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Ohio Revised Science Standards and Model Curriculum High School

Physical Science

SYLLABUS AND MODEL CURRICULUM

COURSE DESCRIPTION

Physical science is a high school level course, which satisfies the **Ohio Core** science graduation requirements of **Ohio Revised Code Section 3313.603**. This section of Ohio law requires a three-unit course with inquiry-based laboratory experience that engages students in asking valid scientific questions and gathering and analyzing information.

Physical science introduces students to key concepts and theories that provide a foundation for further study in other sciences and advanced science disciplines. Physical science comprises the systematic study of the physical world as it relates to fundamental concepts about matter, energy and motion. A unified understanding of phenomena in physical, living, Earth and space systems is the culmination of all previously learned concepts related to chemistry, physics, and Earth and space science, along with historical perspective and mathematical reasoning.

SCIENCE INQUIRY AND APPLICATION

During the years of grades 9 through 12, all students must use the following scientific processes with appropriate **laboratory safety techniques** to construct their knowledge and understanding in all science content areas:

- Identify questions and concepts that guide scientific investigations;
- Design and conduct **scientific investigations**;
- Use technology and mathematics to improve investigations and communications;
- Formulate and revise explanations and models using logic and evidence (critical thinking);
- Recognize and analyze explanations and models; and
- Communicate and support a scientific argument.

COURSE CONTENT

The following information may be taught in any order; there is no ODE-recommended sequence.

STUDY OF MATTER

- Classification of matter
  - Heterogeneous vs. homogeneous
  - Properties of matter
  - States of matter and its changes
- Atoms
  - Models of the atom (components)
  - Ions (cations and anions)
  - Isotopes
- Periodic trends of the elements
  - Periodic law
  - Representative groups
- Bonding and compounds
  - Bonding (ionic and covalent)
  - Nomenclature
- Reactions of matter
  - Chemical reactions
  - Nuclear reactions

ENERGY AND WAVES

- Conservation of energy
  - Quantifying kinetic energy
  - Quantifying gravitational potential energy
  - Energy is relative
- Transfer and transformation of energy (including work)
- Waves
  - Refraction, reflection, diffraction, absorption, superposition
  - Radiant energy and the electromagnetic spectrum
  - Doppler shift
- Thermal energy
- Electricity
  - Movement of electrons
  - Current
  - Electric potential (voltage)
  - Resistors and transfer of energy

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FORCES AND MOTION

- Motion
  - Introduction to one-dimensional vectors
  - Displacement, velocity (constant, average and instantaneous) and acceleration
  - Interpreting position vs. time and velocity vs. time graphs
- Forces
  - Force diagrams
  - Types of forces (gravity, friction, normal, tension)
  - Field model for forces at a distance
- Dynamics (how forces affect motion)
  - Objects at rest
  - Objects moving with constant velocity
  - Accelerating objects

THE UNIVERSE

- History of the universe
- Galaxy formation
- Stars
  - Formation; stages of evolution
  - Fusion in stars

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CONTENT ELABORATION: STUDY OF MATTER

Classification of Matter

Matter was introduced in the elementary grades and the learning progression continued through middle school to include differences in the physical properties of solids, liquids and gases, elements, compounds, mixtures, molecules, kinetic and potential energy and the particulate nature of matter. Content in the chemistry syllabus (e.g., electron configuration, molecular shapes, bond angles) will be developed from concepts in this course.

Matter can be classified in broad categories such as homogeneous and heterogeneous or classified according to its composition or by its chemical (reactivity) and physical properties (e.g., color, solubility, odor, hardness, density, conductivity, melting point and boiling point, viscosity and malleability).

Solutions are homogenous mixtures of a solute dissolved in a solvent. The amount of a solid solute that can dissolve in a solvent generally increases as the temperature increases since the particles have more kinetic energy to overcome the attractive forces between them. Water is often used as a solvent since so many substances will dissolve in water. Physical properties can be used to separate the substances in mixtures, including solutions.

Phase changes can be represented by graphing the temperature of a sample vs. the time it has been heated. Investigations must include collecting data during heating, cooling and solid-liquid- solid phase changes. At times, the temperature will change steadily, indicating a change in the motion of the particles and the kinetic energy of the substance. However, during a phase change, the temperature of a substance does not change, indicating there is no change in kinetic energy. Since the substance continues to gain or lose energy during phase changes, these changes in energy are potential and indicate a change in the position of the particles. When heating a substance, a phase change will occur when the kinetic energy of the particles is great enough to overcome the attractive forces between the particles; the substance then melts or boils. Conversely, when cooling a substance, a phase change will occur when the kinetic energy of the particles is no longer great enough to overcome the attractive forces between the particles; the substance then condenses or freezes. Phase changes are examples of changes that can occur when energy is absorbed from the surroundings (endothermic) or released into the surroundings (exothermic).

When thermal energy is added to a solid, liquid or gas, most substances increase in volume because the increased kinetic energy of the particles causes an increased distance between the particles. This results in a change in density of the material. Generally, solids have greater density than liquids, which have greater density than gases due to the spacing between the particles. The density of a substance can be calculated from the slope of a mass vs. volume graph. Differences in densities can be determined by interpreting mass vs. volume graphs of the substances.

