Ohio Science

Physics Content Statements: Grades 9-12

Adopted 2018

Physics

1. **Motion graphs** P.M.1

   a. Construct a method to measure the changing velocity of an object falling from a height of at least 5.0 m and that of an object rising into the air for at least 5.0 m. P.M.1.DSK.A

   a. Given a position vs. time graph or velocity vs. time graph write a driving scenario that fits the graph given. P.M.1.ICSC.A

   b. Given a position vs. time graph, velocity vs. time graph or acceleration vs. time graph sketch the other two corresponding graphs. P.M.1.ICSC.B

   a. Determine the collision point for two constant velocity buggies traveling at different velocities and moving towards each other. P.M.1.RAS.A

   b. Create a position vs. time graph from given data and determine the velocity of an object at two different times. Use that data to determine the average acceleration of the object during that interval of time. P.M.1.RAS.B

   c. Given a velocity vs. time graph showing quadrants I and IV, label portions of the graph where acceleration is positive or negative and describe the motion of the object as increasing or decreasing by relating slope of the line to sign of acceleration. This clarifies the misconception of negative acceleration always indicating that an object is slowing down. P.M.1.RAS.C

   d. Given unlabeled graphs with a variety of shapes (e.g., constant positive slope, increasing positive slope, zero slope), give an example for an object that would produce a graph for each of the relevant motion graphs. P.M.1.RAS.D

2. Problem solving P.M.2

a. Use a constant velocity buggy and an accelerating cart to investigate the simultaneous motion of two objects. Collect data individually on the motion of each object as it travels down a ramp. Use the data to make a prediction for when the accelerating object will overtake the constant velocity object if released at a specified later time. Test your prediction. Compare predictions with actual results and provide possible explanations for any discrepancies. P.M.2.DSK.A

b. Investigate the motion of a freely falling body using either a ticker timer or a motion detector. Use mathematical analysis to determine a value for "g." Compare the experimental value to known values of "g." Suggest sources of error and possible improvements to the experiment. P.M.2.DSK.B

a. Using kinematic equations, solve simultaneous equations to determine when an accelerating object will overtake an object moving at constant velocity (e.g., the police officer and speeder problem). Consider constraints such as the maximum velocity the accelerating object can travel and reaction times if applicable. P.M.2.ICSC.A

b. Experimentally determine reaction time or velocity of a jump using kinematic equations and data collected in class (e.g., distance a ruler drops before catching, height of jump, time in air). P.M.2.ICSC.B

a. Use the kinematic equations to solve for unknown quantities regarding an accelerated body in one dimension. P.M.2.RAS.A

b. Solve for information in one part of a problem and use the results to solve for information in subsequent parts. P.M.2.RAS.B

3. Projectile motion P.M.3

a. Design an experiment to collect data that will determine the launch velocity of a projectile launcher. Use the data to predict the range of the projectile at a given angle and attempt to hit a target with a projectile. Then, describe any assumptions made (e.g., neglecting air resistance, accounting for any uncertainty in the measurements). P.M.3.DSK.A

a. Predict the range of a ball rolling off a table by measuring the speed of the ball on the table and determining the time the ball will take to fall by measuring the height of the table. Using a target placed on the floor, determine how accurate predictions were. Then, identify sources of uncertainty in measurements and explain the effect these had on experimental results. P.M.3.ICSC.A

a. Solve problems involving horizontal projectiles and recognize that the horizontal velocity does not affect the time that a horizontal projectile will spend in the air. P.M.3.RAS.A

4. **Investigation of motion** P.M.4

    a. Given a ramp and a low-friction rolling cart, investigate accelerated motion. Design a procedure to collect relevant position vs. time data for the rolling cart and create a graph of the data. Use the position vs. time graph to determine the acceleration of the rolling cart, either by taking the slope of the graph at various times to determine the velocity and then graphing the velocity values to get a velocity vs. time graph and taking the slope of the graph or by linearizing the data and making use of appropriate kinematics equations. P.M.4.DTES.A

    a. Given a toy car that travels at a constant velocity, collect data to determine the velocity of the car from a position vs. time graph. The speeds of the cars can be varied by replacing a battery with an aluminum cylinder of the same length or a wooden dowel wrapped in aluminum foil. P.M.4.DSK.A

    a. Predict where a rolling cart and a constant velocity car will be at the same position on a ramp. Make this prediction by graphing the data for both cars on the same coordinate grid and using algebraic analysis of the data obtained from the previous parts (e.g., the acceleration of the rolling cart and the velocity of the car). Test the prediction and analyze any sources of uncertainty. P.M.4.ICSC.A

