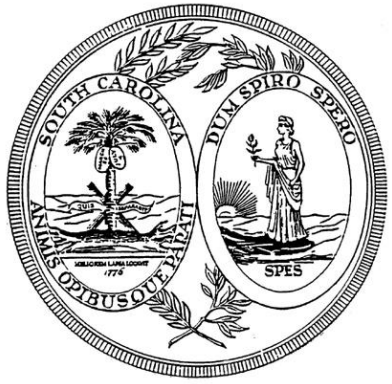
South Carolina Academic Standards and Performance Indicators for Science 2014



Instructional Unit Resource

Physics

South Carolina Academic Standards and Performance Indicators for Science 2014 Physics Instructional Unit Resource

As support for implementing the *South Carolina Academic Standards and Performance Indicators for Science 2014*, the standards for Physics have been grouped into possible units. In the Overview of Units below, the titles for those possible units are listed in columns. Refer to the Overview document to note these unit titles and how Standards, Conceptual Understandings, Performance Indicators, Science and Engineering Practices, and Crosscutting Concepts align. Following the Overview of Units, an Instructional Unit document is provided that delivers guidance and possible resources in teaching our new *South Carolina Academic Standards and Performance Indicators for Science 2014*. The purpose of this document is to provide guidance as to how all the standards in this grade may be grouped into units and how those units might look. Since this document is merely guidance, districts should implement the standards in a manner that addresses the district curriculum and the needs of students. This document is a living document and instructional leaders from around the state will continuously update and expand these resource documents. These documents will be released throughout the 2016-2017 school year with the intentionality of staying ahead of instruction. Teachers should also note that links to the Standards document, A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas, the SEP Support Document, and the Support Document 2.0 are embedded throughout the Instructional Unit format for reference.

Acknowledgments

Jean Baptiste Massieu, famous deaf educator, made a statement that is now considered a French proverb. “Gratitude is the memory of the heart. Indeed, appreciation comes when you feel grateful from the depths of your heart. The head keeps an account of all the benefits you received and gave. But the heart records the feelings of appreciation, humility, and generosity that one feels when someone showers you with kindness.” It is with sincere appreciation that we humbly acknowledge the dedication, hard work and generosity of time provided by teachers and instructional leaders across the state that have made and are continuing to make the Instructional Unit Resources possible.

Physics Overview of Units

Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
FORCES AND MOTION	WORK, ENERGY, AND MOMENTUM	ELECTRICITY AND MAGNETISM	WAVES	LIGHT AND OPTICS	THERMODYNAMICS	NUCLEAR AND MODERN PHYSICS
Standard	**Standard**	**Standard**	**Standard**	**Standard**	**Standard**	**Standard**
H.P.1 H.P.2	H.P.1 H.P.2 H.P.3	H.P.1 H.P.2 H.P.3	H.P.1 H.P.3	H.P.1 H.P.3	H.P.1 H.P.3	H.P.1 H.P.3
Conceptual Understanding	**Conceptual Understanding**	**Conceptual Understanding**	**Conceptual Understanding**	**Conceptual Understanding**	**Conceptual Understanding**	**Conceptual Understanding**
H.P.2A H.P.2B H.P.2C	H.P.2B H.P.3A H.P.3B	H.P.2D H.P.3E	H.P.3D	H.P.3F	H.P.3C	H.P.3G
Performance Indicators	**Performance Indicators**	**Performance Indicators**	**Performance Indicators**	**Performance Indicators**	**Performance Indicators**	**Performance Indicators**
H.P2A.1 H.P.2B.8 H.P.2A.2 H.P.2B.9 H.P.2A.3 H.P.2B.10 H.P.2A.4 H.P.2C.1 H.P.2A.5 H.P.2C.2 H.P.2A.6 H.P.2C.3 H.P.2B.1 H.P.2C.4 H.P.2B.2 H.P.2C.5 H.P.2B.3	H.P.2B.4 H.P.3A.3 H.P.2B.5 H.P.3A.4 H.P.2B.6 H.P.3A.5 H.P.2B.7 H.P.3B.1 H.P.3A.1 H.P.3B.2 H.P.3A.2 H.P.3B.3	H.P.2D.1 H.P.3E.5 H.P.2D.4 H.P.3E.6 H.P.2D.5 H.P.3E.7 H.P.2D.7 H.P.3E.1 H.P.3E.2 H.P.3E.3 H.P.3E.4	H.P.3D.1 H.P.3D.2 H.P.3D.3 H.P.3D.4	H.P.3F.1 H.P.3F.2 H.P.3F.3 H.P.3F.4 H.P.3F.5 H.P.3F.6	H.P.3C.1 H.P.3C.2 H.P.3C.3 H.P.3D.1	H.P.3G.1 H.P.3G.2 H.P.3G.3 H.P.3G.4 H.P.3G.5
***Science and Engineering Practices**	***Science and Engineering Practices**	***Science and Engineering Practices**	***Science and Engineering Practices**	***Science and Engineering Practices**	***Science and Engineering Practices**	***Science and Engineering Practices**
S.1A.2 S.1A.5 S.1A.3 S.1A.6 S.1A.4 S.1A.8	S.1A.2 S.1A.7 S.1A.3 S.1A.8 S.1A.5	S.1A.2 S.1A.6 S.1A.3 S.1A.8 S.1A.5 S.1B.1	S.1A.2 S.1A.5 S.1A.6	S.1A.1 S.1A.5 S.1A.2 S.1A.6 S.1A.3 S.1A.8	S.1A.1 S.1A.4 S.1A.2 S.1A.3	S.1A.2 S.1A.8 S.1A.5 S.1A.6
***Crosscutting Concepts**	***Crosscutting Concepts**	***Crosscutting Concepts**	***Crosscutting Concepts**	***Crosscutting Concepts**	***Crosscutting Concepts**	***Crosscutting Concepts**
1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5,	2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	1, 2, 3, 5, 6, 7	1,2,3,4,5,6,7	1,2,3,4,5,6,7