Atoms

Content introduced in middle school, where the atom was introduced as a small, indestructible sphere, is further developed in the physical science syllabus. Over time, technology was introduced that allowed the atom to be studied in more detail. The atom is composed of protons, neutrons and electrons that have measurable properties, including mass and, in the case of protons and electrons, a characteristic charge. When bombarding thin gold foil with atomic-sized, positively charged, high-speed particles, a few of the particles were deflected slightly from their straight-line path. Even fewer bounced back toward the source. This evidence indicates that most of an atom is empty space with a very small positively charged nucleus. This experiment and other evidence indicate the nucleus is composed of protons and neutrons, and electrons that move about in the empty space that surrounds the nucleus. Additional experimental evidence that led to the development of other historic atomic models will be addressed in the chemistry syllabus.

All atoms of a particular element have the same atomic number; an element may have different isotopes with different mass numbers. Atoms may gain or lose valence electrons to become anions or cations. Atomic number, mass number, charge and identity of the element can be determined from the numbers of protons, neutrons and electrons. Each element has a unique atomic spectrum that can be observed and used to identify an element. Atomic mass and explanations about how atomic spectra are produced are addressed in the chemistry syllabus.

Periodic Trends of the Elements

Content from the middle school level, specifically the properties of metals and nonmetals and their positions on the periodic table, is further expanded in this course. When elements are listed in order of increasing atomic number, the same sequence of properties appears over and over again; this is the periodic law. The periodic table is arranged so that elements with similar chemical and physical properties are in the same group or family. Metalloids are elements that have some properties of metals and some properties of nonmetals. Metals, nonmetals, metalloids, periods and groups or families including the alkali metals, alkaline earth metals, halogens and noble gases can be identified by their position on the periodic table. Elements in Groups 1, 2 and 17 have characteristic ionic charges that will be used in this course to predict the formulas of compounds. Other trends in the periodic table (e.g., atomic radius, electronegativity, ionization energies) are found in the chemistry syllabus.

Bonding and Compounds

Middle school content included compounds are composed of atoms of two or more elements joined together chemically. In this course, the chemical joining of atoms is studied in more detail. Atoms may be bonded together by losing, gaining or sharing valence electrons to form molecules or three- dimensional lattices. An ionic bond involves the attraction of two oppositely charged ions, typically a metal cation and a

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nonmetal anion formed by transferring electrons between the atoms. An ion attracts oppositely charged ions from every direction, resulting in the formation of a three-dimensional lattice. Covalent bonds result from the sharing of electrons between two atoms, usually nonmetals. Covalent bonding can result in the formation of structures ranging from small individual molecules to three-dimensional lattices (e.g., diamond). The bonds in most compounds fall on a continuum between the two extreme models of bonding: ionic and covalent.

Using the periodic table to determine ionic charge, formulas of ionic compounds containing elements from groups 1, 2, 17, hydrogen and oxygen can be predicted. Given a chemical formula, a compound can be named using conventional systems that include Greek prefixes where appropriate. Prefixes will be limited to represent values from one to 10. Given the name of an ionic or covalent substance, formulas can be written. Naming organic molecules is beyond this grade level and is reserved for an advanced chemistry course. Prediction of bond types from electronegativity values, polar covalent bonds, writing formulas and naming compounds that contain polyatomic ions or transition metals will be addressed in the chemistry syllabus.

Reactions of Matter

In middle school, the law of conservation of matter was expanded to chemical reactions, noting that the number and type of atoms and the total mass are the same before and after the reaction. In this course, conservation of matter is expressed by writing balanced chemical equations. At this level, reactants and products can be identified from an equation and simple equations can be written and balanced given either the formulas of the reactants and products or a word description of the reaction. Stoichiometric relationships beyond the coefficients in a balanced equation and classification of types of chemical reactions are addressed in the chemistry syllabus.

During chemical reactions, thermal energy is either transferred from the system to the surroundings (exothermic) or transferred from the surroundings to the system (endothermic). Since the environment surrounding the system can be large, temperature changes in the surroundings may not be detectable.

While chemical changes involve changes in the electrons, nuclear reactions involve changes to the nucleus and involve much larger energies than chemical reactions. The strong nuclear force is the attractive force that binds protons and neutrons together in the nucleus. While the nuclear force is extremely weak at most distances, over the very short distances present in the nucleus the force is greater than the repulsive electrical forces among protons. When the attractive nuclear forces and repulsive electrical forces in the nucleus are not balanced, the nucleus is unstable. Through radioactive decay, the unstable nucleus emits radiation in the form of very fast-moving particles and energy to produce a new nucleus, thus changing the identity of the element. Nuclei that undergo this process are said to be radioactive. Radioactive isotopes have several medical applications. The radiation they release can be used to kill undesired cells (e.g., cancer cells). Radioisotopes can be introduced into the body to show the flow of materials in biological processes.

