Ohio Science

Physical Science Content Statements: Grades 9-12

Adopted 2018

Physical Science

1. **Classification of matter** PS.M.1

   a. Devise a method to purify water in developing countries. PS.M.1.DTES.A

   a. Design a procedure to separate a homogeneous or heterogeneous mixture. PS.M.1.DSK.A

   b. Investigate the effect of various factors (e.g., temperature, surface area of solute, stirring) on the rate materials (e.g., sugar cubes, salt crystals) dissolve. PS.M.1.DSK.B

   a. Using data from various physical separation techniques, construct a particle diagram for a mixture based on the particulate nature of matter. PS.M.1.ICSC.A

   b. Explain the process of burning a candle in terms of physical and chemical changes. PS.M.1.ICSC.B

   c. Compare acids and bases found in the home (e.g., household cleaning products, soaps, coffee, soda, vinegar, fruit juices, antacids) using experimentally determined pH data from meters or from universal indicators. PS.M.1.ICSC.C

   d. Using a phase change diagram determine the phase of water and other substances at different temperatures. PS.M.1.ICSC.D

   a. Identify samples of matter as homogeneous or heterogeneous (e.g., salt water, chicken noodle soup). PS.M.1.RAS.A

   b. Explain the location of acids, bases and neutral substances on the pH scale. PS.M.1.RAS.B

   c. Identify the various phase changes and classify them as endothermic or exothermic. PS.M.1.RAS.C

2. **Atoms** PS.M.2

   a. Design and implement a procedure to test for the presence of common dissolved ions. PS.M.2.DSK.A

   a. Research cations and anions and how they function in everyday products (e.g., hair products, car washes, dryer sheets). PS.M.2.ICSC.A

   b. Describe the difference between hard and soft water. PS.M.2.ICSC.B

   c. Model the formation of ions with particle diagrams or manipulatives. PS.M.2.ICSC.C

   d. Interpret the presence of dissolved ions in water with respect to human health. PS.M.2.ICSC.D

   a. Describe the location, charge, and relative size of a proton, neutron, and electron. PS.M.2.RAS.A

   b. Use information from the periodic table to calculate numbers of protons, neutrons and electrons for an element. Use this information to draw a Bohr model of the element. PS.M.2.RAS.B

   c. Define isotope and provide an example. PS.M.2.RAS.C

   d. Explain the importance of valence electrons. PS.M.2.RAS.D

   e. Use the periodic table and/or electron dot diagrams to identify the ionic charge of elements in groups 1, 2, 17, and 18. PS.M.2.RAS.E

3. **Periodic trends of the elements** PS.M.3

   a. Design an alternate arrangement of elements in the periodic table. PS.M.3.DTES.A

   a. Develop a flow chart or dichotomous key to identify a substance as a metal, nonmetal or metalloid. PS.M.3.ICSC.A

   b. Explain the differences between the properties/ionic charge of 2 elements chosen from groups 1, 2, 17, and 18. PS.M.3.ICSC.B

   a. Using the periodic table and/or electron dot diagrams, identify the ionic charge of elements in groups 1, 2, 17, and 18. PS.M.3.RAS.A

   b. Explain why elements are grouped into families. PS.M.3.RAS.B

   c. Identify metals, nonmetals, metalloids, alkali metals, alkaline earth metals, halogens and noble gases based on their positions on the periodic table. PS.M.3.RAS.C

4. **Bonding and compounds** PS.M.4

   a. Using modeling, compare ionic and covalent compounds in terms of molecular and three-dimensional lattice formation. PS.M.4.ICSC.A

   b. Use naming conventions to find an example of a covalent compound and an ionic compound in an ingredient list. PS.M.4.ICSC.B

   c. Explain why having a standard set of naming and formula writing rules is important. PS.M.4.ICSC.C

   a. Describe how ionic and covalent bonds are formed in terms of valence electrons. PS.M.4.RAS.A

   b. Given elements and their locations on the periodic table, predict if they will form ionic or covalent compounds. PS.M.4.RAS.B

   c. Name the Greek prefixes 1-10. PS.M.4.RAS.C

   d. Given two elements, predict the chemical formula and name of an ionic compound (e.g., calcium and chlorine = CaCl₂ = calcium chloride). PS.M.4.RAS.D

   e. Name binary covalent molecules and binary ionic compounds when given formulas. PS.M.4.RAS.E

   f. Determine the formulas for covalent molecules and binary ionic compounds when given their names. PS.M.4.RAS.F

