Ohio Learning Standards for Physics

Motion

- Graph Interpretations
    - Position vs Time
    - Velocity vs Time
    - Acceleration vs Time
- Problem Solving
    - Using graphs (average velocity, instantaneous velocity, acceleration, displacement, change in velocity)
    - Uniform acceleration including free fall (initial velocity, final velocity, time, displacement, acceleration, average velocity)
- Projectiles
    - Independence of horizontal and vertical motion
    - Problem-solving involving horizontally launched projectiles

Forces, Momentum, and Motion

- Newton's laws applied to complex problems
- Gravitational force and fields
- Elastic forces
- Friction force (static and kinetic)
- Air resistance and drag
- Forces in two dimensions
    - Adding vector forces
    - Motion down inclines
    - Centripetal forces and circular motion
    - Momentum, impulse, and conservation of momentum

Energy

- Gravitational potential energy
- Energy in springs
- Nuclear energy
- Work and power
- Conservation of Energy

Waves

- Wave properties
  - Conservation of energy
  - Reflection
  - Refraction
  - Interference
  - Diffraction
- Light phenomena
  - Ray diagrams (propagation of light)
  - Law of reflection (equal angles)
  - Snell's Law
  - Diffraction patterns
  - Wave-particle duality of light
  - Visible spectrum and color

Electricity and Magnetism

- Charging objects (friction, contact, and induction)
- Coulomb's Law
- Electric fields and electric potential energy
- DC circuits
  - Ohm's law
  - Series circuits
  - Parallel circuits
  - Mixed circuits
  - Applying conservation of charge and energy (junction and loop rules)
- Magnetic fields and energy
- Electromagnetic interactions

Physics Learning Targets

Unit 1 Physics Toolkit

Mathematics and Logic. The student will be able to

- Use Scientific Methods of investigation
- Use the International System of Measurements (SI): The metric system
- Do Dimensional Analysis using conversion factors
- Perform arithmetic operations using scientific notation
- Distinguish between accuracy and precision
- Determine the precision of measured quantities
- Construct graphs using independent and dependent variables
- Describe the relationship between variables on a graph
- Identify common mathematical relationships (direct and inverse, linear and quadratic, positive and negative correlations) shown on graphs

Unit 2 Motion, part 1

Velocity. The student will be able to
- Describe positive and negative displacements of objects
- Describe positive and negative velocities of objects
- Interpret position vs time graphs showing no motion, constant motion, constantly accelerated motion, and non-uniform motion
- Explain how the tangent line on position vs time graphs shows the instantaneous velocity of objects
- After constructing a position vs time graph, use tangent lines to determine instantaneous velocities of objects
- Explain how instantaneous velocity is the same as average velocity for an object moving with constant velocity
- Calculate average velocity of an object moving with constant velocity, given initial and final velocities.

Unit 3 Motion, part 2

Acceleration
- Interpret velocity vs time graphs showing no motion, constant motion, constantly accelerated motion, and changing accelerations
- Explain how the slope of a velocity vs time graph represents the acceleration of an object
- Calculate the slope of any tangent line of a velocity vs time graph
- Explain how a horizontal line on a velocity vs time graph indicates constant speed, and a non-horizontal line represents accelerated motion
- Describe acceleration as positive if Δv of an object is positive, or negative if Δv of an object is negative.

- Given the initial velocity of an object, predict the outcome of positive or negative acceleration on the motion of the object by telling whether the object will speed up, slow down, or have constant velocity
- Calculate the area under the curve of velocity vs time graphs and interpret the results of your calculation as displacement
- Interpret a horizontal line on an acceleration vs time graph as constant velocity, and a non-horizontal line as accelerated motion
- Calculate the area under the curve of acceleration vs time graphs and interpret the results of the calculation as change in velocity
- Use kinematic equations to solve complex problems for objects moving with uniform acceleration, including problems involving objects in free fall
- State that the acceleration due to gravity is 9.81 m/s^2