For any radioisotope, the half-life is unique and constant. Graphs can be constructed that show the amount of a radioisotope that remains as a function of time and can be interpreted to determine the value of the half-life. Half-life values are used in radioactive dating.

Other examples of nuclear processes include nuclear fission and nuclear fusion. Nuclear fission involves splitting a large nucleus into smaller nuclei, releasing large quantities of energy. Nuclear fusion is the joining of smaller nuclei into a larger nucleus accompanied by the release of large quantities of energy. Nuclear fusion is the process responsible for formation of all the elements in the universe beyond helium and the energy of the sun and the stars.

Further details about nuclear processes including common types of nuclear radiation, predicting the products of nuclear decay, mass-energy equivalence and nuclear power applications are addressed in the chemistry and physics syllabi.

EXPECTATIONS FOR LEARNING: COGNITIVE DEMANDS

This section provides definitions for Ohio's science cognitive demands, which are intrinsically related to current understandings and research about how people learn. They provide a structure for teachers and assessment developers to reflect on plans for teaching science, to monitor observable evidence of student learning and to develop summative assessment of student learning of science.

VISIONS INTO PRACTICE

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

- Visually compare the inside structure of various balls (tennis ball, golf ball, baseball, basketball/kickball and soccer ball). Determine what makes the ball bounce the highest (and/or travel farthest), compare, analyze the data, draw conclusions and present findings in multiple formats.
- Explore the benefits of radiation and how it can be used as a tool to sustain life (sterilization and food irradiation processes, nuclear medicine). Include details about how the radiation works to accomplish the benefit and the extent (limit or range) that the benefit will continue as opposed to becoming a harm to life (plants, animals or human beings) on Earth. Draw conclusions and present an argument based on supporting data as to when radiation poses a threat as opposed to being beneficial. Present findings in multiple formats.

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INSTRUCTIONAL STRATEGIES AND RESOURCES

This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on, minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology and technological and engineering design. Resources selected are printed or Web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

- **The Rutherford experiment** is a simulation that shows high-speed particles bombarding a thin foil. While the simulation is not to scale, it does provide a dynamic visual to help students understand what is happening at the atomic level that explains the experimental evidence.

COMMON MISCONCEPTIONS

- Students may think that models are physical copies of the real thing, failing to recognize models as conceptual representations. (AAAS, 1993)
- Students know models can be changed, but at the high school level, they may be limited by thinking that a change in a model means adding new information or that changing a model means replacing a part that was wrong. (AAAS, 1993)
- Students often do not believe models can duplicate reality. (AAAS, 1993)
- Students often think that breaking bonds releases energy. (Ross, 1993)
- When multiple models are presented, they tend to think there is one "right one". (AAAS, 1993)

DIVERSE LEARNERS

Strategies for meeting the needs of all learners including **gifted students**, **English Language Learners** (ELL) and students with **disabilities** can be found at the **Ohio Department of Education site**. Resources based on the Universal Design for Learning principles are available at **www.cast.org**.

CLASSROOM PORTALS

"**Teaching High School Science**" is a series of videos-on-demand produced by Annenberg that show classroom strategies for implementing inquiry into the high school classroom. While not all of the content is aligned to physical science, the strategies can be applied to any content.

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CONTENT ELABORATION: ENERGY AND WAVES

Energy and Waves

Building upon knowledge gained in elementary and middle school, major concepts about energy and waves are further developed. Conceptual knowledge will move from qualitative understandings of energy and waves to ones that are more quantitative using mathematical formulas, manipulations and graphical representations.

- **Conservation of Energy**
  Energy content learned in middle school, specifically conservation of energy and the basic differences between kinetic and potential energy, is elaborated on and quantified in this course. Energy has no direction and has units of Joules (J). Kinetic energy, E_k, can be mathematically represented by $E_k = ½mv^2$. Gravitational potential energy, E_g, can be mathematically represented by $E_g = mgh$,. The amount of energy of an object is measured relative to a reference that is considered to be at a point of zero energy. The reference may be changed to help understand different situations. Only the change in the amount of energy can be measured absolutely. The conservation of energy and equations for kinetic and gravitational potential energy can be used to calculate values associated with energy (i.e., height, mass, speed) for situations involving energy transfer and transformation. Opportunities to quantify energy from data collected in experimental situations (e.g., a swinging pendulum, a car traveling down an incline) must be provided.
- **Transfer and Transformation of Energy**
  In middle school, concepts of energy transfer and transformation were addressed, including conservation of energy, conduction, convection and radiation, the transformation of electrical energy, and the dissipation of energy into thermal energy. Work also was introduced as a method of energy transfer into or out of the system when an outside force moves an object over a distance. In this course, these concepts are further developed. As long as the force, F, and displacement, Δx, are in the same or opposite directions, work, W, can be calculated from the equation $W = F\Delta x$. Energy transformations for a phenomenon can be represented through a series of pie graphs or bar graphs. Equations for work, kinetic energy and potential energy can be combined with the law of conservation of energy to solve problems. When energy is transferred from one system to another, some of the energy is transformed to thermal energy. Since thermal energy involves the random movement of many trillions of subatomic particles, it is less able to be organized to bring about further change. Therefore, even though the total amount of energy remains constant, less energy is available for doing useful work.
- **Waves**
  As addressed in middle school, waves transmit energy from one place to another, can transfer energy between objects and can be described by their speed, wavelength, frequency and amplitude. The relationship between speed, wavelength and frequency also was addressed in middle school Earth and Space Science as the motion of seismic waves through different materials is studied.

