Unit Objectives

## Unit 1 – Motion and Kinematics

The student will devise a method for determining the limits of instrumentation.

The student will distinguish between distance and position.

The students will create a procedure for conducting an experiment on an object in constant motion.

The students will distinguish among speed, velocity, average velocity, instantaneous velocity, and displacement.

The student will use statistical analysis to determine degree of error.

The student will calculate both positive and negative vector sums of velocities.

The student will construct a scientific model for a particle in one dimension experiencing constant net force.

The student will apply graphical analysis to the relationship among XT, VT, AT, and V2- Δx.

The student will distinguish between acceleration and velocity.

The student will describe and solve kinematic problems in one dimension.

The student will construct motion maps that show both velocity and acceleration.

## Unit 2 – Fields and Energy

The student will explain how fields solve the problem of action at a distance.

The student will create field line diagram and vector field diagrams for magnetic, electric, and gravitational fields.

The student will state the common names given to energy possessed by particles and fields

The student will determine which of two states has more field energy by examining diagrams showing the relative position of magnets, charges, or masses

The student will identify the parts of a system that are involved in energy transfer

The student will explain the conservation of energy

The student will outline the various containers for energy and the changes that take place transfer energy between containers.

The student will create graphs to determine the strength of the Earth’s g-field.

The student will use the strength of the g-field to calculate the gravitational force on an object.

The student will state the common names given to energy possessed by particles and fields

The student will identify the parts of a system that are involved in energy transfer

The student will outline the various containers for energy and the changes that take place transfer energy between containers.

The student will define and explain how work affects a system

The student will communicate how friction and heat affect a given system

The student will create and interpret energy bar charts and energy flow diagrams

The student will explain the significance of the “area under” a Force vs. change in length graph (any Newtons vs. meters graph).

The student will explain the significance of the slope of a force vs. change in length graph.

The student will explain the gravitational potential as a property of the g-field

The student will explain what is meant by and differentiate between conservative and non-conservative forces.

The student will identify the parts of a system that are involved in energy transfer.

The student will create and interpret energy bar charts and energy flow diagrams.

The student will solve mathematical problems involving energy transfer.

The student will solve mathematical problems involving the rate of energy transfer.

The student will explain what it means for two particles to be bound or unbound

The student will explain what is meant by the term bond energy.

The student will outline how particles in a system can become bound or unbound based on the transfer of energy.

The student will identify “real world” examples of binding and unbinding and analyze the energy transfer in the system.

The student will describe the phases of matter in terms of the positions and motions of the particles of which they are made

The student will explain how energy is stored in solids, liquids, and gases by identifying relative amounts of KE and EPE

The student will explain how temperature and KE are related

The student will analyze how pressure affects the components of a MIP system

The student will create and interpret the temperature curve for water

The student will explain the specific heat capacity of a substance and identify how it is involved in energy transfer.

The student will explain latent heat of a substance and identify how it is involved in energy transfer.

The student will differentiate between the latent heats of fusion and vaporization

The student will solve mathematical problems involving heat and energy transfer.

## Unit 3 – Mechanics

The student will define the local gravitational field intensity in terms of force and mass.

Describe how a plumb line and bob can be used to find the center of mass of an irregularly shaped object.

Predict whether an object will topple, given the location of the center of mass and the area of support of the object.

Distinguish among different equilibria.

Give examples of how a human is effected by the need to keep the body’s center of mass over the support base.

The student construct vector diagrams, including resultants of forces.

The student will distinguish between a vector quantity and a scalar quantity, and give examples of each.

The student calculate resultants of vectors, and resolve a vector into horizontal and vertical components.

The student will distinguish between mass and weight.

The student distinguish between the kilogram and the newton.

The student will design a force versus mass investigation.

The student will plot a force versus mass graph, express the equation, and discover the significance of the slope and the significance of the intercept.

The student create force diagrams for systems of objects.

The student will apply force diagrams in the solution of force problems.

The student will define equilibrium, and find the equilibrant.

The student will determine magnitude and direction of tension, friction, support/normal force, and/or force due to gravity.

The student will define inertia.

The student will state Newton’s First Law of Motion.

The student will cite examples of Newton’s First Law of Motion.

The student will state Newton’s third law of motion in words, diagram, and in formula.

Given an action force, identify the reaction force.

Explain why the *accelerations* caused by an action force and a reaction force do not have to be equal.

Explain why an action force is not canceled by the reaction force.

Explain why, regardless of your strength, there is a limit on how hard you can hit an object.

The student will discover Newton’s Second Law of Motion in both words and formula.

The student will define net force.

The student will plot an acceleration versus force graph, express the equation, and discover the significance of the slope and the significance of the intercept.

The student will plot an acceleration versus mass graph, express the equation, and discover the significance of an inverse relation.

The student will determine the constant of proportionality in the A-F and A-M system.

The student will be able to state the relation between the concept of directly proportional and inversely proportional.

Apply Newton’s second law to explain why the acceleration of an object in free fall does not depend upon the mass of the object.

The student will determine the net force of a system using force diagrams (and trigonometry as needed).

The student will be able to solve ∑F=ma.