Unit 4 Forces, Part 1

Newton's Laws of Motion
- Distinguish between field forces and contact forces
- Explain that the origin of contact forces (such as friction and the normal force) are the result of electric forces between charged particles in atoms of the materials that are in contact
- Construct free body diagrams with accurately drawn scale-length arrows representing force vectors
- Define weight, drag, elastic force, thrust, tension, and friction, and identify the direction in which they act
- Explain the concept of inertia using real-world examples
- Use Newton's second law of motion to solve complex problems—problems where multiple forces must be first quantified
- Distinguish weight from mass
- Use all three of Newton's laws of motion to solve complex problems that involve systems of many objects that move together as one—such as calculating the apparent weight of an object in an elevator that is accelerating, and calculating the forces and accelerations of masses connected together by a cord that passes over a pulley (Atwood Machine).
- Use the normal force and net force to solve problems of objects in contact with each other
- Use Newton's 2nd Law of motion to explain why all objects fall at the same rate in the absence of air resistance
- Use Newton's 3rd Law to explain the concepts of drag and lift on objects moving in fluids
- Use Newton's 2nd Law and force diagrams to quantify forces on objects moving through fluids

Unit 5 Forces, Part 2

Vectors, Friction, Static forces
- Draw force vectors to scale from reference points on coordinate systems
- Resolve the components of vectors using trigonometry
- Use trigonometry to find resultant vectors by combining multiple vectors acting at a single point
- Identify and define two types of friction—static and kinetic
- Calculate friction forces using normal force and coefficients of friction

- Given descriptions of objects in contact, moving or still, determine the coefficient of static and kinetic friction
- Use the concept of friction to predict the motion of objects in real life situations
- Explain how to increase or decrease friction forces between objects
- Solve problems involving inclined planes to determine components of weight forces, friction forces, normal forces, and motion
- Analyze the net force and determine the equilibrant on objects experiencing multiple forces

Unit 6 Motion, Part 3

Projectile Motion and circular motion
- Analyze the vertical and horizontal components of a projectile's velocity as two vectors that are independent of each other
- Solve problems involving range, time, initial height, and velocity of a horizontally launched projectile
- Draw free body diagrams of force vectors acting on an object moving in a circle, indicating that the centripetal force points towards the center and keeps the object moving in a circle
- Explain that centripetal force is the net force that causes an acceleration (indicated by a change in direction, even when speed is constant) of objects moving in a circle or curved path
- Predict the motion of an object moving in a circle if the centripetal force is suddenly removed
- Use velocity and radius and the formula $a_c = \dfrac{v^2}{r}$ to solve problems of centripetal acceleration
- Use Newton's 2nd Law to solve for centripetal force on an object

Unit 7 Force, Part 3

Gravity
- Compare the relative strength of the four fundamental forces and recognize that gravity is the weakest of the four
- Solve problems involving the gravitational force between two objects using Newton's Law of Universal Gravitation
- Use the force of gravity to predict the path of an orbiting object
- Identify the properties of gravitational fields

Unit 8 Force, Part 4

Momentum
- Define momentum and show that it is directly proportional to mass and velocity of an object.
- Use the concept of impulse to explain how momentum of a system can change
- Demonstrate the relationship between force, time and change in momentum
- Solve problems using the impulse-momentum theorem
- Calculate an object's momentum and show that it is in the same direction as the motion of the object
- Explain how linear momentum is conserved in a closed, isolated system
- Identify examples of transfer of momentum
- Describe the transfer of momentum during elastic, inelastic, and totally inelastic collisions

- Apply the law of conservation of momentum using real-life phenomena and predict the motion of objects after a collision