  In elementary and middle school, reflection and refraction of light were introduced, as was absorption of radiant energy by transformation into thermal energy. In this course, these processes are addressed from the perspective of waves and expanded to include other types of energy that travel in waves. When a wave encounters a new material, the new material may absorb the energy of the wave by transforming it to another form of energy, usually thermal energy. Waves can be reflected off solid barriers or refracted when a wave travels form one medium into another medium. Waves may undergo diffraction around small obstacles or openings. When two waves traveling through the same medium meet, they pass through each other then continue traveling through the medium as before. When the waves meet, they undergo superposition, demonstrating constructive and destructive interference. Sound travels in waves and undergoes reflection, refraction, interference and diffraction. In the physics syllabus, many of these wave phenomena will be studied further and quantified.

  Radiant energy travels in waves and does not require a medium. Sources of light energy (e.g., the sun, a light bulb) radiate energy continually in all directions. Radiant energy has a wide range of frequencies, wavelengths and energies arranged into the electromagnetic spectrum. The electromagnetic spectrum is divided into bands: radio (lowest energy), microwaves, infrared, visible light, X-rays and gamma rays (highest energy) that have different applications in everyday life. Radiant energy of the entire electromagnetic spectrum travels at the same speed in a vacuum. Specific frequency, energy or wavelength ranges of the electromagnetic spectrum are not required. However, the relative positions of the different bands, including the colors of visible light, are important (e.g., ultraviolet has more energy than microwaves). Radiant energy exhibits wave behaviors including reflection, refraction, absorption, superposition and diffraction, depending in part on the nature of the medium. For opaque objects (e.g., paper, a chair, an apple), little if any radiant energy is transmitted into the new material. However the radiant energy can be absorbed, usually increasing the thermal energy of the object and/or the radiant energy can be reflected. For rough objects, the reflection in all directions forms a diffuse reflection and for smooth shiny objects, reflections can result in clear images. Transparent materials transmit most of the energy through the material but smaller amounts of energy may be absorbed or reflected.

  Changes in the observed frequency and wavelength of a wave can occur if the wave source and the observer are moving relative to each other. When the source and the observer are moving toward each other, the wavelength is shorter and the

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observed frequency is higher; when the source and the observer are moving away from each other, the wavelength is longer and the observed frequency is lower. This phenomenon is called the Doppler shift and can be explained using diagrams. This phenomenon is important to current understanding of how the universe was formed and will be applied in later sections of this course. Calculations to measure the apparent change in frequency or wavelength are not appropriate for this course.

- **Thermal Energy**

  In middle school, thermal energy is introduced as the energy of movement of the particles that make up matter. Processes of heat transfer, including conduction, convection and radiation, are studied. In other sections of this course, the role of thermal energy during heating, cooling and phase changes is explored conceptually and graphically. In this course, rates of thermal energy transfer and thermal equilibrium are introduced.

  Thermal conductivity depends on the rate at which thermal energy is transferred from one end of a material to another. Thermal conductors have a high rate of thermal energy transfer and thermal insulators have a slow rate of thermal energy transfer. The rate at which thermal radiation is absorbed or emitted by a system depends on its temperature, color, texture and exposed surface area. All other things being equal, in a given amount of time, black rough surfaces absorb more thermal energy than smooth white surfaces. An object or system is continually absorbing and emitting thermal radiation. If the object or system absorbs more thermal energy than it emits and there is no change in phase, the temperature increases. If the object or system emits more thermal energy than is absorbed and there is no change in phase, the temperature decreases. For an object or system in thermal equilibrium, the amount of thermal energy absorbed is equal to the amount of thermal energy emitted; therefore, the temperature remains constant. In chemistry, changes in thermal energy are quantified for substances that change their temperature.

- **Electricity**

  In earlier grades, these concepts were introduced: electrical conductors and insulators; and a complete loop is needed for an electrical circuit that may be parallel or in a series. In this course, circuits are explained by the flow of electrons, and current, voltage and resistance are introduced conceptually to explain what was observed in middle school. The differences between electrical conductors and insulators can be explained by how freely the electrons flow throughout the material due to how firmly electrons are held by the nucleus.