**Teachers have the discretion to enhance the selected SEP's and CCCs.*

Unit Title
Physics: Forces and Motion
Standard http://ed.sc.gov/scdoe/assets/file/agency/ccr/Standards-Learning/documents/South_Carolina_Academic_Standards_and_Performance_Indicators_for_Science_2014.pdf
H.P.2 The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.

Conceptual Understanding
H.P.2A. The linear motion of an object can be described by its displacement, velocity, and acceleration.
New Academic Vocabulary **Some students may need extra support with the following academic vocabulary in order to understand what they are being asked to understand and do. Teaching these terms in an instructional context is recommended rather than teaching the words in isolation. A great time to deliver explicit instruction for the terms would be during the modeling process. Ultimately, the student should be able to use the academic vocabulary in conversation with peers and teachers. These terms are pulled from the essential knowledge portion of the Support Doc 2.0 (http://ed.sc.gov/instruction/standards-learning/science/support-documents-and-resources/) and further inquiry into the terms can be found there.**

Inertial frame	Scalar	Average velocity	Kinematics
Reference frame	Vector	Uniform (constant) velocity	Linear
Relative velocity	Speed	Instantaneous velocity	Free Fall
Displacement	Velocity	Average acceleration	Contact Force
Distance	Acceleration	Constant Acceleration	Non-contact force
Position	Average speed	Acceleration due to Gravity	Midpoint
Graphing	Y-axis	X-axis	

Performance Indicators **Text highlighted below in *orange* and *italicized/underlined* shows connections to SEP's**
H.P.2A.1 *Plan and conduct controlled scientific investigations* on the straight-line motion of an object to include an interpretation of the object's displacement, time of motion, constant velocity, average velocity, and constant acceleration. H.P.2A.2 *Construct explanations* for an object's change in motion using one-dimensional vector addition.

H.P.2A.3 *Use mathematical and computational thinking* to apply formulas related to an object's displacement, constant velocity, average velocity and constant acceleration. Interpret the meaning of the sign of displacement, velocity, and acceleration.
H.P.2A.4 *Develop and use models* to represent an object's displacement, velocity, and acceleration (including vector diagrams, data tables, motion graphs, dot motion diagrams, and mathematical formulas).
H.P.2A.5 *Construct explanations* for what is meant by "constant" velocity and "constant" acceleration (including writing descriptions of the object's motion and calculating the sign and magnitude of the slope of the line on a position-time and velocity-time graph).
H.P.2A.6 *Obtain information to communicate* the similarities and differences between distance and displacement; speed and velocity; constant velocity and instantaneous velocity; constant velocity and average velocity; and velocity and acceleration.