The students will plot Ffriction vs materials (column graph), Ffriction vs surface area, and Ffriction vs Fsupport; and interpret appropriate equations, slopes, and intercepts.

The students will distinguish between kinetic and static friction.

The student will apply friction principles to solve force problems.

The students will compare and contrast the motion of an object rolled off a horizontal table to that of an object dropped at the same time.

The students will describe the horizontal and vertical motions as independent of each other.

The students will determine the trajectory of a projectile.

The student will be able to solve for time of flight, maximum height, and landing position, and other parameters in projectile motion.

## Unit 4 – Momentum and Impulse

The student will distinguish among inertia, momentum, and impulse.

The student will state examples of how both the size of the force and the length of the time interval effect the change in momentum.

The student will explain why impulses are greater when an object bounces than when the same object simply comes to rest in a collision.

The student will identify and create engineering applications of Impulse-Change in Momentum.

The student will apply conservation of momentum to elastic and inelastic collisions.

The student will predict the outcome of a collision using vector analysis of conservation of momentum.

The student will solve for unknowns in the conservation of momentum equation.

The student will apply conservation of energy to conservation of momentum.

The students will design a method to analyze an accident.

Define angular momentum, conservation of angular momentum.

The student will apply the angular momentum equation to calculate and support the relationships among momentum, mass, radius, and velocity.

The student will demonstrate examples of angular momentum and conservation of angular momentum.

## Unit 5 – Uniform Circular Motion

Distinguish between period and frequency.

The student will apply the tangential velocity equation to calculate and support the relationships among period, circumference, and velocity.

The student will distinguish between a rotating body and revolving body, and state examples of each.

Define centripetal force and centripetal acceleration.

Use arguments of Frames of Reference to determine inertial and non-inertial systems.

Distinguish between real and fictitious forces, and give examples of each.

The students will apply the centripetal acceleration equation to solve problems including centripetal force, centripetal acceleration, tangential velocity, period, and radius.

Students will apply mathematical inequalities to solve maximum/minimum limiting cases.

## Unit 6 – Gravitation

The students will solve for any unknown in Newton’s law of gravitation

The students will plot acceleration versus mass of central body and acceleration versus orbital radius of orbital systems, and determine the Universal Gravitational constant.

The students will explain the significance of the inverse square law.

The students will solve problems using the inverse square law.

The students will distinguish between g (the acceleration due to gravity) and G (the universal gravitational constant) and explain how each is determined.

The students will explain Newton’s idea that the moon, like an apple, falls toward earth.

The students will explain why the moon does not fall into Earth, nor the planets into the sun.

The students will translate across representations why an astronaut in earth orbit appears weightless even though there is a gravitational force on the astronaut.

The students will explain how the sun and moon cause the ocean tides.

The students will be able to identify conic section as applied to Kepler’s Three Laws.

The student will diagram in correct proportion Kepler’s Second Law.

The student will solve problems showing Kepler’s Third Law and Newton’s Universal Law of Gravitation.

Specify the geosynchronous satellite orbit to monitor weather (or other environmental monitoring) activity. The funding for the satellite was split between Tunisia, Ghana, and Ethiopia (or other geographical countries or areas). All three countries require continuous monitoring.

## Unit 7 – Electrostatics

The student will demonstrate that like charges will repel while unlike charges will attract.

The student will demonstrate that a charged particle can be attracted to a neutral particle, while two neutral particles neither attract nor repel.

The student will describe that although two charges are evident, the phenomenon is due to the surplus or deficit of electrons.

The student will demonstrate that the sum total of all charges within a system remains constant.

The student will describe methods of charge transfer.

The student will construct a model of matter representative of fixed and mobile charges.

The student will distinguish between conductors and insulators.

The student will demonstrate that molecules may be naturally polarized.

The student will compare and contrast the behavior of forces due to gravitation and coulomb fields.

The student will calculate the ratio of gravitational force to coulomb force.

The student will calculate the magnitude and direction of coulomb force due to multiple particles.

The student will model forces as the interaction of fields of like and unlike charged particles.

The student will calculate the magnitude and direction of coulomb force on a particle within an arbitrary E-field geometry.

The student will compare the intensity of the E-field at different locations based on the concentration of the E-field lines at those locations.

## Unit 8 – Electrical Potential

The student will model fields through field and equipotential lines.

Using equipotential lines or planes, the student will calculate the change in potential energy.

Students will infer E-field geometry through analysis of equipotential contours.

Students will calculate E-field intensity from measurements of potential differences.

Students will demonstrate that no potential difference over a distance indicates zero E-field.

Students will differentiate between zero potential and zero change in potential.

Students will calculate potentials and potential differences for assemblies of point charges.

Students will approximate the E-field magnitude and direction at a point based on the local potential difference.

Students will illustrate and calculate E-fields due to multiple charges and equipotential contours.

The student will calculate the fundamental charge of the electron.

Students will illustrate the interaction between a conductor and E-field in electrostatic equilibrium.

Students will model the behavior of conduction electrons in a uniform E-field.

Students will reframe gravitational potential energy to electrical potential energy.

Students will calculate the electrical potential energy of a charged particle in an E-field.