  By convention, electric current is the rate at which positive charge flows in a circuit. In reality, it is the negatively charged electrons that are actually moving. Current is measured in amperes (A), which is equal to one coulomb of charge per second (C/s). In an electric circuit, the power source supplies the electrons already in the circuit with electric potential energy by doing work to separate opposite charges. For a battery, the energy is provided by a chemical reaction that separates charges on the positive and negative sides of the battery. This separation of charge is what causes the electrons to flow in the circuit. These electrons then transfer energy to other objects and transform electrical energy into other forms (e.g., light, sound, heat) in the resistors. Current continues to flow, even after the electrons transfer their energy. Resistors oppose the rate of charge flow in the circuit. The potential difference or voltage across an energy source is a measure of potential energy in Joules supplied to each coulomb of charge. The volt (V) is the unit of potential difference and is equal to one Joule of energy per coulomb of charge (J/C). Potential difference across the circuit is a property of the energy source and does not depend upon the devices in the circuit. These concepts can be used to explain why current will increase as the potential difference increases and as the resistance decreases. Experiments, investigations and testing (3-D or virtual) must be used to construct a variety of circuits, and measure and compare the potential difference (voltage) and current. Electricity concepts are dealt with conceptually in this course. Calculations with circuits will be addressed in the physics syllabus.

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VISIONS INTO PRACTICE

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

- Design, build and test a ramp system onto which a ball can be placed so that it rolls down a ramp and continues a specific distance on the table. Describe what properties of the system were important (and those not important) in the design. Provide different target distances for the launched ball to travel on the designed course and hit a given target within three trials.
- 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 for a modern convenience. Present findings and draw a conclusion using data and research in multiple formats.

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- "**Waves, Light, and Sound**" from The Physics Zone links to many animations of waves that can be used with absent students or students who need more reinforcement. Simulations also may be good to slow down some of the phenomena that students observe in class so they can make observations that are more detailed. Some of the simulations can only be accessed by members, but many of the simulations have unrestricted access.
- **Modeling workshops** are available nationally that help teachers develop a framework for using guided inquiry in their instruction.

Career Connection

As students explore the flow of electric current, resistors, and transfer of energy, they will identify issues found after a severe storm disrupts electricity across an area. Students will look into how current flows and what occurs during a storm that interrupts or interferes with the transfer of electricity. Students will identify potential problems caused by the storm. Then, they will generate a plan to restore electricity by determining which careers are needed and their respective roles in the process. Students will research aspects of careers, such as: job outlook for these careers in Ohio; current demand; education and training requirements (high school and beyond); and wages, working conditions, and typical tasks.

COMMON MISCONCEPTIONS

Students often think that:

- Potential energy is a thing that objects hold (like cereal stored in a closet).
- The only type of potential energy is gravitational.
- Doubling the velocity of a moving object will double its kinetic energy.
- Stored energy is something that causes energy later; it is not energy until it has been released.
- Objects do not have any energy if they are not moving.
- Energy is a thing that can be created and destroyed.
- Energy is literally lost in many energy transformations.
- Gravitational potential energy depends only upon the height of an object.
- Energy can be changed completely from one form to another with no loss of useful energy.

DIVERSE LEARNERS

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CONTENT ELABORATION: FORCES AND MOTION

Forces and Motion

Building upon content in elementary and middle school, major concepts of motion and forces are further developed. In middle school, speed has been dealt with conceptually, mathematically and graphically. The concept that forces have both magnitude and direction can be represented with a force diagram, that forces can be added to find a net force and that forces may affect motion has been addressed in middle school. At the high school level, mathematics (including graphing) is used when describing these phenomena, moving from qualitative understanding to one that is more quantitative. For the physical science course, all motion is limited to objects moving in a straight line either horizontally, vertically, up an incline or down an incline, that can be characterized by segments of uniform motion (e.g., at rest, constant velocity, constant acceleration). Motions of two objects may be compared or addressed simultaneously (e.g., when or where would they meet).

- **Motion**

  The motion of an object depends on the observer's frame of reference and is described in terms of distance, position, displacement, speed, velocity, acceleration and time. Position, displacement, velocity and acceleration are all vector properties (magnitude and direction). All motion is relative to whatever frame of reference is chosen, for there is no motionless frame from which to judge all motion. The relative nature of motion will be addressed conceptually, not mathematically. Non- inertial reference frames are excluded. **Motion diagrams** can be drawn and interpreted to represent the position and velocity of an object. Showing the acceleration on motion diagrams will be reserved for physics.

  The displacement or change in position of an object is a vector quantity that can be calculated by subtracting the initial position from the final position ($\Delta x = x_f - x_i$). Displacement can be positive or negative depending upon the direction of motion. Displacement is not always equal to the distance travelled. Examples should be given where the distance is not the same as the displacement.

  Velocity is a vector property that represents the rate at which position changes. Average velocity can be calculated by dividing displacement (change in position) by the elapsed time ($v_{avg} = (x_f - x_i)/(t_f - t_i)$). Velocity may be positive or negative depending upon the direction of motion and is not always equal to the speed. Provide examples of when the average speed is not the same as the average velocity. Objects that move with constant velocity have the same displacement for each successive time interval. While speeding up or slowing down and/or changing direction, the velocity of an object changes continuously, from instant to instant. The speed of an object at any instant (clock reading) is called instantaneous speed. An object may not travel at this instantaneous speed for any period of time or cover any distance with that particular speed, especially if the speed is continually changing.

