Magnetism

Missouri Grade-Level Expectations (or other standards)

NGSS: HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Learning Goal	Proficiency Scales
Students will be able to analyze the interaction of magnets and magnetic fields.	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Student demonstrates mastery with the learning goal as evidenced by: ● Determining the force experienced by a charged particle in a magnetic field. ● Understanding the force exerted on a current-carrying wire in a magnetic field. 2: Student demonstrates he/she is nearing proficiency by: ● Recognizing or recalling specific vocabulary, such as *domains, poles, magnetic field, magnetic force, attraction, repulsion, electrons, protons, right-hand rule.* ● Performing processes such as: ○ Demonstrating the essential relationship between electric current and magnetic fields. ○ Representing magnetic fields using field lines.

	○ Demonstrating that an electric current can produce an electric field and a changing magnetic field can produce an electric current. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets
○ calculate the size and direction of the force in terms of q, v, and, B, and explain why the magnetic force can perform no work; ○ calculate the size and direction of a magnetic field from information about the forces experienced by charged particles moving through that field; and ○ describe the paths of charged particles moving in uniform magnetic fields. ○ calculate the magnitude and direction of the field at a point in the vicinity of such a wire; ○ use superposition to determine the magnetic field produced by two long wires; and ○ calculate the force of attraction or repulsion between two long current-carrying wires.
Learning Design

Waves

Missouri Grade-Level Expectations (or other standards)

NGSS-HS-PS:

4-1:Use mathematical representations to support a claim regarding relationships among the frequency, wavelength,and speed of waves traveling in various media.

4-2: Evaluate questions about the advantages of using a digital transmission and storage of information.

4-3: Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

4-4:Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

4-5: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

## Learning Goal Students will be able to deduce the function and purpose of a wave based on its physical characteristics and behavior.	## Proficiency Scales 4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Student demonstrates mastery with the learning goal as evidenced by: ● Modeling the physical characteristics of a traveling wave. ● Describing the behavioral characteristics of a traveling wave. ● Describing the conditions under which the waves reaching an observation point from two or more sources will all interfere. ● Relating the amplitude produced by two or more sources that interfere to the amplitude produced by a single source. 2: Student demonstrates he/she is nearing proficiency by:

	● Recognizing and recalling specific vocabulary, such as: *reflection, refraction, diffraction, interference, frequency, period, velocity, Doppler shift, and amplitude.*
	
	● Performing processes such as:
	  ● Labeling and define all parts of a wave.
	  ● Describing the order of EM spectrum.
	  ● Summarizing various types of interference.
	  ● Describing the interaction of waves in terms of reflection, refraction and diffraction of a wave at a boundary between two media.
	
	1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Describing the characteristics and properties of waves
- Describing how to calculate the speed of a wave
- Distinguishing between the two types of waves
- Discriminating between sound waves and electromagnetic waves
- Explaining the Doppler Effect
- Manipulating the electromagnetic spectrum based on frequency and wavelength
- Investigating waves as a means of digital storage and transmission and contrast with other means
- Identifying graphs that represent traveling waves and determine the amplitude, wavelength, and frequency of a wave from such a graph;
- Applying the relationship ($v=f\lambda$) among velocity, frequency, and wavelength for a traveling wave; and
- Describing qualitatively what factors determine the speed of waves through space in both longitudinal and transverse types.
- Understanding qualitatively the Doppler effect for waves in order to explain why there is a frequency shift in both the moving-

source and moving-observer case; and

Learning Design

Conceptual-Space Systems

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Missouri Grade-Level Expectations (or other standards)

NGSS: HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
NGSS: HS-ESS1-4: Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

Learning Goal	Proficiency Scales
Students will be able to prove relational properties of objects in our solar system.	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Student demonstrates mastery with the learning goal as evidenced by: ● Demonstrating an understanding of Newton's Law of Universal