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1. **Newton's laws applied to complex problems** P.F.1

    a. Plan and conduct an investigation using an Atwood machine. Vary one of the masses to determine the effect it has on the acceleration of the system. This can be accomplished by measuring the time for one mass to fall a known distance and using kinematics equations to solve for the acceleration or by measuring the acceleration using smart pulleys and computer data logging if it is available. Then, state the relationship mathematically and verify the numerical values from data. P.F.1.DSK.A

    a. Draw free body diagrams for objects and use them to apply Newton's Second Law to solve for the acceleration of a mass. P.F.1.ICSC.A

    b. Design a demonstration for one of Newton's Laws and present the demonstration to the class. The demonstration should provide clear evidence for the law and sufficient data should be collected to support claims. Have classmates critique the demonstration and provide suggested improvements. P.F.1.ICSC.B

    c. Calculate the drag force (air resistance) on coffee filters by dropping different quantities and analyzing the experimental data. Determine the factors that affect terminal velocity. P.F.1.ICSC.C

    a. Solve for the acceleration of a mass that is acted upon by multiple forces acting in one dimension. P.F.1.RAS.A

    b. Solve problems for both horizontal and vertical acceleration. P.F.1.RAS.B

2. **Gravitational forces and fields** P.F.2

    a. Use the Phet Gravity Force Lab to investigate the relationship between masses of objects, distance between them and gravitational force. Verify the force law for gravitational interaction using values from the simulation. P.F.2.DSK.A

    a. Solve problems using the equation for universal gravitation (e.g., determine the net force on a mass at a point between Earth and another stellar object, determine why the gravitational force between two people is negligible, determine the value for g from the equation and Newton's Second Law). P.F.2.RAS.A

3. **Elastic forces** P.F.3

    a. Construct a bungee jump apparatus to safely drop a fragile object (e.g., flour bag) to within a specified distance of the ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction, test bungees to compare elastic force and gravitational force on the object and use data to critique and modify designs. P.F.3.DTES.A

    a. Plan and conduct a scientific investigation to determine the relationship between the force exerted on a spring and the amount it stretches. Represent the data graphically. Analyze the data to determine patterns and trends and model the relationship with a mathematical equation. Describe the relationship in words and support the conclusion with experimental evidence. P.F.3.DSK.A

    a. Draw a free body diagram that shows the forces acting on a mass that is hanging from a spring. Draw the forces acting on a mass that is attached to an ideal spring that is not stretched in the vertical direction and is then released. Diagrams can be drawn at the initial position, the equilibrium position, the maximum stretched distance, and at the points halfway between equilibrium and the ends of the motion. The forces and the motion of the spring should only be discussed qualitatively at this point. P.F.3.ICSC.A

    a. Calculate the force on a mass that is hanging in equilibrium by relating the force of gravity and the force applied by the spring. P.F.3.RAS.A

4. **Friction forces (static and kinetic)** P.F.4

   a. Plan and conduct an investigation to determine the coefficient of kinetic friction between two surfaces. Collect sufficient relevant data and analyze the data graphically to determine the value for the coefficient of kinetic friction. Then, compare the value to either the accepted value of kinetic friction when possible or to the results of other students and discuss any differences and sources of uncertainty in measurements. P.F.4.DSK.A

   b. Conduct an investigation to measure the coefficient of static friction between two surfaces by changing variables such as mass, incline and types of surfaces. P.F.4.DSK.B

   c. Design an investigation to support or refute the claim that speed or surface area affects the value for the force of friction between two surfaces. Present experimental designs and results to the class and allow others to question the design and the validity of the results. P.F.4.DSK.C

   a. Solve problems involving calculations of the force of kinetic friction between two surfaces. Problems should include objects moving at constant velocity, objects that are accelerating due to an external force other than friction, and situations where friction is the only force acting on an object to slow it to a stop. Kinematic equations may be included to allow students to determine stopping distance or time for an object to slide to a stop. Draw free body diagrams in conjunction with these problems. P.F.4.RAS.A