  Acceleration is a vector property that represents the rate at which velocity changes. Average acceleration can be calculated by dividing the change in velocity divided by elapsed time ($a_{avg} = (v_f - v_i)/(t_f - t_i)$). At this grade level, it should be noted that acceleration can be positive or negative, but specifics about what kind of motions produce positive or negative accelerations will be addressed in the physics syllabus. The word "deceleration" should not be used because students tend to associate a negative sign of acceleration only with slowing down. Objects that have no acceleration can either be standing still or be moving with constant velocity (speed and direction). Constant acceleration occurs when the change in an object's instantaneous velocity is the same for equal successive time intervals.

  Motion can be represented by position vs. time and velocity vs. time graphs. Specifics about the speed, direction and change in motion can be determined by interpreting such graphs. For physical science, graphs will be limited to positive x-values and show only uniform motion involving segments of constant velocity or constant acceleration. Motion must be investigated by collecting and analyzing data in the laboratory. Technology can enhance motion exploration and investigation through video analysis, the use of motion detectors and graphing data for analysis.

  Objects that move with constant velocity and have no acceleration form a straight line (not necessarily horizontal) on a position vs. time graph. Objects that are at rest will form a straight horizontal line on a position vs. time graph. Objects that are accelerating will show a curved line on a position vs. time graph. Velocity can be calculated by determining the slope of a position vs. time graph. Positive slopes on position vs. time graphs indicate motion in a positive direction. Negative slopes on position vs. time graphs indicate motion in a negative direction. While it is important that students can construct graphs by hand, computer graphing programs or graphing calculators also can be used so more time can be spent on graph interpretation and analysis.

  Constant acceleration is represented by a straight line (not necessarily horizontal) on a velocity vs. time graph. Objects that have no acceleration (at rest or moving at constant velocity) will have a straight horizontal line for a velocity vs. time graph. Average acceleration can be determined from the slope of a velocity vs. time graph. The details about motion graphs should not be taught as rules to memorize, but rather as generalizations that can be developed from interpreting the graphs.

- **Forces**

  Force is a vector quantity, having both magnitude and direction. The (SI) unit of force is a Newton. One Newton of net force will cause a 1 kg object to experience an acceleration of 1 m/s^2. A Newton also can be represented as kg·m/s^2. The opportunity to measure force in the lab must be provided (e.g., with a spring scale or a force probe). Normal forces and tension forces are introduced conceptually at this level. These forces and other forces introduced in prior grades (friction, drag, contact, gravitational, electric and magnetic) and can be used as examples

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of forces that affect motion. Gravitational force (weight) can be calculated from mass, but all other forces will only be quantified from force diagrams that were introduced in middle school. In physical science, only forces in one dimension (positive and negative) will be addressed. The net force can be determined by one-dimensional vector addition. More quantitative study of friction forces, universal gravitational forces, elastic forces and electrical forces will be addressed in the physics syllabus.

Friction is a force that opposes sliding between two surfaces. For surfaces that are sliding relative to each other, the force on an object always points in a direction opposite to the relative motion of the object. In physical science, friction will only be calculated from force diagrams. Equations for static and kinetic friction are found in the physics syllabus.

A normal force exists between two solid objects when their surfaces are pressed together due to other forces acting on one or both objects (e.g., a solid sitting on or sliding across a table, a magnet attached to a refrigerator). A normal force is always a push directed at right angles from the surfaces of the interacting objects. A tension force occurs when a non-slack rope, wire, cord or similar device pulls on another object. The tension force always points in the direction of the pull.

In middle school, the concept of a field as a region of space that surrounds objects with the appropriate property (mass for gravitational fields, charge for electric fields, a magnetic object for magnetic fields) was introduced to explain gravitational, magnetic and electrical forces that occur over a distance. The field concept is further developed in physical science. The stronger the field, the greater the force exerted on objects placed in the field. The field of an object is always there, even if the object is not interacting with anything else. The gravitational force (weight) of an object is proportional to its mass. Weight, Fg, can be calculated from the equation $F_g = m\,g$, where g is the gravitational field strength of an object which is equal to *9.8 N/kg* (m/s^2) on the surface of Earth.

- **Dynamics**

  An object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced net force acts on it. The rate at which an object changes its speed or direction (acceleration) is proportional to the vector sum of the applied forces (net force, F_{net}) and inversely proportional to the mass ($a = F_{net}/m$). When the vector sum of the forces (net force) acting on an object is zero, the object does not accelerate. For an object that is moving, this means the object will remain moving without changing its speed or direction. For an object that is not moving, the object will continue to remain stationary. These laws will be applied to systems consisting of a single object upon which multiple forces act. Vector addition will be limited to one dimension (positive and negative). While both horizontal and vertical forces can be acting on an object simultaneously, one of the dimensions must have a net force of zero.