Unit 9 Energy, Part 1

Mechanical Energy
- Use trigonometry to calculate the work done by a force applied at any angle relative to the displacement of an object
- Explain the relationship among work and power and correctly calculate each
- Explain why no work is done on an object when force and displacement are at right angles to each other (such as in circular motion)
- Analyze the gravitational potential energy and kinetic energy of a system in terms of gravitational fields
- Explain that gravitational potential energy is the energy transferred into or out of the gravitational field
- Recognize that a single mass does not have gravitational potential energy, only systems of attractive masses do
- Describe the transfer of energy into or out of a gravitational field as two objects move closer together or further apart
- Identify systems involving elastic potential energy
- Explain how doing work changes potential, elastic, and kinetic energy
- Use the law of conservation of energy in a closed isolated system to demonstrate that energy is conserved
- Measure quantities for potential and kenetic energy to show how one type of energy can be converted into another
- Recognize that the law of conservation of energy does not apply to situations involving mass-energy conversions

Unit 10 Waves, Part 1

Wave Properties
- Calculate the elastic potential energy of an object using the equation $PE_{Spring} = \frac{1}{2}kx^2$
- Apply the law of conservation of energy to wavelength, frequency, amplitude, and speed of waves
- Describe a standing wave as a self-interfering wave
- Describe light as a bundle of energy called a photon
- Relate the energy in a photon as a function of frequency
- Describe the duality of light properties—wave and particle
- Predict how light waves are absorbed as thermal energy, are transmitted, or are reflected, but conform to the law of conservation of energy, when striking transparent, translucent, and opaque objects
- Explain radiant energy as an electromagnetic wave that spreads out in all directions from a source
- Explain how the different parts of the electromagnetic spectrum, including visible light, correspond to different radiant energies

- Explain how reflection and absorption of white light on a pigment results in the perception of color

Unit 11 Waves, Part 2

Reflection
- Describe the law of reflection
- Apply the law of reflection to predict wave behaviors
- Construct ray diagrams that show reflected light as it passes through a plane mirror

Unit 12 Waves, Part 3

Light Phenomena
- Describe refraction as a function of the change in the speed of light as it travels from one medium into another
- Solve for index of refraction using the speed of a wave in a medium compared to the speed of light in a vacuum
- Construct ray diagrams that show reflected light as it passes through converging and diverging lenses
- Solve problems of refraction using Snell's Law
- Predict the locations of constructive and destructive interference as a function of wavelength, slit width, and spacing
- Explain how light falling on two slits produces an interference pattern
- Describe the cause of constructive and destructive interference in terms of the wave model of light
- Describe the cause of diffraction patterns
- Explain how a diffraction grating works
- Measure and explain the amount of bending of a wave when it goes through an opening or around a barrier (diffractions) based on the wavelength and size of the opening or barrier

Unit 13 Electricity, Part 1

Static Charge
- Use the law of conservation of electric charge to predict the net charge of a closed system
- Define the law of conservation of charge
- Trace the movement of electrons as a neutral object is charged by friction, contact, or induction
- Explain the difference between charging by friction, contact, and induction
- Describe the behavior of charge distribution on an electrical conductur (spread out) and an electrical insulator (localized)
- Apply the particle model of matter to explain the interaction between a charged and a neutroal object
- Explain the attractive force resulting from a charged object coming in contact with a neutral metal conductor or a neutral insulator
- Compare the electrical force (repulsive and attractive, cancel each other) and the gravitational force (only attractive and accumulative)

- Model the electrical force as the result of the distance between point charges
- Solve problems using Coulomb's law between two point charges, or three or more charges in a line if the vector sum is zero
- Calculate the electric field strength of a charged object or a collection of charges (principle of superposition)
- Use electric field diagrams as a model to show relative field strength
- Explain that the electric field around a charge is always present, even if the object is not interacting with anything else
- Represent an electric field with arrows in a field diagram, including the fields of dipoles and capacitors (field lines are not required)
- Explain the motion of charges (kinetic energy) in terms of work and a system's electric potential energy
- Analyze the transference of electric potential enrgy into or out of a closed system when two charges are moved closer or further apart
- Recognize a single point charge does not hae electrical potential energy, but systems of attracting and repelling charges