***Science and Engineering Practices**

Support for the guidance, overviews of learning progressions, and explicit details of each SEP can found in the Science and Engineering Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf). It is important that teachers realize that the nine science and engineering practices are not intended to be used in isolation. Even if a performance indicator for a given standard only lists one of the practices as a performance expectation, scientists and engineers do not use these practices in isolation, but rather as part of an overall sequence of practice. When educators design the learning for their students, it is important that they see how a given performance expectation fits into the broader context of the other science and engineering practices. This will allow teachers to provide comprehensive, authentic learning experiences through which students will develop and demonstrate a deep understanding of scientific concepts.

H.P.1A.2 Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others
H.P.1A.3 Plan and conduct controlled scientific investigations to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
H.P.1A.5 Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
H.P.1A.6 Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
H.P.1A.8 Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.

***Cross Cutting Concepts** (http://www.nap.edu/read/13165/chapter/8) **The link above provides support from the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) The text in blue and *italicized/underlined* below provides a brief explanation of how the specific content ties to the CCC's.**
2. Cause and effect Mechanism and explanation: The National Research Council (2012) states that "events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts" (p. 84). *Forces cause a change in the motion and stability of an object. Newton's Laws of motion explains the cause and effect relationships between forces, motion, and mass.* 3. Scale, proportion, and quantity: The National Research Council (2012) states that "in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance" (p. 84). *The ideas of ratio and proportionality are important here, along with being able to predict the effect of a change in one variable on another. For example, how will the speed of an object change, if the time traveled is increased, but the distance remains the same?* 7. Stability and change: The National Research Council (2012) states that "For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study" (p. 84). *The motion of an object remains stable unless an outside force causes a change in that motion. The rate of change is dependent upon force and mass.*

**Teachers have the discretion to enhance the selected SEP's and CCC's.*

Prior Knowledge
● 5.P.5 Speed, Velocity ● 8.P.2 Position, Speed, Average Velocity
Subsequent Knowledge
● N/A

Possible Instructional Strategies/Lessons **Strategies and lessons that will enable students to master the standard and/or indicator.**
● Hot Wheelin' Physics: This is a short activity that will generate data for students to make speed calculations. Link can be found at http://sciencespot.net/Media/hotwheel.pdf

- Kinematic Practice Problems: with constant acceleration. This worksheet provides problems that can be worked for classroom practice, homework, formative assessment, etc. Link can be found at http://www.lcps.org/cms/lib4/VA01000195/Centricity/Domain/14819/1-D%20kinematics%20practice%20packet.pdf

- Create your own sail: In this activity, students will create a sail out of materials (napkins, construction paper, plastic bags, coffee stirrers, felt, wax paper, popsicle sticks, etc.). Students will test their sails on a teacher-constructed device. For example, a foam base with straws connected on either side can be used. A fishing line can be fed through the straws and both sides of the fishing line can be attached to rulers. The rulers can then be attached between two desks and the "wind" provided by a fan. Students calculate their speed and acceleration of their sailboat. Link can be found at http://tryengineering.org/lessons/sailaway.pdf

- Free Fall Practice Problems: This worksheet provides problems that can be worked for classroom practice, homework, formative assessment, etc. Link can be found at http://www.midwayisd.org/cms/lib/TX01000662/Centricity/Domain/190/Acceleration%20due%20to%20gravity%20worksheet.pdf

- Egg Drop: Students are required to create a contraption (Students can be allowed to use anything except liquids, glass, gases and materials purchased specifically for packing, i.e. styrofoam peanuts and bubble wrap.). They bring their contraption to school on Egg Drop Day. The egg is supplied and students have 20 minutes to complete the contraption assembly. The teacher can play "Free Fallin'" by Tom Petty, just for fun. Then, the class goes to the stadium. Students are placed in a group of four or five and each group has a timer. A clipboard can be provided for one student to record the times. Caution - Make sure there are no students underneath the landing spot. Students write a formal lab report. In addition, they are required to calculate the height of the stadium and the velocity their contraption traveled during the drop. Link can be found at http://www.skitsap.wednet.edu/cms/lib/WA01000495/Centricity/Domain/1233/egg_drop_another_teachers_with_physics_infor.pdf

- Motion Matching Lab: Students make and test predictions regarding linear motion and position-time and velocity-time graphs using motion detectors.