5. **Air resistance and drag** P.F.5

   a. Determine the magnitude of the air resistance or drag acting on an object when provided with all other forces and the acceleration. P.F.5.RAS.A

   b. Represent the force of air resistance in free body diagrams. P.F.5.RAS.B

6. **Forces in two dimensions** P.F.6

   a. Investigate the relationship between acceleration and the angle of the incline for an object accelerating down an incline in the absence of friction using a low friction cart. P.F.6.DSK.A

   b. Investigate the relationship between acceleration and mass of the object. This can be done at a fixed angle with or without the presence of frictional force. Discuss why no relationships exist. P.F.6.DSK.B

   c. Collect data to investigate the relationship between the speed of an object moving in a circular path and the force needed to keep the object moving in that path. Plot a graph of force vs. velocity and analyze the relationship. P.F.6.DSK.C

   a. Draw a free-body diagram for an object that is accelerating along a horizontal surface under the influence of a force that acts at a known angle to the horizontal. Use the free-body diagram to solve for the acceleration of the object. The object may be acted on by friction and subject to more than one external force. P.F.6.ICSC.A

   b. Use a free-body diagram and trigonometry or scale diagrams to determine the acceleration of an object accelerating down a frictionless incline. Make use of kinematic equations to solve for the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided. P.F.6.ICSC.B

   a. Solve for the components of a force that is at an angle to a known reference. Add force components that act at right angles. Both can be done using either trigonometry or by drawing scale diagrams. P.F.6.RAS.A

   b. Solve problems involving an object accelerating down an incline with a known force of friction. Use kinematic equations to solve for the time to slide down the incline, the final velocity, or the length of the incline when the appropriate information is provided. P.F.6.RAS.B

   c. Solve problems involving objects moving in circular motion (e.g., satellites orbiting planets, cars driving around horizontal curves, planes flying in horizontal and vertical circles). Identify what force is providing the necessary centripetal force for each situation. P.F.6.RAS.C

7. **Momentum, impulse and conservation of momentum** P.F.7

   a. Research a stretch of road where there are many accidents. Evaluate potential causes related to laws of motion and propose a design change to the road to reduce the number of accidents. P.F.7.DTES.A

   b. Design a system to safely stop a vehicle. Construct a working model that allows a raw egg mounted on the front of a vehicle to remain whole when the vehicle stops before impacting a wall. Test components and systems to collect and analyze data. Use data to refine designs and retest. Use a design portfolio to keep track of trials and revisions to the design throughout the process. Discuss advantages and disadvantages of various braking systems. P.F.7.DTES.B

   a. Research the effect of snow, rain and ice on the coefficients of friction between tires and the road and use this knowledge to create a presentation for other students on the importance of driving appropriately for the road conditions. Present data using posters to display in the school to raise awareness among the students about the effects that changes in weather conditions can have on driving. P.F.7.ICSC.A

1. **Gravitational potential energy** P.E.1

   a. Design a gravity-fed water system, connecting concepts of rise/fall to gravitational potential energy. Evaluate the system's real-world function compared to predicted performance, considering factors affecting performance (e.g., effects of pipe diameter). Use data to critique designs and propose changes for reconstruction. P.E.1.DTES.A

   a. Solve problems involving gravitational potential energy. Use problems that involve objects near the surface of Earth as well as objects that have a large distance between their centers of mass, such as a satellite orbiting Earth. P.E.1.RAS.A

2. **Energy in springs** P.E.2

   a. Attempt to measure/calculate k values for a variety of bungee shock cords. Then construct a bungee jump apparatus to safely drop a fragile object (ex. flour bag, egg) to within a specified distance of the ground from an appropriate height, using calculations alone to determine length and strength of bungee cord required. After construction, compare elastic force and gravitational force on the object and use data to critique designs and propose changes for reconstruction. P.E.2.DTES.A

   a. Referring to a force vs. distance graph for a spring, interpret what the slope of the line represents (the spring constant, k, measured in N/m) and what the area under the line represents (the energy stored in the spring in joules). P.E.2.ICSC.A

   a. Calculate the amount of energy stored in a spring that is stretched or compressed a certain distance. P.E.2.RAS.A

   b. Referring to a force vs. distance graph, recognize that the force of a spring is changing as a spring oscillates. P.E.2.RAS.B