	Gravitation. ● Explaining the motion of an object in orbit under the influence of gravitational forces. ● Using mathematical representations (Kepler and Newtonian) to predict motion of orbiting objects. 2: Student demonstrates he/she is nearing proficiency by: ● Recognizing or recalling specific vocabulary, such as: *orbit, field, centripetal, force, acceleration, radius, circumference, Kepler, Newtonian, and period* ● Performing processes such as: ○ describing the motion and causes of orbiting objects without using mathematical representations. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Applying Kepler's Laws and Newton's Universal Law of Gravitation to planetary motion
- determining the gravitational force that one spherically symmetrical mass exerts on another; and
- determining the strength of the gravitational field at a specified point outside a spherically symmetrical mass.
- recognizing that the motion does not depend on the object's mass; describe qualitatively how the velocity, period of revolution, and centripetal acceleration depend upon the radius of the orbit; and derive expressions for the velocity and period of revolution in such an orbit; and
- deriving and applying the relations among kinetic energy, potential energy, and total energy for such an orbit.

Learning Design

Kinematics

Missouri Grade-Level Expectations (or other standards)

NGSS: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object its mass, and its acceleration.

Learning Goal	Proficiency Scales
Students will be able to model motion of an object as it relates to its position, velocity, and acceleration.	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Student demonstrates mastery with the learning goal as evidenced by: ● Describing the relationships among position, velocity and acceleration. ● Analyzing displacement, velocity and acceleration vectors. ● Understanding the motion in a uniform gravitational field. 2: Student demonstrates he/she is nearing proficiency in the learning goal by: ● Recognizing or recalling specific vocabulary, such as *displacement, velocity, acceleration, vector, components, resultant, frame of reference.*

	● Performing processes such as: ○ Producing and extrapolating data from graphs of position vs. time and velocity vs. time. ○ Illustrating an understanding of motion with reference to kinematic equations. ○ Understanding the motion in a uniform gravitational field for projectiles launched horizontally as well as at angles regarding the horizontal and vertical components of position, velocity and acceleration. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Calculate displacement, velocity and acceleration of objects moving in one and two dimensions
    - graphically represent a moving object's position, velocity and acceleration as functions of time, and identify or sketch graphs of these motions;
    - use the kinematic equations to solve problems involving motion with constant velocity and constant acceleration; and
    - describe in words the motion, and subsequent changes in motion, for objects moving with a constant velocity or with constant acceleration.
    - add and subtract displacement, velocity and acceleration vectors in one and two dimensions to find the resultant vector; and
    - determine the components of a given displacement, velocity and acceleration vector along a specified, mutually perpendicular axes.
    - write down expressions for the horizontal and vertical components of position, velocity and acceleration as functions of time, and sketch or identify graphs of these components; and

○ use kinematic equations in analyzing the motion of a projectile that is projected with an arbitrary initial velocity.
Learning Design

Work, Energy, Power

Missouri Grade-Level Expectations (or other standards)
NGSS: HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **NGSS: HS-PS3-2:** Develop and use ;models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.

Learning Goal	Proficiency Scales
Students will be able to relate an object's energy to the amount of work performed on	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal.

or by the object.	3: Students demonstrate mastery with the learning goal as evidenced by: ● Calculating the work performed by a specified constant force on an object that undergoes a specified displacement and relate the amount of work to energy transferred; ● Determining the amount of mechanical energy transferred during work, when non-conservative forces are absent (The Principle of Conservation of Mechanical Energy). ● Calculating the potential and kinetic forms of mechanical energy that an object has by virtue of its mass, speed and position; and ● Calculate the power required to maintain the motion of an object. ● Calculating the work performed by a force. ● Applying the Law of Conservation of Energy to situations where change is occurring. 2: Student demonstrates he/she is nearing proficiency as evidenced by: ● Recognizing or recalling specific vocabulary, such as: *conservation, potential, kinetic, height, mechanical, nonmechanical, gravitational, efficiency, work, heat, sound, friction, static, and power.* ● Performing basic processes, such as: ○ Listing and partially describing sources and transfers of energy. ○ Describing LOCOE with teacher supplying terms. ○ Planning and building a device that demonstrates some energy transfer with some success. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Define and describe work
- Define and describe energy
- Define and describe power
- State the two forms of mechanical energy and explain how energy is changed in a closed system
- State three forms of potential energy
- Describe how work and potential and kinetic energy are related verbally and mathematically
- State the law of conservation of energy and describe the transfer of energy in a system
- Build model that demonstrates energy transfer