- The Moving Man: Interactive simulation that explores position, velocity and acceleration. Set the parameters, watch the man move, and the data being graphed simultaneously. Link can be found at: https://phet.colorado.edu/en/simulation/legacy/moving-man

- Ladybug Motion 2D: Interactive simulation that explores the relationships between velocity, acceleration and their vectors. Link can be found at https://phet.colorado.edu/en/simulation/legacy/ladybug-motion-2d

- Projectile Motion: Interactive simulation in which students fire various objects out of a cannon and explore how various conditions affect that path of the projectile. Link can be found at: https://phet.colorado.edu/en/simulation/legacy/projectile-motion

Resources

- Scalars & Vectors: Mr. Andersen explains the differences between scalar and vectors quantities. He also uses a demonstration to show the importance of vectors and vector addition (Andersen, 2011). This resource can be found at http://www.bozemanscience.com/scalars-vectors

- Position vs Time Graph Part 1: Mr. Andersen shows how to interpret a position vs. time graph for an object with constant velocity. The slope of the line is used to find the velocity. A phet simulation is also included (Andersen, 2011). This resource can be retrieved from http://www.bozemanscience.com/position-vs-time-graph-part-1

- Position vs Time Graph Part 2: Mr. Andersen shows how to read a position vs. time graph to determine the velocity of an object. Objects that are accelerating are covered in this podcast. He also introduces the tangent line (or the magic pen) (Andersen, 2011). This resource can be retrieved from http://www.bozemanscience.com/position-vs-time-graph-part-2

- Speed, Velocity & Acceleration: Mr. Andersen explains the basic quantities of motion. Demonstration videos and practice problems are also included. The difference between scalar and vector quantities is also discussed (Andersen, 2011). This resource can be found at http://www.bozemanscience.com/speed-velocity-acceleration/?rq=speed%2C%20velocity%2C%20acceleration

- Felix Baumgartner: Felix Baumgartner reached an estimated speed of MACH 1.24 jumping from the stratosphere, making him the first man to break the speed of sound in freefall. (Red Bull Stratos, 2012). This resource can be found at http://www.redbullstratos.com/gallery/?mediaId=media1902415096001

- Luke Aikins: Luke Aikins skydives from 25,000 feet with no parachute. This resource can be found at https://www.youtube.com/watch?v=fWOOoXtiXiA

- Dan Fullerton: Dan Fullerton has videos on all physics topics at a variety of levels (Regents, Honors, and AP Physics). This resource can be found at http://www.aplusphysics.com/

- The Moving Man: Interactive simulation on position, velocity and acceleration. This resource can be found at https://phet.colorado.edu/en/simulation/legacy/moving-man

- Ladybug Motion 2D: Interactive simulation on velocity and acceleration vectors. This resource can be found at https://phet.colorado.edu/en/simulation/legacy/ladybug-motion-2d

- Projectile Motion: Interactive simulation on projectile motion. This resource can be found at: https://phet.colorado.edu/en/simulation/legacy/projectile-motion

Sample Formative Assessment Tasks/Questions

Additional sample formative assessment tasks/questions for grade bands are located at the end of each of the SEP Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf)

- Practice problems on white boards.

- Student snowballs - Students work a problem on a sheet of paper (without their name on it), crumple their paper, and toss it into a teacher-provided basket. The teacher will redistribute the papers amongst the students. Students will check the papers as the problem is worked out on the board (either by teacher or student).

- Task cards- Problems printed on index cards (or card stock paper) and assigned a point value that depends on the amount of work required to solve the problem. Students choose which problems to solve and have them checked by the teacher as they go. Students must obtain a specific amount of points to complete the assignment.

Unit Title
Physics: Forces and Motion
Standard http://ed.sc.gov/scdoe/assets/file/agency/ccr/Standards-Learning/documents/South_Carolina_Academic_Standards_and_Performance_Indicators_for_Science_2014.pdf
H.P.2 The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.

Conceptual Understanding
H.P.2B. The interactions among objects and their subsequent motion can be explained and predicted by analyzing the forces acting on the objects and applying Newton's laws of motion.
New Academic Vocabulary **Some students may need extra support with the following academic vocabulary in order to understand what they are being asked to understand and do. Teaching these terms in an instructional context is recommended rather than teaching the words in isolation. A great time to deliver explicit instruction for the terms would be during the modeling process. Ultimately, the student should be able to use the academic vocabulary in conversation with peers and teachers. These terms are pulled from the essential knowledge portion of the Support Doc 2.0 (http://ed.sc.gov/instruction/standards-learning/science/support-documents-and-resources/) and further inquiry into the terms can be found there.**