5. **Reactions of matter** PS.M.5
   a. Explain why Na + Br₂ yields NaBr and not NaBr₂. PS.M.5.ICSC.A
   b. Investigate safe chemical reactions (e.g., vinegar and baking soda in a Ziploc bag) to determine if they are exothermic or endothermic. PS.M.5.ICSC.B
   c. Use the half-life of C-14 to explain appropriate uses of carbon dating. PS.M.5.ICSC.C
   d. Describe how the radioactive isotopes of several elements are used in medical testing. PS.M.5.ICSC.D
   e. Describe the short- and long-term effects of nuclear wastes on the environment. PS.M.5.ICSC.E
   f. Research and interpret the consequences, information and technology involved in the discovery or synthesis of new elements. Include historical references (e.g., Madame Curie). PS.M.5.ICSC.F
   a. Give an example where temperature change is observable without measurement, where temperature change is observable with a thermometer, and where temperature change is impossible to measure. PS.M.5.RAS.A
   b. Balance a chemical equation when provided the formulas of reactants and products. PS.M.5.RAS.B
   c. Describe alpha, beta and gamma radiation. PS.M.5.RAS.C
   d. Compare nuclear fission and nuclear fusion. PS.M.5.RAS.D
   e. Identify applications of radioisotopes. PS.M.5.RAS.E

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1. **Conservation of energy** PS.EW.1
   a. Devise a procedure to calculate the speed of an object at constant velocity using a meter stick and a stopwatch or a frame-by-frame motion video. Use measured speed and mass to calculate kinetic energy. PS.EW.1.DSK.A
   a. Calculate potential energy given an object's mass and its height above a reference point. PS.EW.1.RAS.A
   b. Calculate the kinetic energy of a moving object given the mass and velocity. PS.EW.1.RAS.B
   c. Calculate the drop heights of objects based on their velocity at impact. PS.EW.1.RAS.C
   d. Explain how the gravitational potential energy of an object varies based on the position of the reference point. PS.EW.1.RAS.D
   e. Use the principle of conservation of energy to solve for an unknown quantity in a problem (e.g., beginning gravitational potential energy equals final kinetic energy for a falling object). PS.EW.1.RAS.E

2. **Transfer and transformation of energy (including work)** PS.EW.2

   a. Design and build a roller coaster with at least two loops and one hill. Use the roller coaster to calculate kinetic and potential energy and identify the quantity of energy transferred out of the system during the ride. Then engineer a new design that would decrease the energy loss from the system. PS.EW.2.DTES.A

   a. Design and conduct an investigation to estimate the energy lost (dissipated) in each bounce of a bouncing ball. PS.EW.2.DSK.A

   b. Design a method to estimate the energy transferred to the surrounding environment as thermal energy through work done by frictional forces. PS.EW.2.DSK.B

   a. Use data to explain energy transformations occurring in a closed system. PS.EW.2.ICSC.A

   b. Label the rollercoaster to identify places where energy is converted from one type to another (e.g., where kinetic energy is being converted into gravitational potential energy). PS.EW.2.ICSC.B

   c. Explain how the gravitational potential energy of an object varies based on the position of the reference point. PS.EW.2.ICSC.C

   a. Calculate the amount of work done by a force applied to an object. PS.EW.2.RAS.A

   b. Calculate the amount of work transferred into or out of a system using changes in energy. PS.EW.2.RAS.B

   c. Calculate the velocity at the bottom and top of each hill based on conservation of energy. PS.EW.2.RAS.C

   d. Measure the velocity of the object at the bottom of each hill. PS.EW.2.RAS.D

   e. Compare the measured velocity to the calculated velocity. PS.EW.2.RAS.E

3. Waves PS.EW.3

a. Design an experiment to investigate radiant energy transmission, absorption, and reflection with a variety of materials (e.g., opaque, transparent, rough, smooth). PS.EW.3.DTES.A

b. Investigate the relationship between speed, frequency and wavelength for a transverse wave traveling through a Slinky®. Make claims about what happens to the speed and the wavelength of the wave as the frequency is increased and give evidence to support any claims. For example, use information from the investigation to explore the implications of cell phone usage. Include beneficial and harmful aspects of the use of this technology. PS.EW.3.DTES.B

a. Construct a model to compare mechanical waves and electromagnetic waves. PS.EW.3.DSK.A

b. Research an observable wave phenomenon and design a demonstration to present to the class. PS.EW.3.DSK.B

a. Give examples and illustrate wave behaviors including reflection, refraction, absorption, diffraction, and superposition. PS.EW.3.ICSC.A