Students will apply conservation of energy principles to electrical potential energy and kinetic energy.

Students will model many interacting particles in bound and unbound states.

Students will connect electrical theory to the functioning of electrical and electromechanical devices, and explanations of day-to-day phenomena.

## Unit 9 – Resistance

Students will model flow of charge as current.

Students will specify current direction and flow of charge, and calculate current.

Students will model semiconductor junction behavior and use the model to explain the VI characteristics of a diode.

Students will model resistance in a conductor as being directly proportional to length and inversely proportional to cross sectional area.

Students will calculate resistances.

Students will measure potential differences with a voltmeter.

## Unit 10 – Circuits

Students will uncover Ohm’s law through a V-I plot where circuit resistance is the inverse of the graph’s slope.

Students will apply Ohm’s law to calculate circuit parameters and associated power dissipation.

Students will employ energy conservation principles to equate power dissipation with power being supplied.

Students will calculate the voltage differences and resulting current in a series circuit.

Students will calculate the equivalent resistance of resistors in series.

Students will calculate the equivalent resistance of a parallel resistor network.

Students will employ Ohm’s law, Kirchhoff’s laws, and equivalent resistance calculations to predict the potentials across, currents through, and power dissipated in resistive circuit elements.

## Unit 11 – Capacitance

Students will describe the flow of charge in an RC charge/discharge cycle.

Students will distinguish between conventional current and electron flow.

Students will describe the effect on capacitance as spacing and surface area are modified.

Students will calculate the change in capacitance as the gap between plates is filled with a known dielectric material.

Students will describe the behavior of charge, capacitance, E-field and potential under conditions of constant applied potential and constant charge when plate spacing is changed; when the dielectric is changed.

Students will contrast simplified (parallel plate) capacitor construction with engineered embodiments.

Students will identify the conflict existing between working voltage and capacitance within the scope of physical constraints.

Students will calculate equivalent capacitance values from simple series and parallel configurations.

Students will calculate voltage and charge distributions in simple parallel, series, and series/parallel capacitor configurations.

Students will calculate the initial current in an RC circuit and will identify the shape of the charge and discharge curves for voltage across circuit elements, and the associated current.

Students will calculate the RC time constant and identify the significance of that value on a voltage or current vs. time plot of a charge or discharge curve.

## Unit 12 – Wave Model

The student will define basic wave terminology.

The student will distinguish between longitudinal and transverse waves, direction of disturbance, and direction of wave motion.

The student will apply the wave equation to calculate and support the relationships among frequency, wavelength (λ), and speed of waves in various media.

The student will explain and differentiate among various wave phenomena and wave motions.

The student will describe what it is that travels when a wave moves outward from a vibrating source.

The student will apply wave vocabulary and phenomenon to sound waves in air.

The student will distinguish between the speed of sound and light.

The student will apply wave mechanics (particularly resonance and wave superposition) to the production of sound in various musical instruments.

The student will apply geometric representations in the solution of faster than the speed of sound problems.

The student will describe conditions for the Doppler effect and sonic booms.

The student will solve problems for the Doppler shift mathematically.

The student will propose reasons why and prove that the speed of sound varies in different materials.

## Unit 13 – Ray Model of Light and Geometric Optics

The student will explain how frequency, wavelength, and speed vary in the electromagnetic spectrum and how these effect characteristics such as: energy, absorption, color, etc.

The student will explain what the lines in continuous, absorption, and emission spectra represent and how they can be used to identify elements

The student will explain the effects of various forms of EM radiation on various materials.

The student will predict the path of reflected light, given the direction of light striking a surface.

The student will explain why the image formed by a plane mirror is virtual.

The student will indicate and measure the angles of incidence and reflection.

The student will explain why some materials reflect, absorb, or transmit light.

The student will distinguish between converging and diverging mirrors.

The student will distinguish between virtual and real images.

The student will construct ray diagrams for concave and convex mirrors

The student will solve problems using the lens maker’s formula and their ray diagrams.

The student will define spherical aberrations and give corrections for each mirror system.

The student will describe applications of all three mirrors (including modern instrumentation).

The student will construct ray diagrams for convex mirrors.

The student will solve problems using the lens maker’s formula and their ray diagrams.

## Unit 14 – Refraction

The student will be able to indicate the angle of incidence and angle of refraction on diagrams while appropriately distinguishing the proper direction of refraction.

The student will explain how a prism separates light into colors.

The student will define spherical and chromatic aberrations and give corrections for each lens system.

The student will describe conditions and explain why atmospheric refraction phenomenon occur.

The student will solve problems using Snell’s law including

## Unit 15 – Optical Technologies

The student will describe the dual nature of light, citing supporting evidence for both sides and failures for both. These should include the photoelectric effect, and phenomena such as rectilinear propagation, reflection, refraction, polarization and how they bear on the dual nature of light.

The student will evaluate questions about the advantages of using a digital transmission and storage of information.

The student will communicate technical information about how some technological devices use the principles of wave behavior and wave interactions to transmit and capture information and energy.

The student will describe and communicate a basic understanding of light as it is used for multiple technologies (such as medical imaging, communications, etc.)