  A force is an interaction between two objects. Both objects in the interaction experience an equal amount of force, but in opposite directions. Interacting force pairs are often confused with balanced forces. Interacting force pairs can never cancel each other out because they always act on different objects. Naming the force (e.g., gravity, friction) does not identify the two objects involved in the interacting force pair. Objects involved in an interacting force pair can be easily identified by using the format "A acts on B so B acts on A." For example, the truck hits the sign therefore the sign hits the truck with an equal force in the opposite direction. Earth pulls the book down so the book pulls Earth up with an equal force. The focus of the content is to develop a conceptual understanding of the laws of motion to explain and predict changes in motion, not to name or recite a memorized definition. In the physics syllabus, all laws will be applied to systems of many objects.

EXPECTATIONS FOR LEARNING: COGNITIVE DEMANDS

This section provides definitions for Ohio's science cognitive demands, which are intrinsically related to current understandings and research about how people learn. They provide a structure for teachers and assessment developers to reflect on plans for teaching science, to monitor observable evidence of student learning and to develop summative assessment of student learning of science.

VISIONS INTO PRACTICE

This section provides examples of tasks that students may perform; this includes guidance for developing classroom performance tasks. It is not an all-inclusive checklist of what should be done, but is a springboard for generating innovative ideas.

- Research the ranges of human reaction time and braking accelerations. Design a traffic light pattern (e.g., how long the light should stay yellow) for a particular intersection, given the speed limits. Present the design and rationale to the class. Compare the results for different speed limits. Explain any patterns and trends observed.
- Investigate the relationship between position and time for a cart that rolls down a ramp from rest. Graph the results. Make a claim about how position and time are related and use evidence to support the claim. Present the findings to the class. Based on the presentations of other investigations, propose sources of error and provide suggestions for how the experiments can be improved.

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BACK TO PHYSICAL SCIENCE OUTLINE

INSTRUCTIONAL STRATEGIES AND RESOURCES

This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands-on, minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-basedtasks that incorporate technology and technological and engineering design. Resources selected areprinted or Web-based materials that directly relate to the particular Content Statement. It is not intended to be a prescriptive list of lessons.

- "**Forces in 1 Dimension**" is an interactive simulation that allows students to explore the forces at work when trying to push a filing cabinet. An applied force is created and the resulting friction force and total force acting on the cabinet are then shown. Forces vs. time, position vs. time, velocity vs. time, and acceleration vs. time graphs can be shown as can force diagrams representing all the forces (including gravitational and normal forces).
- "**Motion Diagrams**" is a tutorial from Western Kentucky University that shows how to draw motion diagrams for a variety of motions. It includes an animated physlet. Motion diagrams in physical science will only show position and velocity and will not show acceleration.
- The Physics Classroom supports this tutorial on **one-dimensional motion** that gives a thorough explanation of acceleration, including an animation to use with students who may still be having difficulties with acceleration.
- **Modeling workshops** are available nationally that help teachers develop a framework for incorporating guided inquiry in their instruction.

COMMON MISCONCEPTIONS

It is often thought that the exertion of a force requires a conscious decision by a thinking entity. Using the common terms "action" and "reaction" when designating forces from the perspective of Newton's third law can reinforce this misconception. Using the descriptor "interacting force pair" does not perpetuate this misconception and honors the fact that the two forces are mutually important.

Students often think that:

- **If the speed** is constant, then there is no acceleration.
- High velocities coincide with large accelerations and low velocities coincide with small accelerations.

DIVERSE LEARNERS

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CLASSROOM PORTALS

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CONTENT ELABORATION: THE UNIVERSE

The Universe

In early elementary school, observations of the sky and space are the foundation for developing a deeper knowledge of the solar system. In late elementary school, the parts of the solar system are introduced, including characteristics of the sun and planets, orbits and celestial bodies. At the middle school level, energy, waves, gravity and density are emphasized in the physical sciences, and characteristics and patterns within the solar system are found.

In the physical science course, the universe and galaxies are introduced, building upon the previous knowledge about space and the solar system in the earlier grades.

- **History of the Universe**
  The Big Bang Model is a broadly accepted theory for the origin and evolution of our universe. It postulates that 12 to 14 billion years ago, the portion of the universe seen today was only a few millimeters across (**NASA**).

  According to the "**big bang**" theory, the contents of the known universe expanded explosively into existence from a hot, dense state 13.7 billion years ago (NAEP 2009). After the big bang, the universe expanded quickly (and continues to expand) and then cooled down enough for atoms to form. Gravity pulled the atoms together into gas clouds that eventually became stars, which comprise young galaxies. Foundations for the big bang model can be included to introduce the supporting evidence for the expansion of the known universe (e.g., Hubble's law and red shift or cosmic microwave background radiation). A discussion of Hubble's law and red shift is found in the *Galaxy formation* section, below.