Learning Design

Electrostatics

Missouri Grade-Level Expectations (or other standards)

NGSS: HS-PS2-4: Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
NGSS: HS-PS2-5: Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
NGSS: HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces

between objects and the changes in energy of the objects due to the interaction.

Learning Goal	Proficiency Scales
Students will be able to analyze the electrostatic interaction of electrical charges through electrical fields.	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Students demonstrates mastery with the learning goal as evidenced by: ● Describing the types of charge and the attraction and repulsion of charges. ● Using Coulomb's law to calculate the size and direction of the electrical force on a positive or negative charge due to other specified point charges. ● Analyzing the motion of a specified charge and mass under the influence of an electrostatic force. ● Modeling the concept of an electric field. ● Modeling the concept of electric potential. 2: Student demonstrates he/she is nearing proficiency by: ● Recognizing or recalling specific vocabulary, such as *electric charge, electric force , Coulomb's Law, attraction, repulsion, electrons, protons, neutrons, electric potential, electric potential energy, potential difference, voltage.* ● Performing processes such as: ○ Explaining the essentials of the effects of the inverse square law on two charged particles. ○ Demonstrating the essential relationship between electric

	charge, electric field strength and electrostatic forces. ○ Representing electric fields using field lines. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Describe the fundamental rule at the base of all electrical phenomena
- Explain how an object becomes electrically charged
- Use Coulomb's law to understand the relationship among force, charge and distance
- Describe two ways electric charges can be transferred
- Describe what happens when a charged object is placed near a conducting surface
- Describe how to measure the strength of an electric field at different points
- Illustrate electric fields with vectors and by electric field lines
- define it in terms of the force on a test charge;
- describe and calculate the electric field of a single point charge;
- calculate the size and direction of the electric field produced by two or more point charges;
- calculate the size and direction of the force on a positive or negative charge placed in a specified field;
- interpret an electric field diagram; and
- analyze the motion of a specified charge and mass in a uniform electric field.
- understanding the concept of electric potential, so that they can
- determine the electric potential (in volts) in the vicinity of one or more electric charges;
- calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference;
- determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials;
- calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential;
- calculate how much work is required to move a test charge from one location to another in the field of fixed point charges; and

- calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to establish the charge system.

Learning Design

Dynamics

Missouri Grade-Level Expectations (or other standards)

NGSS: HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object its mass, and its acceleration.
NGSS: HS-PS2-2: Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

Learning Goal	Proficiency Scales
Students will be able to relate	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal.

acceleration to mass, velocity, and the forces that affect motion.	3: Student demonstrates mastery of the learning goal as evidenced by: ● Analyzing situations in which an object remains at rest or moves with a constant velocity and momentum (p=mv). ● Describing the relationship between the net force that acts on an object and the resulting change in the object's velocity and momentum. ● Identifying the action and reaction pairs of forces (impulses) on objects that are interacting. 2: Student demonstrates he/she is nearing proficiency in the learning goal by: ● Recognizing or recalling specific vocabulary, such as: *inertia, mass, force, net force, acceleration, momentum, equilibrium, conservation, momentum, impulse, change in momentum, free-body diagram, Newton's Laws of Motion.* ● Performing processes such as: ○ Constructing free-body diagrams. ○ Exhibiting an understanding of Newton's Three Laws of Motion. ○ Calculating the impulse applied to an object as it relates to the change in momentum. ○ Conceptualizing and categorizing collisions including conservation of momentum but are unsuccessful at analyzing the success or failure of the model. 1: Student demonstrates limited understanding or skill with the learning goal.

