# Physics: Physics in the Universe Units and Objectives

*This course covers the skills and content of a first year physics course with the context of the Earth and its place in the Universe. Topics include experimental design, waves, earthquakes, motion, plate tectonics, forces, energy, climate, momentum, gravity, planetary motion, projectiles and the solar system. (Fall 2019)*

| Physics Units | NGSS |
|---|---|
| Science Practices | |
| Constant Velocity | |
| Waves | PS4-1 |
| Application of Waves: Big Bang | ESS1-2 |
| Application of Waves:<br>Earth's Interior and Plate Tectonics | ESS1-5, ESS2-1, ESS2-3 |
| Acceleration and Gravity | PS2-1, PS2-4 |
| Forces | |
| Momentum | PS2-2, PS2-3 |
| Energy | PS3-2 |
| Orbital Motion | ESS1-4 |
| Application of Orbital Motion:<br>Seasons and Climate | PS3-1, PS3-3, ESS2-4, ESS3-5 |

# Physics: Physics in the Universe Objectives

## 1. SCIENTIFIC PRACTICES

| OBJ | PITU: Students will be able to... |
|---|---|
| **1a** | **DATA COLLECTION. I can confidently collect quality data as part of a scientific investigation.** |
| 1a1 | I can apply the following three key techniques for obtaining data that accurately depicts a relationship: (i) maximize the domain of the independent variable, (ii) collect as many different data points as possible, and (iii) utilize repeated trials to obtain an average value and a measure of its *uncertainty*, (difference in the highest and lowest repeated trials). |
| 1a2 | I can distinguish between an independent variable and a dependent variable. |
| 1a3 | I can evaluate and critique other teams' data according to the three key techniques for collecting data (see 1a1). |
| **1b** | **DATA REPRESENTATION. I can organize, analyze, and interpret data.** |
| 1b1 | I can appropriately organize data into tables, and given a computer generated graph, I can sketch "free-hand graphs" that have: labeled axes (variable and units), maximum values listed on each axis, and a best fit line/curve, (no data points). |
| 1b2 | I can calculate uncertainty using repeated trials, and use this value to determine if there is a trend or no trend in the data. |
| 1b3 | I can use a spreadsheet (e.g., GRAPHICAL ANALYSIS) to plot data sets on a scatter plot, generate an appropriate trendline, and obtain values for slope and y-intercept. |
| **1c** | **GRAPHING. Using data from an experiment, I can use a graph to make predictions.** |
| 1c1 | I can plot the independent and dependent variables on the appropriate axes. |
| 1c2 | I can create a best-fit trendline in a scatter plot. |
| 1c3 | I can make predictions using graphs (extrapolate and interpolate) |

## 2. CONSTANT VELOCITY

| OBJ | PITU: Students will be able to... |
|---|---|
| **2a** | **EXPERIMENTS. I can design, construct, and carry-out an experiment on an object moving at a constant velocity using appropriate science practices.** |
| 2a1 | I can obtain the following equation from position vs. time graphs: $v = d/t$ |
| 2a2 | I can convert between standard and nonstandard units, and metric measures. |
| **2b** | **GRAPHS. I can create, interpret, and examine graphs of constant velocity .** |
| 2b1 | I can use a position vs. time graph to quantitatively determine $d$ and $\Delta t$ from the x- and y-axes, and velocity by calculating the slope. |
| 2b2 | I can qualitatively describe the velocity of an object by examining the steepness of a position vs. time graph. |
| 2b3 | I can sketch a free-hand graph of an object's velocity vs. time when given its position vs. time graph, (and vice versa) for constant velocity motion . |
| **2c** | **ALGEBRA. I am able to make predictions by algebraically solving the constant velocity equation, ($v = d/t$).** |
| 2c1 | I can identify what each of the following variables represent: *d, v, t* and know each variables' standard units. |
| 2c2 | I can recognize that the forward direction is represented by positive values, and the backwards direction is represented by negative values; (+) & (-) implies direction. |