b. Identify the placement of each type of wave (e.g., gamma, x-ray, ultraviolet, visible, infrared, micro, radio) along the electromagnetic spectrum. PS.EW.3.ICSC.B

c. Compare the relative wave energy, frequency and wavelength of different regions of the electromagnetic spectrum. PS.EW.3.ICSC.C

d. Describe how the Doppler shift effect can produce a change in frequency for sound waves. PS.EW.3.ICSC.D

e. Explain how sound or radiant waves are used in medicine or everyday life applications (e.g., ultrasound, lasers, x-rays). PS.EW.3.ICSC.E

a. Design an experiment to investigate radiant energy transmission, absorption, and reflection with a variety of materials (e.g., opaque, transparent, rough, smooth). PS.EW.3.RAS.A

4. Thermal Energy PS.EW.4

a. Use thermal conductivity concepts to improve a cooler design to keep beverages cold. Improve the design of the cooler to further reduce the transfer of thermal energy. PS.EW.4.DTES.A

a. Design a method to investigate the thermal conductivity of potential materials to be used in the design. PS.EW.4.DKS.A

a. Graphically compare potential materials based on the results of the investigations. PS.EW.4.ICSC.A

a. Differentiate between a thermal insulator and a thermal conductor. Provide examples of each. PS.EW.4.RAS.A

5. **Electricity** PS.EW.5

   a. Given several circuit boards where current does not flow, determine why the current is not flowing and implement a solution to resolve the problem. PS.EW.5.DTES.A

   b. Design a circuit that produces the maximum amount of light from a given set of materials (e.g., light bulbs, LEDs, various lengths of wires, batteries). PS.EW.5.DTES.B

   c. Design an alarm system that uses a change in a circuit to indicate that the alarm has been triggered, (e.g., a short circuit changing current flow through a branch, a branch of a circuit opening to cease current flow). PS.EW.5.DTES.C

   a. Design an investigation to determine the relationship between potential difference and current through a resistor. PS.EW.5.DSK.A

   a. Illustrate electric flow in parallel and series circuits. Explain situations where each type of circuit is more advantageous. PS.EW.5.ICSC.A

   b. Explain how resistance is an important concept in an engineering design context (e.g., determining how many light fixtures a circuit can handle, understanding how lack of insulation can cause short circuits). PS.EW.5.ICSC.B

   c. Explain how the system sets off the alarm in terms of changes in current or potential difference in the circuit. PS.EW.5.ICSC.C

   a. Differentiate how electrons move in an insulator vs. a conductor. PS.EW.5.RAS.A

   b. Compare the flow of electrons in a circuit to the flow of electrical energy. PS.EW.5.RAS.B

   c. Analyze a circuit or schematic, to determine if it is a series or parallel circuit. PS.EW.5.RAS.C

   d. Define and measure current, voltage and resistance. PS.EW.5.RAS.D

   e. Explain that cells are joined together to form a battery. Explain conceptually how batteries generate electric current. PS.EW.5.RAS.E

1. **Motion** PS.FM.1

   a. Build a model of a device that could be used to determine the speed of a car travelling down the street. PS.FM.1.DTES.A

   b. Investigate how knowledge of the intersection point for two moving objects is used for controlling traffic patterns (e.g., air traffic control, trains). PS.FM.1.DTES.B

   a. Conduct an investigation to determine the acceleration of a freely falling object. PS.FM.1.DSK.A

   b. Design a system or method to collect the data needed to calculate the speed of a car travelling down the street. PS.FM.1.DSK.B

   c. Design a procedure to accurately measure the acceleration of a cart rolling down a ramp from rest. Collect data necessary to investigate the relationship between position and time for the cart. Analyze the data to determine the acceleration of the cart. Use this value to determine the speed of the cart at the end of the ramp. Measure the velocity of the cart at the end of the ramp (e.g., motion sensor) and compare it to the value calculated from the experimental data. PS.FM.1.DSK.C

   d. Design a procedure to investigate the motion of two objects with different constant speeds (e.g., battery operated cars). Predict where two objects will cross paths when released at different times. PS.FM.1.DSK.D

   a. Given real-world examples, explain how the frame of reference of an observer affects the appearance of motion. PS.FM.1.ICSC.A

   b. Create a velocity vs. time graph for an object using data from its position vs. time graph. PS.FM.1.ICSC.B

   c. Write a story describing an object's motion that corresponds to a velocity vs. time graph. PS.FM.1.ICSC.C

   d. Present to the class how data will be measured and how it will be used to determine the speed of the car. PS.FM.1.ICSC.D

