves are reflected from a smooth surface according to the law of reflection – the angle of incidence is equal to the angle of reflection.
- Analyze interference and the principle of superposition in waves (mechanical and electromagnetic) to distinguish between constructive and destructive interference.

Phy.2.2.3

- Compare mechanical and electromagnetic waves in terms of the following:
 - how they are produced,
 - wave speed,
 - type of material (medium) required,

- motion of particles,
- patterns for refraction related to medium,
- reflection,
- interference,
- the Doppler effect.
- Compare characteristics of types of mechanical waves – longitudinal (compressional), transverse and surface waves – in terms of how they are produced and motion of particles.
- Identify sound as a compressional wave and visible light as an electromagnetic wave.

Essential Standard and Clarifying Objectives

Phy.2.3 Analyze the nature of moving charges and electric circuits.

Phy.2.3.1 Explain Ohm's law in relation to electric circuits.

Phy.2.3.2 Differentiate the behavior of moving charges in conductors and insulators.

Phy.2.3.3 Compare the general characteristics of AC and DC systems without calculations.

Phy.2.3.4 Analyze electric systems in terms of their energy and power.

Phy.2.3.5 Analyze systems with multiple potential differences and resistors connected in series and parallel circuits, both conceptually and mathematically, in terms of voltage, current and resistance.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.2.3.1

- Recognize that a difference in potential (voltage) creates current within a conductor; the amount of current also depends on the resistance of the conductor.
- Develop a cause-and-effect model for current in a circuit - current is directly proportional to the voltage and inversely proportional to the resistance (Ohm's law), $I = \frac{V}{R}$ or $V = IR$.
- Given a schematic circuit diagram, determine current, voltage, or resistance from two known quantities.

Phy.2.3.2

- Identify conductors as materials that have electrons that are free to move throughout the sample; Metals are good conductors of electrical charge.
- Identify insulators as materials where electrons are held tightly to individual nuclei; Rubber and glass are examples of insulators that because of their properties develop static charge readily through friction with other materials.
- Explain classification as a conductor or insulator based on the ability of electric charge to move through the material.

Phy.2.3.3

Compare alternating and direct current systems based on the source of electrical energy, transmission over distances, ease of use in varied electrical devices, etc.

Phy.2.3.4

- Develop the concept of power using dimensional analysis (unit cancellation) where electrical power can be calculated from current, voltage and/or resistance measurements, $P = VI = I^2R = \frac{V^2}{R}$.
- Since power is defined as the rate of work done or energy transferred, energy used by a device can be calculated by multiplying power and time, $E_e = Pt$.

Phy.2.3.5

- Analyze series circuits to distinguish the following patterns for current, voltage, and equivalent resistance:
 - Current is the same throughout the circuit, $I_t = I_1 = I_2 = I_3 = \dots$
 - Voltage drop across each resistor is proportional to the resistance and additive for the circuit, $V_t = V_1 + V_2 + V_3 + \dots$
 - Equivalent resistance for the circuit is the sum of resistances, $R_{eq} = R_1 + R_2 + R_3 + \dots$
- Analyze parallel circuits to distinguish the following patterns for current, voltage, and equivalent resistance:
 - Current in parallel branches divides in an inverse proportion to the resistance; the sum of the current through each device equals the current supplied, $I_t = I_1 + I_2 + I_3 + \dots$
 - Voltage drop across each branch is the same, $V_t = V_1 = V_2 = V_3 = \dots$
 - Equivalent resistance for the parallel branch is the inverse of the sum of the resistance reciprocals, $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ (Equivalent resistance in a parallel arrangement is lower than any one resistance in the arrangement.)

- Conclude that multiple potential difference (voltage) sources are additive when arranged in series; current moving from positive to negative constitutes a negative potential difference. (e.g. - Two six volt batteries in series connecting positive to negative terminals have a combined potential difference of twelve volts; a six volt battery in series connecting positive to positive terminals with a three volt battery would establish a combined potential difference of three volts.) *Network circuits where a second emf is located in a branch should not be included in the standard level course.*
- Analyze series-parallel combination circuits by determining equivalent resistance of portions of the circuit until it can be reduced to a simple series or parallel circuit.

Interactions of Energy and Matter

Essential Standard and Clarifying Objectives

Phy.3.1 Explain charges and electrostatic systems.

Phy.3.1.1 Explain qualitatively the fundamental properties of the interactions of charged objects.