Force	Air resistance	Newton's 2nd Law	Newton's 3rd Law	Vector components
Inertia	Gravity	Axis of rotation	Torque	
Mass	Moment arm	Lever arm	Center of mass	
Net force	Newton's 1st Law	Rigid bodies	Dynamics	

Performance Indicators **Text highlighted below in *orange* and *italicized/underlined* shows connections to SEP's**
H.P.2B.1 *Plan and conduct controlled scientific investigations* involving the motion of an object to determine the relationships among the net force on the object, its mass, and its acceleration (Newton's second law of motion, F_{net} = ma) and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion. H.P.2B.2 *Use a free-body diagram to represent* the forces on an object. H.P.2B.3 *Use Newton's Third Law of Motion to construct explanations* of everyday phenomena (such as a hammer hitting a nail, the thrust of a

rocket engine, the lift of an airplane wing, or a book at rest on a table) and identify the force pairs in each given situation involving two objects and compare the size and direction of each force.
H.P.2B.8 *Develop and use models* (such as a computer simulation, drawing, or demonstration) and Newton's Second Law of Motion to construct explanations for why an object moving at a constant speed in a circle is accelerating.
H.P.2B.9 *Construct explanations* for the practical applications of torque (such as a see-saw, bolt, wrench, and hinged door).
H.P.2B.10 *Obtain information to communicate* physical situations in which Newton's Second Law of Motion does not apply.

***Science and Engineering Practices**

Support for the guidance, overviews of learning progressions, and explicit details of each SEP can found in the Science and Engineering Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf). It is important that teachers realize that the nine science and engineering practices are not intended to be used in isolation. Even if a performance indicator for a given standard only lists one of the practices as a performance expectation, scientists and engineers do not use these practices in isolation, but rather as part of an overall sequence of practice. When educators design the learning for their students, it is important that they see how a given performance expectation fits into the broader context of the other science and engineering practices. This will allow teachers to provide comprehensive, authentic learning experiences through which students will develop and demonstrate a deep understanding of scientific concepts.

S.1A.2 Develop and use models *to* (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others
S.1A.3 Plan and conduct controlled scientific investigations to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.
S.1A.6 Construct explanations of phenomena using (1) primary or secondary scientific evidence and models, (2) conclusions from scientific investigations, (3) predictions based on observations and measurements, or (4) data communicated in graphs, tables, or diagrams.
S.1A.8 Obtain and evaluate scientific information to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.

***Cross Cutting Concepts** **(http://www.nap.edu/read/13165/chapter/8)**

The link above provides support from the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) The text in blue and *italicized/underlined* below provides a brief explanation of how the specific content ties to the CCC's.

2. Cause and effect Mechanism and explanation: The National Research Council (2012) states that "events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are

mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts" (p. 84). *Forces cause a change in the motion and stability of an object. Newton's Laws of motion explain the cause and effect relationships between forces, motion, and mass.*

5. Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations. *Newton's Laws explain how matter is affected by forces as it interacts with other types of matter, i.e. car crashing into a wall.*

**Teachers have the discretion to enhance the selected SEP's and CCC's.*

Prior Knowledge
● 5.P.2 Properties of Matter (Mass) ● 5.P.5 Forces ● 8.P.2 Forces, Newton's Laws of Motion
Subsequent Knowledge
● N/A

Possible Instructional Strategies/Lessons

Strategies and lessons that will enable students to master the standard and/or indicator.

- Newton's Laws Worksheet: This worksheet is one example of possible practice problems. It also reviews symbols, formulas, and the laws of motion. Link can be found at http://www.cstephenmurray.com/Acrobatfiles/IPC/ch3and4/chap3no1.pdf

- Action/Reaction Pairs Practice: This worksheet provides students with the opportunity to determine the action force and the reaction force that are paired together. It can be used as a problems sheet, or cut apart and divided amongst the groups as a part of the lesson. Link can be found at http://www.mayfieldschools.org/Downloads/Newtons%203rd%20Law%20Wkst%20side%202%20and%20KEY.pdf

- Farmer Brown versus Old Dobbin the Horse: This is a story that puts all of Newton's laws into perspective. Students volunteer to play the part of Farmer Brown, Old Dobbin, and the narrator. They are required to produce a free-body diagram and an explanation as to why Old Dobbin is incorrect. Link can be found at http://www.batesville.k12.in.us/physics/phynet/mechanics/newton3/HorseAndCart.html