  Technology provides the basis for many new discoveries related to space and the universe. Visual, radio and x-ray telescopes collect information from across the entire electromagnetic spectrum; computers are used to manage data and complicated computations; space probes send back data and materials from remote parts of the solar system; and accelerators provide subatomic particle energies that simulate conditions in the stars and in the early history of the universe before stars formed.
- **Galaxy formation**
  A galaxy is a group of billions of individual stars, star systems, star clusters, dust and gas bound together by gravity. There are **billions of galaxies in the universe**, and they are classified by size and shape. The Milky Way is a spiral galaxy. It has more than 100 billion stars and a diameter of more than 100,000 light years. At the center of the Milky Way is a collection of stars bulging outward from the disk, from which extend spiral arms of gas, dust and most of the young stars. The solar system is part of the Milky Way galaxy.

  Hubble's law states that galaxies that are farther away have a greater red shift, so the speed at which a galaxy is moving away is proportional to its distance from the Earth. Red shift is a phenomenon due to Doppler shifting, so the shift of light from a galaxy to the red end of the spectrum indicates that the galaxy and the observer are moving farther away from one another. Doppler shifting also is found in the *Energy and Waves* section of this course.
- **Stars**
  Early in the formation of the universe, stars coalesced out of clouds of hydrogen and helium and clumped together by gravitational attraction into galaxies. When heated to a sufficiently high temperature by gravitational attraction, stars begin nuclear reactions, which convert matter to energy and fuse the lighter elements into heavier ones. These and other fusion processes in stars have led to the formation of all the other elements. (NAEP 2009). All of the elements, except for hydrogen and helium, originated from the nuclear fusion reactions of stars (College Board Standards for College Success, 2009).

  Stars are classified by their color, size, luminosity and mass. A **Hertzprung-Russell diagram** must be used to estimate the sizes of stars and predict how stars will evolve. Most stars fall on the main sequence of the H-R diagram, a diagonal band running from the bright hot stars on the upper left to the dim cool stars on the lower right.

  A star's mass determines the star's place on the main sequence and how long it will stay there. Patterns of stellar evolution are based on the mass of the star. Stars begin to collapse as the core energy dissipates. Nuclear reactions outside the core cause expansion of the star, eventually leading to the **collapse of the star**.

  Note: Names of stars and naming the evolutionary stage of a star from memory will not be assessed. The emphasis is on the interpretation of data (using diagrams and charts) and the criteria and processes needed to make those determinations.

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VISIONS INTO PRACTICE

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- Investigate features of a solid planetary body using the **WorldWide Telescope**. Identify features that are oldest verses those that are youngest and draw conclusions about the reasons for the differences using current theory to support the conclusions.
- Investigate the relative ages of star clusters by plotting data and analyzing the

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results of the graph created (creating an H-R diagram). Draw conclusions based on the results of the graph and discuss possible implications of the information learned (see **Student Instructions** and **Star Gauge**).

- 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 wavelength-study 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)
- 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. There are links at the NASA site to connect students to astronauts and scientists to allow for primary and secondary resources in the research. Present a final product (can be an e-portfolio, presentation or formal poster session) to an authentic audience.

INSTRUCTIONAL STRATEGIES AND RESOURCES

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- A **collection of videos** is provided by NASA about the **James Webb Telescope** – the largest space-based observatory ever built to date. From galaxy evolution to planetary formation, the Webb telescope will equip scientists to see far beyond previous endeavors.
- Investigate the **star life cycle** with interactive media or gain an overview of astronomical spectroscopy in studies of stellar spectra.
- It is important to keep the evidence **supporting the big bang model** at the grade 9-10 level. Students should understand where the evidence for the theory is found and the importance of data that support the expansion of the universe. This article provides a higher level of detail than is required for this course, but sections of the article are helpful and appropriate in understanding the foundational support.
- **NASA** provides science modules to support teaching about red shift and Doppler effects from a cosmology viewpoint. There also are NASA documents that can assist in teaching about **stellar evolution**.
- Use an **interactive HR Diagram** to explore different patterns that can exist on the chart and the evolution of specific types of stars.
- **Astronomy: Eliciting Student Ideas** is a workshop produced by Annenberg that uses constructivism by examining student beliefs on what causes the seasons and their explanations for the phases of the moon that are explored in the video-on-demand "**A Private Universe**."
- **The Quantum Mechanical Universe** is a video produced by Annenberg about a current look at where we have been and a peek into the future.
- **Dying stars and Birth of Elements** is a computer-based exercise where high school students analyze realistically simulated X-ray spectra of a supernova remnant and determine the abundances of various elements in them. In the end, they will find that the elements necessary for life on Earth – the iron in their blood, the calcium in their bones – are created in these distant explosions.
- "**A Star is Born... but How**?" and "**Stars**" are two tutorials on the Windows to the Universe from the National Earth Science Teachers Association that give details about star formation.
- **Exploring Mars** is a video produced by Annenberg that shows students in a grade 11 integrated science class who explore how the Mars landscape may have formed.

COMMON MISCONCEPTIONS

- **NASA** provides general student misconceptions pertaining to the universe and the big bang theory.
- Students' understanding of the magnitude of the universe needs to developed where they can make sense of how large is a billion or a million. Keely, Eberle & Tugel (2005) suggests teaching the notion of scale with familiar objects that students can see, like the moon and sun. Gradually introduce the nearby planets and then planets further away (p.182)

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