Phy.3.1.2 Explain the geometries and magnitudes of electric fields.

Phy.3.1.3 Explain how Coulomb's law relates to the electrostatic interactions among charged objects.

Phy.3.1.4 Explain the mechanisms for producing electrostatic charges including charging by friction, conduction, and induction.

Phy.3.1.5 Explain how differences in electrostatic potentials relate to the potential energy of charged objects.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.3.1.1

- Identify basic principles related to the nature of electrical charge – like charges repel and opposite charges attract; there are two types of electric charge (positive and negative); positively charged objects have an electron deficiency while negatively charged objects have an excess of electrons.
- Conclude that charge is conserved in a closed system – since charge is a result of fundamental properties of particles, charge (like atoms) cannot be created nor destroyed.

Phy.3.1.2

- Construct diagrams to illustrate electric fields and explain its vector nature -
 - around single positive and negative charges,
 - between a pair of like charges,
 - between a pair of unlike charges,
 - two oppositely charged parallel plates,
 - a hollow sphere,
 - an irregular shaped metal object.
- Compare the strength of various points in an electric field where
 - $E = \frac{F}{q}$ or $\frac{kq}{r^2}$ and $V = \frac{kq}{r}$ for a point charge
 - $E = \frac{V}{d}$ for the uniform electric field between parallel plates.
- Distinguish between charge distribution on plates and a hollow conducting sphere where no electric field exists inside.

Phy.3.1.3

- Conceptually and mathematically explain electrical attraction and repulsion using Coulomb's law - the electrical force is directly proportional to the product of two charges and inversely proportional to the square of the distance between them, $F_e = \frac{kq_1q_2}{r^2}$.
- Determine the magnitude and direction of an electric force between two charges.

Phy.3.1.4

Explain situations where objects become charged (by friction, conduction or induction) in terms of the transfer or rearrangement of electrons -

- two neutral objects charged by friction,
- a neutral object becoming positively charged by induction and conduction,
- a neutral object becoming negatively charged by induction and conduction.

Phy.3.1.5

- Compare work done on an object by lifting (changes in location in a gravitational field) to work done on a charged particle by pushing it against the electric field of a charged object – both positive and negative.
- Define electric potential energy as the energy of a charge based on its location and distinguish electric potential (voltage) as being the same for all charges.

- Conclude that a gravitational field is always in one direction while electric fields have two possible directions; by convention, the direction is determined by the direction of force on a positive test charge – away from (out of) a positive charge and toward (into) a negative charge.

Essential Standard and Clarifying Objectives

Phy.3.2 Explain the concept of magnetism.

Phy.3.2.1 Explain the relationship between magnetic domains and magnetism.

Phy.3.2.2 Explain how electric currents produce various magnetic fields.

Phy.3.2.3 Explain how transformers and power distributions are applications of electromagnetism.

Unpacking

What does this standards mean a child will know and be able to do?

Phy.3.2.1

- Define magnetic domains and compare alignment of domains in a piece of magnetic and nonmagnetic material.
- Interpret magnetic field lines in space surrounding bar magnets.
- Summarize the attractions of unlike poles and the repulsion of like poles.
- Develop a cause-and-effect model for magnetism relating electron-spin (charge in motion) of ferromagnetic elements to orientation and alignment of domains.

Phy.3.2.2

- Construct a model showing magnetic fields produced around a current-carrying wire and wire coil (solenoid).
- Compare the strength of an electromagnet with varied number of coils, voltage, and/or core material.
- Develop a cause-and-effect model for electromagnetism relating current (movement of charge) to the production of a magnetic field.

Phy.3.2.3

- Explain the process of electromagnetic induction as described by Faraday's law - the induced voltage in a coil is proportional to the product of the number of loops and the rate at which the magnetic field changes within the loops. (No mathematical calculations.)

- Summarize the production of alternating current using a generator (rotating wire loop in a magnetic field) and explain the energy transformation – mechanical energy converted to electrical energy.
- Explain the use of transformers to alter the voltage/current; recognize that the law of conservation of energy requires that an increase in one quantity is accompanied by a decrease in the other so that the product of current and voltage (power) is ideally constant, $\frac{V_p}{N_p} = \frac{V_s}{N_s}$,

$$P_{in} = P_{out} \text{ or } V_p I_p = V_s I_s$$

- Explain why transformers are not 100% efficient.