- Newton's Crash Test Dummy/Collision Lab: This lab can be used to satisfy many performance indicators. This can be developed into a PBL unit for students to see the consequences of driving too fast. Students create a test dummy out of playdough. They attach the dummy to a toy car and run the apparatus down a ramp. They are required to manipulate the ramp so that they have three different accelerations and as a result three different forces. Students must determine what type of collision has occurred. Also, they must provide a calculations sheet with acceleration, force, and velocity (using the Law of Conservation of Momentum) and a free-body diagram for each of the three situations. As a formal assessment, students take the information learned from the lab and make a presentation using one of the following roles and situations:
    - Police Officer - teaching a defensive driving class to a group of teenagers
    - Newspaper Reporter - writing or reporting an investigative story concerning a car collision-
    - Car Manufacturer - designing a car that could withstand the consequences of Newton's three laws
    - Teenager - explaining his/her version of the car collision to their parents
    - Other - must be teacher-approved

  Link can be found at http://w3.shorecrest.org/~Lisa_Peck/photoalbum/newton_crashdummy09/crash_dummy.html

- Torque and a Seesaw: Virtual activity where students place two children at various points on a seesaw and observe the effect. You can "turn on physics" to see an explanation as the simulation is running. Teachers can design a virtual lab to go with the simulation or have students explore and see what they come up with. Link can be found at http://www.fearofphysics.com/Seesaw/seesaw.html

Resources

- Newton's Three Laws of Motion: Mr. Andersen defines Newton's three laws of motion. He describes how the first law relates to inertia, how the second law relates to mass and acceleration, and how the third law allows a rocket to launch. (Andersen, 2011). This resource is available from http://www.bozemanscience.com/newtons-three-laws-of-motion

- Newton's Laws: (Henderson, 2016). Interactive student resources on Newton's Laws. This resource can be found at http://www.physicsclassroom.com/Physics-Tutorial/Newton-s-Laws

- Forces and Motion Basics: phET simulation of Net Force -This resource can be found at https://phet.colorado.edu/en/simulation/forces-and-motion-basics

- Newton's Laws Interactive: This interactive gives students the opportunity to manipulate the forces acting on the object. They are able to

visualize exactly what is happening with each law. Also, there is information about Newton, a quiz, and a glossary to assist both teacher and student. This resource can be found at http://www.sciencechannel.com/games-and-interactives/newtons-laws-of-motion-interactive/

- NBCLearn videos: This resource will assist student with practical application of forces, i.e. Newton's First Law and NFL football, Newton's Second and Third Laws and golf. This resource can be found at http://www.nbclearn.com/portal/site/learn
- High School Physics: Free Body Diagrams: Examples of free-body diagram questions. This resource can be found at http://aplusphysics.com/courses/regents/videos/FBDs/FBDs.html

Sample Formative Assessment Tasks/Questions

Additional sample formative assessment tasks/questions for grade bands are located at the end of each of the SEP Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf)

- Tug-of-War: Have students calculate their weight in newtons. Place students on teams and predict which team will win. In their prediction, they must include a free-body diagram illustrating the unbalanced or balanced forces. This can be considered Data Collection.

- Concept map: Compare the three laws. Students must write the law in their own words and support it with a free-body diagram.

Unit Title

Physics: Forces and Motion

Standard

http://ed.sc.gov/scdoe/assets/file/agency/ccr/Standards-Learning/documents/South_Carolina_Academic_Standards_and_Performance_Indicators_for_Science_2014.pdf

H.P.2 The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.

Conceptual Understanding

H.P.2C. The contact interactions among objects and their subsequent motion can be explained and predicted by analyzing the normal, tension, applied, and frictional forces acting on the objects and by applying Newton's Laws of Motion.

New Academic Vocabulary

Free-body diagram	Applied Force	Static friction	Spring constant, k

Normal force	Frictional force	Coefficient of static friction	Weight
Tension	Kinetic (dynamic) friction	Hooke's law	

Performance Indicators

Text highlighted below in *orange* and *italicized/underlined* shows connections to SEP's.

H.P.2C.1 *Use a free-body diagram to* represent the normal, tension (or elastic), applied, and frictional forces on an object.

H.P.2C.2 *Plan and conduct controlled scientific investigations to* determine the variables that could affect the kinetic frictional force on an object.

H.P.2C.3 *Obtain and evaluate information to* compare kinetic and static friction.