Unit 14 Electricity, Part 2

Moving Charge
- Explain that electric potential difference and electric fields move through a wire almost instantaneously upon the connection of a circuit, but the electrons themselves move only a few centimeters per hour in a current-carrying wire
- Apply the law of conservation of charge to model the amount of current flowing in and out of a circuit junction (junction rule)
- Apply the law of conservation of charge to model the potential differences across batteries and resistors (loop rule)
- Calculate the potential difference across batteries and resistors (Ohm's law)
- Determine the resistance by finding the slope on a graph of potential difference vs. Current
- Identify whether two circuit elements are in series, parallel, or neither
- Calculate the equivalent resistance for a circuit containing resistors in series and parallel
- Design and construct simple ohmic resistive circuits using the loop rule and junction rule
- Explain conceptually and calculate how current and potential difference are distributed differently among parallel and series circuit elements
- Use the particle theory of matter to explain the difference between magnetic and non-magnetic materials
- Explain how moving charges create magnetic fields
- Use a compass to find the direction of a magnetic field at different points in space
- Use magnetic field line diagrams to model relative field strength and magnetic field direction
- Use magnetic fields to describe the concept of magnetic potential energy
- Explain why only systems of attracting or repelling poles can have magnetic potential energy, and that a single magnetic pole does not have magnetic potential energy
- Explain motions of magnetic objects in terms of work and the system's magnetic potential energy
- Explain that the electric and magnetic forces are two aspects of a single electromagnetic force
- Describe the connection between moving charges and magnetic fields

- Explain earth's magnetic field in terms of moving electric charges in the interior of the earth
- Explain how a magnetic force acting on a moving charged particle is perpendicular to both the magnetic field and the direction of the motion of the charged particle (third right-hand rule)
- Identify that there is no magnetic force acting on a particle that is moving parallel to a magnetic field
- Explain how a changing magnetic field induces an electric field
- List the factors that determine the strength of an induced current in a wire by a magnetic field (strength of magnetic field, velocity of relative motion, number of loops in the wire)
- Apply the concepts of electric and magnetic forces that demonstrate the conversion of mechanical energy to electric energy (generator) ♦ Explain how a changing electric field induces a magnetic field
- Describe the strength of the magnetic force induced by current in a wire (speed of a moving particle, magnitude of the charge, strength of the magnetic field, angle between velocity and magnetic field)
- Apply the concept of electric and magnetic forces that demonstrate the conversion of electrical energy to mechanical energy (motor)
- List evidence that supports the relationship between electric and magnetic fields
- Explain the origin of electromagnetic waves by changing the motion of charges or by changing magnetic fields
- Explain that electromagnetic waves travel at the speed of light
- Construct a device that produces or receives electromagnetic waves (speaker, microphone, radio, tv)

Unit 15 Energy, Part 2

Nuclear Energy
- Explain and illustrate mass-energy equivalence ($E = mc^2$)
- Calculate the energy released in nuclear fission and fusion reactions
- Compare and contrast alpha, beta, gamma, and positron emissions
- Predict the products of radioactive decay

Physics Pacing Guide

1st Quarter	2nd Quarter
Unit 1 Physics Toolkit	**Unit 5** Forces, Part 2: Vectors, Friction, Statics
Unit 2 Motion, Part 1: Velocity	**Unit 6** Motion, Part 3 Projectile Motion, Circular motion
Unit 3 Motion, Part 2: Acceleration	**Unit 7** Forces, Part 3: Gravity
Unit 4 Forces, Part 1: Newton's Laws	

3rd Quarter	4th Quarter
Unit 8 Forces, Part 4: Momentum	**Unit 12** Waves, Light Phenomena
Unit 9 Energy, Part 1: Mechanical Energy	**Unit 13** Electricity, Part 1: Static Charge
Unit 10 Waves, Part 1: Properties	**Unit 14** Electricity, Part 2: Moving Charge
Unit 11 Waves, Part 2: Reflection	**Unit 15** Energy, Part 2: Nuclear Energy