   e. Make a claim about the relationship between position and time for an accelerating object and use evidence to support the claim. Present the findings to the class. PS.FM.1.ICSC.E

   f. Produce position vs. time graphs and motion diagrams for two moving objects. PS.FM.1.ICSC.F

   a. Identify examples of data that are vector quantities and examples of data that are scalar quantities. PS.FM.1.RAS.A

   b. Determine the displacement of an object in one dimension, as measured from a frame of reference. Describe how an object can have a distance that is not the same as the displacement. PS.FM.1.RAS.B

   c. Distinguish average velocity from instantaneous velocity. PS.FM.1.RAS.C

   d. Calculate the velocity of an object by measuring the time to travel different distances and determine if the object moves with constant or changing velocity. PS.FM.1.RAS.D

e. Calculate the acceleration of an object from its change in speed during a given time interval. PS.FM.1.RAS.E

f. On a velocity vs. time graph, identify when an object is showing no motion, constant velocity and constant acceleration. PS.FM.1.RAS.F

g. Given a position vs. time graph, velocity vs. time graph, or acceleration vs. time graph identify the other corresponding graphs. PS.FM.1.RAS.G

h. Decide what data must be collected to determine the speed of a car. PS.FM.1.RAS.H

i. Calculate the final velocity of an object from the measured acceleration. PS.FM.1.RAS.I

j. Use motion sensors to determine speed and acceleration of objects. PS.FM.1.RAS.J

k. Determine the speed of two moving objects using their position vs. time graphs. PS.FM.1.RAS.K

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2. **Forces** PS.FM.2

a. Design a Rube Goldberg machine that completes a task, (e.g., makes a fidget spinner spin, pops a balloon). Explain energy transfers in the machine caused by the force of gravity, friction, tension and normal forces. PS.FM.2.DTES.A

a. Determine the relationship between weight of an object in newtons (measured with a spring scale) and mass of an object in kilograms. Graph data for a variety of objects and interpret the graph to determine the gravitational field strength at the location where the measurements were taken. PS.FM.2.DSK.A

a. Investigate the relationship between the frictional force on an object and the normal force between the object and the surface. PS.FM.2.ICSC.A

b. Draw force diagrams for an object in the Rube Goldberg machine that is in equilibrium and for an object that is accelerating. PS.FM.2.ICSC.B

a. Solve problems determining the acceleration of an object from a force diagram. PS.FM.2.RAS.A

b. Identify the forces acting on various objects (e.g., a skydiver, a hanging mass, a chair resting on the floor) and draw force diagrams for the objects. PS.FM.2.RAS.B

c. Use a force diagram to predict the motion of an object. PS.FM.2.RAS.C

d. Calculate the weight of an object from its mass. PS.FM.2.RAS.D

e. Identify the relationship between gravitational field strength and the magnitude of the force on an object placed in the field. PS.FM.2.RAS.E

f. Compare the weight of objects on Earth to the predicted weights on other planets in our Solar System using the planets' gravitational field strength. PS.FM.2.RAS.F

g. Identify the forces present throughout the Rube Goldberg machine. PS.FM.2.RAS.G

h. Calculate the forces involved in one energy transfer in the machine. PS.FM.2.RAS.H

3. **Dynamics (how forces affect motion)** PS.FM.3

   a. Design and test methods that decrease the force on an object (e.g., egg, cell phone) so that it will survive being dropped from a given height. The focus should be on reducing the magnitude of the forces that the object will experience. Redesign and retest the methods based on initial testing. PS.FM.3.DTES.A

   a. Design an investigation to show the importance of seatbelt use. Create a persuasive public message (e.g., poster, television commercial, PSA, jingle or rap) including artifacts from the investigation to support the message. Focus on the forces and accelerations that a person would experience when wearing or not wearing a seat belt. PS.FM.3.DSK.A

   b. Determine and carry out a procedure to measure the amount of force necessary to break an object (e.g., egg, cell phone screen). PS.FM.3.DSK.B

   a. Provide an example of an object in equilibrium and determine the forces that are acting on the object. Create a force diagram of that object labeling the identified forces. PS.FM.3.ICSC.A

   b. Describe the amount of force needed to break an object (e.g., egg, cell phone screen). Use data collected to support the claim. Include any assumptions made. PS.FM.3.ICSC.B