H.P.2C.4 *Analyze and interpret data* on force and displacement to determine the spring (or elastic) constant of an elastic material (Hooke's Law, F=-kx), including constructing an appropriate graph in order to draw a line-of-best-fit whose calculated slope will yield the spring constant, *k*.

H.P.2C.5 *Use mathematical and computational thinking* to apply F_{net} = ma to analyze problems involving contact interactions and gravity.

***Science and Engineering Practices**

Support for the guidance, overviews of learning progressions, and explicit details of each SEP can found in the Science and Engineering Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf). It is important that teachers realize that the nine science and engineering practices are not intended to be used in isolation. Even if a performance indicator for a given standard only lists one of the practices as a performance expectation, scientists and engineers do not use these practices in isolation, but rather as part of an overall sequence of practice. When educators design the learning for their students, it is important that they see how a given performance expectation fits into the broader context of the other science and engineering practices. This will allow teachers to provide comprehensive, authentic learning experiences through which students will develop and demonstrate a deep understanding of scientific concepts.

S.1A.2 Develop and use models to (1) understand or represent phenomena, processes, and relationships, (2) test devices or solutions, or (3) communicate ideas to others

S.1A.3 Plan and conduct controlled scientific investigations to answer questions, test hypotheses, and develop explanations: (1) formulate scientific questions and testable hypotheses based on credible scientific information, (2) identify materials, procedures, and variables, (3) use appropriate laboratory equipment, technology, and techniques to collect qualitative and quantitative data, and (4) record and represent data in an appropriate form. Use appropriate safety procedures.

S.1A.4 Analyze and interpret data from informational texts and data collected from investigations using a range of methods (such as tabulation, graphing, or statistical analysis) to (1) reveal patterns and construct meaning, (2) support or refute hypotheses, explanations, claims, or designs, or (3) evaluate the strength of conclusions.

S.1A.5 Use mathematical and computational thinking to (1) use and manipulate appropriate metric units, (2) express relationships between variables for models and investigations, and (3) use grade-level appropriate statistics to analyze data.
S.1A.8 *Obtain and evaluate scientific information* to (1) answer questions, (2) explain or describe phenomena, (3) develop models, (4) evaluate hypotheses, explanations, claims, or designs or (5) identify and/or fill gaps in knowledge. Communicate using the conventions and expectations of scientific writing or oral presentations by (1) evaluating grade-appropriate primary or secondary scientific literature, or (2) reporting the results of student experimental investigations.

***Cross Cutting Concepts** **(http://www.nap.edu/read/13165/chapter/8)**

The link above provides support from the Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (2012) The text in blue and *italicized/underlined* below provides a brief explanation of how the specific content ties to the CCC's.

2. Cause and effect Mechanism and explanation: The National Research Council (2012) states that "events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts" (p. 84). *Forces cause a change in the motion and stability of an object. Newton's Laws of motion explain the cause and effect relationships between forces, motion, and mass.*

3. Scale, proportion, and quantity: The National Research Council (2012) states that "in considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance" (p. 84). *The ideas of ratio and proportionality are important here along with being able to predict the effect of a change in one variable on another. For example, how will the speed of an object change if the time traveled is increased but the distance remains the same?*

4. Systems and systems models: The National Research Council (2012) states that "Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering" (p. 84). *In this simple mechanical system, the interactions between forces and resulting changes in motion should be modeled using graphs or mathematical relationships.*

**Teachers have the discretion to enhance the selected SEP's and CCC's.*

Prior Knowledge

- 5.P.2 Properties of Matter (Mass)
- 5.P.5 Forces

- 8.P.2 Forces, Newton's Laws of Motion, Frictional Forces

Subsequent Knowledge

- N/A

Possible Instructional Strategies/Lessons

Strategies and lessons that will enable students to master the standard and/or indicator.

- Student-Created Free-Body Diagrams Have students make cut-out free-body diagrams with a theme. For example, if it is fall, students can create a Halloween scene or pumpkin patch.