3. **Work and power** P.E.3

a. Plan an investigation into the rate at which work can be done by a student. Choose a task that does work on a system (e.g., running up a flight of stairs, raising a mass a certain distance) and measure the amount of work done by the student. Calculate each student's average power. Compare the values for the power and discuss possible reasons for differences obtained by similar tasks performed by different students. P.E.3.DSK.A

a. Compare the use of a horizontal force, the use of a force angled above the horizontal, and a force at the same angle below the horizontal to determine which situation transfers the greatest total amount of energy to the system, both with and without friction present. P.E.3.ICSC.A

a. Solve problems determining the work done on an object by a force that acts at an angle to the displacement of the object. Use free body diagrams to solve for unknown forces. P.E.3.RAS.A

b. Solve problems determining the rate at which energy is added or removed from an object or a system of objects. Calculations should be limited to calculations involving the average power or the instantaneous power delivered to an object moving at a constant velocity. P.E.3.RAS.B

4. **Conservation of energy** P.E.4

   a. Investigate a system that transforms mechanical energy to determine the average force of friction on the system and refine the system to improve its efficiency. Compare the efficiency of the system before and after student refinements. P.E.4.DTES.A

   a. Plan and conduct an investigation into an existing system that transforms mechanical energy from one form into another. Determine an unknown quantity or value associated with the system (e.g., spring constant of a rubber band, mass of an unknown object), and make measurements to calculate the unknown quantity. The value for the unknown quantity can be measured directly and compared to the experimentally determined value. Uncertainties in measurement and assumptions made by the students should be included. P.E.4.DSK.A

   b. Design a method to predict where an object sliding down a ramp onto a flat surface will stop. Determine what data and calculations are needed to make accurate predictions. Collect the necessary data and make predictions for a variety of objects. Compare predictions to actual stopping points. Identify assumptions and other factors that account for discrepancies. P.E.4.DSK.B

   a. Solve problems using the principle of energy conservation to determine information about a system, such as the final velocity of a mass or the height an object will obtain. These problems should require the use of free body diagrams and the application of Newton's Laws to solve for unknown forces and may include multiple forms of energy transformations (e.g., initial elastic potential energy transformed into kinetic and gravitational potential energy). External forces, such as friction, should be included in problems. P.E.4.ICSC.A

   a. Draw diagrams or graphs to represent energy flow into or out of a system. P.E.4.RAS.A

5. **Nuclear energy** P.E.5

   a. Design a system to complete a task, such as raising a mass a certain distance or compressing a spring or a spring-loaded lever. Use the smallest amount of initial energy to complete the task. Test and refine the design to minimize energy transferred out of the system. P.E.5.DTES.A

   b. Research consequences of using nuclear energy as a source of electrical energy production in a particular area. Choose to support or oppose the construction of a nuclear power plant in that area. Identify design changes that could be incorporated to a nuclear power plant that would make it more suitable for use in the area. P.E.5.DTES.B

   a. Investigate each energy transformation in the system and take measurements to provide data to calculate the amount of energy present. Calculate energy before and after each transformation. Estimates for energy lost at each transformation should be recorded throughout the design process. P.E.5.DSK.A

   a. Predict the products of a given decay process or identify the decay process given the reactants and products. P.E.5.ICSC.A

   b. For each of the transformations in the system describe the type of energy and show how values for the energy present, lost and remaining at each step in the process were determined. P.E.5.ICSC.B

   c. Research concepts such as nuclear waste storage, decay series, energy production from fossil fuels, and other related concepts to provide scientific evidence for the recommendation. Present and explain the scientific evidence. P.E.5.ICSC.C

   a. From given reactions, calculate the masses of the reactants and the products to find the mass defect and hence the energy released in fission and fusion reactions. P.E.5.RAS.A

   b. Identify the energy present before and after each transformation in the system and accurately calculate the amount of energy present at each step in the process. P.E.5.RAS.B

   c. Relate the scientific principles associated with electrical energy production through nuclear fission to the argument for or against construction of a nuclear power plant. P.E.5.RAS.C