Learning Targets

- Calculate momentum of objects in motion (p=mv)
- Calculate the Impulse acting on objects while an object is undergoing a change in momentum (J=
- Describe the relationship between mass and inertia
- State the relationship between acceleration and net force and mass in terms of Newton's 2nd law
- List the factors that affect the movement of an object, such as friction and air resistance
- Analyze the role of mass and force along with velocity in momentum through collisions
- Explain why an impulse is greater when an object bounces than when the same object comes to a sudden stop
- Describe and calculate how the conservation of momentum applies to collisions
- draw a well-labeled, free-body diagram showing all forces that act on the object;
- determine a state of equilibrium as the absence of a net force or impulse;
- describe state of motion in terms of constant momentum and zero acceleration; and
- apply Newton's 1st Law of Motion (Law of Inertia).
- draw a well-labeled, free-body diagram showing an imbalance of forces that act on the object;
- understand how Newton's Second Law of motion($\Sigma F = ma$) applies to an object subject to forces such as gravity, the pull of strings, or contact forces;
- calculate the acceleration and the change in momentum that results when a constant net force acts over a specified time interval resulting from a impulse;
- determine the size and direction of the net force, or of one of the forces that makes up the net force, from kinematic measurements of an object in motion; and
- apply Newton's 2nd Law of Motion (Law of Force).
- explain the resulting changes in velocity and momentum of the objects interacting or involved in collisions;
- calculate the acceleration and momentum change of objects interacting or involved in collisions;
- apply linear momentum conservation to one-dimensional elastic, inelastic and perfectly inelastic collisions; and
- apply Newton's Third Law of Motion.

Learning Design

Current Electricity

Missouri Grade-Level Expectations (or other standards)

NGSS: Science and Engineering Practices: Analyze data using tools, technologies, and/or models (eg.computational, mathematical) in order to make valid and reliable scientific claims or create an optimal design decision.

Learning Goal	Proficiency Scales
The student will be able to analyze the movement of electrical charges and the resulting energy transferred by the current.	4: Student demonstrates an in-depth inference or advanced application or innovates with the learning goal. 3: Student demonstrates mastery with the learning goal as evidenced by: ● Predicting the rate and flow of positive and negative charges when given the size and direction of the electric current. ● Relating electric current and voltage for a resistor. ● Describing how the resistance of a resistor depends upon its length and cross-sectional area and applying this result in comparing current flow in resistors of different material or different geometry. ● Deriving expressions that relate the electric current, voltage, and resistance to the rate at which heat is produced when current passes through a resistor.

	● Determining the ratio of the voltages across resistors connected in series or the ratio of the currents through resistors connected in parallel. ● Calculating the voltage, current, and power dissipation for any resistor with a single power supply. ● Showing correct methods of connecting voltmeters and ammeters into circuits. 2: Student demonstrates he/she is nearing proficiency by: ● Recognizing or recalling specific vocabulary, such as *electric current, electric resistance, electric power, voltage difference, amp, volt, ohm, Ohm's Law, circuit, series, parallel, watts.* ● Performing processes such as: ○ Building electrical circuits where the resistors are attached to a power source in both series and parallel configurations. ○ Measuring the voltage drops and electrical current using meters placed in an electrical circuit. ○ Calculating the electrical power used in running various resistors connected in both series and parallel configurations. ○ Applying Ohm's law. ○ Identifying on a circuit diagram whether resistors are in series or in parallel. 1: Student demonstrates a limited understanding or skill with the learning goal.

Learning Targets

- Describe the flow of electric charge in a current-carrying wire
- Give examples of voltage sources
- Analyze the relationship among the factors that affect the resistance of a wire
- Describe Ohm's law
- Distinguish between DC and AC and how AC is converted to DC
- Explain how current can be turned on or off in a circuit, and how electrical devices can be connected in a circuit
- Describe the characteristics of a series and parallel circuit

Learning Design