- Interactive Free-Body Diagrams Using the interactive on the Physics Classroom website, students create free-body diagrams for a variety of situations. Students receive immediate feedback, including prompts to help them correct their errors. Link can be found at: http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Free-Body-Diagrams/Free-Body-Diagram-Interactive

- Friction Lab: This is just one example of a friction lab. However, it contains practical, everyday supplies. Students should find a calculated value for the coefficients of friction. Link can be found at http://www.stemmom.org/2012/09/friction-inquiry-lab.html

- Do an Experiment with Friction: Simulation involving vehicles stopping in a traffic jam. Students select the vehicle, speed, type of road and distance at which they will apply the brakes. Students can examine the difference between friction on dry, wet, snowy and icy roads, as well as the relationship between normal force and friction. Link can be found at http://www.fearofphysics.com/Friction/friction.html

- Gravity Force Lab: Interactive simulation that provides a visual representation of the gravitational force between two objects. The properties of the objects can be varied in order to see the effect on the gravitational force. Link can be found at: https://phet.colorado.edu/en/simulation/gravity-force-lab

- Friction from Physics LAB: This can be used as a bell ringer, review or formative assessment. The questions are about the forces acting on a crate and the resulting net force and acceleration. Students select the correct answer and indicate what the evidence they can use to support this claim. Link can be found at:

http://dev.physicslab.org/Document.aspx?doctype=5&filename=Compilations_CPworkbook_Friction.xml

- Forces and Motion: PhET simulation- Students can explore the forces with trying to move an object. The simulation allows students to vary the applied force and view charts and free-body diagrams. Link can be found at: https://phet.colorado.edu/en/simulation/forces-and-motion

- Hooke's Law Lab: Students use a spring, meter stick or ruler, and various masses to determine spring constant. Record the mass and displacement of the spring from equilibrium position and create a graph of force vs. displacement. The slope of the line is the spring constant. This works best with springs designed for a Hooke's law lab.

- Hooke's Law Simulation: PhET simulation that allows students to explore how force, displacement, spring constant, and potential energy are related. Link can be found at: https://phet.colorado.edu/sims/html/hookes-law/latest/hookes-law_en.html

Resources

- Free Body Diagrams: Mr. Andersen shows how to draw free body diagrams of various objects. The major forces (like gravity, normal, tension, friction, air resistance, etc.) are discussed and then applied to various problems. (Andersen, 2011) This resource can be found at http://www.bozemanscience.com/free-body-diagrams

- Science of the Winter Olympics: Science Friction: This resource provides a real-world reference for friction. https://science360.gov/obj/video/89c70f56-8885-46a0-9997-82ebfa025127/science-winter-olympics-science-friction

- NBC Learn - *The Banking on Speed: Bobsled* provides an explanation for types of forces. *Science of Golf: Newton's First and Second Laws of Motion* and *Science of Golf: Newton's Third Law of Motion and Momentum* explores the fundamentals of Newton's Laws within the parameters of the sport of golf. *Science of NFL Football: Newton's First Law* provides real-world examples of Newton's First Law. These resources can be found at http://www.nbclearn.com

- Gravity Force Lab: Gravity Force Lab interactive simulation. This resource can be retrieved from https://phet.colorado.edu/en/simulation/gravity-force-lab

- Friction: Crash Course Physics #6. This video gives a thorough explanation of static and kinetic friction. This resource can be retrieved from https://www.youtube.com/watch?v=fo_pmp5rtzo

- Free Body Diagram Interactive: Interactive free-body diagram activity. This resource can be found at http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Free-Body-Diagrams/Free-Body-Diagram-Interactive

- Physics LAB: Newton's Law of Motion: Friction: This resource can be found at http://dev.physicslab.org/Document.aspx?doctype=5&filename=Compilations_CPworkbook_Friction.xml

- Forces and Motion: PhET simulation of force and friction. This resource can be found at https://phet.colorado.edu/en/simulation/forces-and-motion

- Hooke's Law: PhET simulation of Hooke's Law. This resource can be found at https://phet.colorado.edu/sims/html/hookes-law/latest/hookes-law_en.html

Sample Formative Assessment Tasks/Questions

Additional sample formative assessment tasks/questions for grade bands are located at the end of each of the SEP Support Doc (http://ed.sc.gov/scdoe/assets/File/instruction/standards/Science/Support%20Documents/Complete_2014SEPsGuide_SupportDoc2_0.pdf)

- Concept map - Compare the types of forces.

- Whiteboard free-body diagrams

- Friction Practice problems - snowballs, whiteboards, volunteers, task cards

- Exit Slip Example: Show students a picture or diagram of an object and have them describe the forces, in terms of both direction and magnitude, acting upon that object as well as the effect of those forces. Students must write in complete sentences and provide evidence to support their conclusions.

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