1. **Wave properties** P.W.1

   a. Design a parabolic cooker using principles of ray reflection to design the apparatus. After construction and testing, evaluate the success of the design and examine where performance departs from plan. P.W.1.DTES.A

   a. Plan and conduct an investigation of wave diffraction. Use single or double slit diffraction to experimentally investigate light waves. P.W.1.DSK.A

   a. Solve problems related to constructive and destructive interference between two waves. Graphically represent the locations where constructive and destructive interference are occurring based on the path of each wave. Calculate the distances mathematically. P.W.1.ICSC.A

   a. Solve problems involving standing waves on strings and in open and closed pipes. Explain the conditions required for standing waves to occur. Calculate the frequency of a standing wave of a given harmonic. P.W.1.RAS.A

2. **Light phenomena** P.W.2

   a. Design a laser maze. Present mazes and challenge other students to solve them. P.W.2.DTES.A

   a. Investigate the image formed by a lens. Experimentally determine the focal length of a lens. Investigate the images formed by the lens using a light source placed different distances from the lens (e.g., inside the focal length, outside the focal length, twice the focal length). P.W.2.DSK.A

   b. Experimentally determine the wavelength of a laser using diffraction through a single slit, a double slit, or a diffraction grating. P.W.2.DSK.B

   c. Use mirrors to direct a beam of light or a laser around obstacles. Use calculations to determine placement of mirrors to hit a target. Diagram the placement of mirrors to be used and test their placement. Refine and update the path diagram as needed. P.W.2.DSK.C

   d. Plan and conduct an investigation to determine the index of refraction of a substance. Determine a procedure to collect sufficient and relevant data. Use the data to calculate the index of refraction. Check the calculated value against the theoretical index of refraction (if known). P.W.2.DSK.D

   a. Draw ray diagrams for light reflecting off plane, concave and convex mirrors to determine the location of the image formed. Describe the properties of the image that is formed using diagrams and calculations. P.W.2.ICSC.A

   b. Draw ray diagrams for light refracting through a boundary of two translucent media. Use the diagrams and calculations to describe the properties of the image. Compare images for converging and diverging lenses. P.W.2.ICSC.B

   a. Solve problems to determine the location and properties of an image formed by various mirrors and lenses. P.W.2.RAS.A

   b. Compare the wave model of light to the particle model. P.W.2.RAS.B

   c. Solve refraction problems using Snell's Law to find the index of refraction for a medium. P.W.2.RAS.C

   d. Accurately apply the law of reflection to correctly predict the path of light reflecting from a mirror. P.W.2.RAS.D

   e. Select relevant data to collect in order to determine the index of refraction of a substance. P.W.2.RAS.E

1. **Charging objects** P.EM.1

   a. Investigate alternative solutions to reduce static electricity in clothing tossed in a dryer. P.EM.1.DTES.A

   a. Describe and draw diagrams to explain the process of polarization and the attraction of a charged object and a neutral object in terms of the movement of electrons (e.g., balloon sticking to a wall, balance a meter stick on a golf ball and cause rotation with a charged balloon). P.EM.1.ICSC.A

   a. State the differences between conductors and insulators in terms of electron movement through the materials. P.EM.1.RAS.A

   b. Describe how electrons move in an electroscope and how the electroscope indicates charge. P.EM.1.RAS.B

   c. Represent the methods of charging in a graphic organizer, chart or drawing. P.EM.1.RAS.C

2. **Coulomb's law** P.EM.2

   a. Investigate, in the lab or with a computer simulation, electrostatic repulsion and attraction. Devise two procedures to investigate the effects charge and distance have on the magnitude and direction of the force. P.EM.2.DSK.A

   a. Cite the similarities and differences between the equation for gravitational and for electrical force (Coulomb's Law). P.EM.2.RAS.A

   b. Solve problems using Coulomb's Law to determine the net force on a charge due to two charges that are not collinear. P.EM.2.RAS.B

   c. Explain the relationship between force and distance using a graphical representation. P.EM.2.RAS.C