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1. **History of the universe** PS.U.1

   a. Create or improve a device to collect data from a portion of the universe, understanding that there are situations where we cannot directly observe or measure something in a straightforward way. PS.U.1.DTES.A

   a. Analyze a plot of distance vs. redshift of galaxies to recognize the trend that more distant galaxies are moving away from our location faster. Design a model to show this phenomenon (e.g., drawing dots on a balloon and blowing it up, paperclips on a stretching rubber band). PS.U.1.DSK.A

   a. Use a 12-month calendar to construct a "Cosmic Calendar" to depict the 14-billion-year history of the universe. PS.U.1.ICSC.A

   b. Explain the "raisin cake" analogy for the expansion of the universe and how it makes sense of the observed relationship between distance and redshift of nearby galaxies. PS.U.1.ICSC.B

   c. Investigate features of a solid planetary body using the WorldWide Telescope. Identify features that are oldest vs. those that are youngest and draw conclusions about the reasons for the differences using current theory to support the conclusions. PS.U.1.ICSC.C

   a. Explain that the universe had a beginning in the distant past; the universe is not infinitely old. PS.U.1.RAS.A

   b. Provide evidence that the universe is expanding. PS.U.1.RAS.B

2. **Galaxies** PS.U.2

   a. Research the Hubble space telescope from an engineering perspective. What were the problems encountered by this mission and how they were solved? How was the telescope upgraded over time? What scientific knowledge was gained from these technological improvements and fixes? What future improvements to the Hubble telescope would you make? PS.U.2.DTES.A

   b. Evaluate data analyzing the penetration ability of gamma radiation, X-rays, UV, visible light, infrared and radio wavelengths in Earth's atmosphere. Based on the analysis and pertinent considerations (e.g., certain wavelengths of light are blocked from reaching Earth's surface by the atmosphere, how efficiently telescopes work at different wavelengths, telescopes in space are much more expensive to construct than Earth-based telescopes) recommend to a federal funding agency which telescope project should receive funds for construction. The two projects to consider are:
Project 1 – A UV wavelength telescope, placed high atop Mauna Kea in Hawaii at 14,000 ft. above sea level, which will be used to look at distant galaxies.
Project 2 – A visible wavelength telescope, placed on a satellite in orbit around Earth, which will be used to observe a pair of binary stars located in the constellation Ursa Major (Big Dipper). (Prather, Slater, Adams, & Brissenden, 2008) PS.U.2.DTES.B

   a. Use real-time data from the NASA Hubble Mission to research and document the history of the mission, marking the time, discoveries and impact to humans. Present a final product (e.g., an e-portfolio, presentation, formal poster session). PS.U.2.ICSC.A

   a. Identify three galaxy types: elliptical, spiral and irregular. Identify the Milky Way as a spiral galaxy. PS.U.2.RAS.A

   b. Recognize that our solar system is part of the Milky Way Galaxy. PS.U.2.RAS.B

   c. Explain that galaxies formed in the early universe when gravity caused gas clouds to collapse to form stars. PS.U.2.RAS.C

   d. Explain how we are able to see galaxies. PS.U.2.RAS.D

3. **Stars** PS.U.3

   a. Design a pinhole camera and refine it to project an image of the sun that has a good balance between brightness and resolution. Relate the size of the hole to brightness and resolution. PS.U.3.DTES.A

   a. Explain how gravity wave detection confirmed the existence of black holes. A gravity wave signal was detected in 2015 from two black holes that collided and merged together without creating a huge explosion because the light produced by this event got sucked into the resulting black hole. This could not have happened if the two objects had been stars. PS.U.3.ICSC.A

   b. Use a Hertzsprung-Russell diagram to predict the evolution of stars (e.g., how long the star will last, what it will become after it runs out of fuel). PS.U.3.ICSC.B

   c. Choose a star or star system and draw a sunset from the perspective of a planet that is in the "habitable zone" for that star(s). PS.U.3.ICSC.C

   d. Research how computer simulations are used to model the formation of stars. PS.U.3.ICSC.D

   e. Observe star formation and end states. Document observations. A nearby gas cloud where stars are forming is the Orion nebula which is easy to see with a telescope or binoculars. The bright stars at the center of the nebula are recently formed and illuminate the surrounding gas and dust. The Crab nebula is an example of the end state of a star that is easy to see with a telescope or binoculars. PS.U.3.ICSC.E

   a. Explain how stars form. PS.U.3.RAS.A

   b. Describe the stages of our sun and compare them to those of more and less massive stars. PS.U.3.RAS.B

   c. Explain how stars can end up as white dwarfs, neutron stars and black holes. Compare the sizes of these end products. PS.U.3.RAS.C

   d. Explain fusion reactions in stars and how they are different from chemical reactions. PS.U.3.RAS.D

   e. Describe how the plasma phase differs from the other phases of matter. PS.U.3.RAS.E