3. **Electric fields and electric potential energy** P.EM.3

   a. Use a computer simulation to investigate the effect of charges on the electric field at a point in space and the effect of an external field on a charged particle. Determine the relationships. P.EM.3.DSK.A

   a. Compare Earth's gravitational field with an electric field in terms of when potential energy is increasing and decreasing. P.EM.3.ICSC.A

   b. Explore the Millikan Oil Drop Experiment. Apply the idea of equilibrium to electrical and gravitational forces. P.EM.3.ICSC.B

   a. Solve problems about the force on a charged particle in a constant electric field. Use Newton's Laws, kinematic equations and equations for work and kinetic energy to calculate the acceleration of the particle, the final velocity of the particle and the change in energy of the particle. P.EM.3.RAS.A

   b. Describe the relationship between potential energy and electric fields. P.EM.3.RAS.B

   c. Draw the field lines for a positive charge, a negative charge, a dipole and two parallel plates of charge. P.EM.3.RAS.C

4. **DC circuits** P.EM.4

   a. Use a source of constant voltage to plan and conduct an investigation to determine the relationship between the current and the resistance in a simple DC circuit. Analyze the results mathematically and graphically. Form a claim about the relationship between the current and resistance and support the claim with evidence from the investigation. P.EM.4.DSK.A

   a. Solve problems involving complex circuits with arrangements of resistors in both parallel and series to determine the equivalent resistance of the entire circuit as well as the current, the potential difference, or rate of energy dissipated in individual resistors in the circuit. P.EM.4.ICSC.A

   b. Compare different types of string lights to explore what type of circuits are involved, how blinker bulbs work and how bulbs that are unlit complete a circuit. P.EM.4.ICSC.B

   a. Solve problems involving resistors in series and in parallel to determine the current, potential difference, or rate of energy dissipated in individual resistors in the circuit. P.EM.4.RAS.A

5. **Magnetic fields** P.EM.5

   a. Use a small compass to map the magnetic field around a bar magnet, horseshoe magnet and circular magnet. Explain why the shape of the fields is different. P.EM.5.ICSC.A

6. **Electromagnetic interactions** P.EM.6

   a. Design and build a generator that will convert mechanical energy into electrical energy and light three flashlight bulbs. Draw a labeled design plan and write a paper explaining in detail, and in terms of electromagnetic induction, how the details of the design allow the generator to work. Test the generator in an electric circuit. If it cannot supply the electrical energy to light three flashlight bulbs in a series, redesign the generator. P.EM.6.DTES.A

   b. Design an electromagnetic motor with a limitation on the amount of materials used in construction. Test the design and redesign the motor based on the findings from the testing process. P.EM.6.DTES.B

   a. Investigate the production of a magnetic field by a current carrying wire. Develop and test a hypothesis about the relationship between an independent variable (e.g., amount of current) and the strength of the generated magnetic field. P.EM.6.DSK.A

   b. Using a galvanometer connected to a solenoid and a magnet, design and conduct an investigation to determine when current is induced and what variables affect the strength of the current. P.EM.6.DSK.B

   c. Plan and conduct an investigation to determine the resistance of an unknown resistor. Unanticipated effects on measurements should be accounted for (e.g., internal resistance of the battery or power supply) and assumptions made should be explained (e.g., assuming the resistance of the wires can be ignored or that a voltmeter has an infinite impedance). Experimental design should be checked for safety before conducting the experiment. P.EM.6.DSK.C

   a. Apply Newton's Laws to predict the shape of the path followed by a charged particle moving in a magnetic field. Draw the path and predict the shape for heavier and lighter particles as well as particles with different charge. P.EM.6.ICSC.A

   b. Predict the direction of a magnetic field in a current carrying wire. Use a compass and wire demonstration device to check the prediction. P.EM.6.ICSC.B

   c. Draw a circuit diagram of the experimental design before conducting the experiment, labeling the elements of the circuit. P.EM.6.ICSC.C

   a. State the factors that affect the force on a moving charged particle in a magnetic field and determine the path taken by the charged particle. P.EM.6.RAS.A

   b. Use the right-hand rules to determine the direction of a charged particle in a magnetic field. P.EM.6.RAS.B

   c. Discuss the benefits and origins of Earth's magnetic field. P.EM.6.RAS.C

   d. Calculate the resistance of the resistor, using either an average of the data or by graphing the data and analyzing it. P.EM.6.RAS.D