## 3. WAVES

| OBJ | PITU: Students will be able to... |
|---|---|
| **3a** | **PROPERTIES. I understand the properties of waves.** |
| 3a1 | I understand a wave's energy is carried in its amplitude, which manifests itself as loudness in sound and brightness in light. |
| 3a2 | I understand wave motion: back and forth motion of source (oscillation) moves in a straight-line through a medium away from source (propagation). |
| 3a3 | I can distinguish between transverse (secondary) and longitudinal (compressional/primary) waves. |
| **3b** | **CHARACTERISTICS. I can define and measure characteristics of waves, and explain the interrelationships among them.** |
| 3b1 | I can measure and calculate the following wave characteristics: period, frequency, wavelength, amplitude, and propagational speed. |
| 3b2 | I understand relationships among all wave characteristics, and how changes to one characteristic affects the others. This includes comparing/contrasting period, frequency, and using units. |
| 3b3 | I can identify wave characteristics from a position vs. time graph: period, frequency, and amplitude. |
| 3c | **EQUATION. (PS4-1). I can use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** |
| 3c1 | Algebraic $v = f\lambda$. I am able to make predictions by algebraically solving the wave equation, ($v = f\lambda$). |
| 3c2 | Conceptual $v = f\lambda$. I can demonstrate an understanding of how the frequency and period of a wave depend on the source's motion, and move at a particular speed dependent only on the medium, and whose wavelength must adjust such that $v = f\lambda$. |

## 4. APPLICATION OF WAVES: BIG BANG

| OBJ | PITU: Students will be able to... |
|---|---|
| **4a** | **I understand how visible light spectra are produced and their applications to astronomy** |
| 4a1 | I can describe and differentiate emission, absorption and continuous spectra - including how they are formed and what information can be inferred from them. |
| 4a2 | I can describe and differentiate the emission spectra produced by charged hydrogen and helium - both the graphical (quantitative) and observable (qualitative). |
| **4b** | **I understand how distance affects wave properties** |
| 4b1 | I can apply the inverse square law qualitatively and quantitatively to measurements of both light and sound |
| **4c** | **I understand how movement of the source or observer affects wave properties** |
| 4c1 | I can apply the Doppler effect qualitatively to graphical and observable measurements of both light and sound |
| **4d** | **I can explain how spectral analysis supports the idea of an expanding universe** |
| 4d1 | I can describe how the spectrum from a star or galaxy will change depending on the relative motion of the star or galaxy. |
| 4d2 | I can describe the relationship between galactic redshift and distance and the implications of this relationship. |
| 4d3 | I can explain how spectral analysis gives insight into the size and age of the universe. |

# 5. APPLICATIONS OF WAVES: PLATE TECTONICS AND EARTH'S INTERIOR

| OBJ | PITU: Students will be able to... |
|---|---|
| **5a** | **I can describe and explain the evidence used to construct the layers and composition of the Earth's interior** |
| 5a1 | I can measure the density of an object using the displacement method. |
| 5a2 | I can explain the scientific evidence that supports the compositional layering of the Earth. |
| 5a3 | I can identify and describe the three types of seismic waves (primary, secondary, surface waves). |
| 5a4 | I can apply my understanding of seismic wave behavior to support the relative thickness and mechanical (solid/liquid) layering of the Earth. |
| **5b** | **I can explain how a seismograph is used to characterize an earthquake** |
| 5b1 | I can differentiate primary and secondary waves based on their behavior and from analysis of a seismogram. |
| 5b2 | I can determine the epicenter and magnitude of an earthquake using triangulation. |
| 5b3 | I can list the advantages and disadvantages of different earthquake scales (Richter, Moment Magnitude, Mercalli). |
| **5c** | **I can describe the process used to map the ocean floor and the variety of seafloor features discovered by sonar mapping** |
| 5c1 | I can use an ultrasonic motion detector to create a topographic representation of an unknown surface and explain how sonar is used to measure depth in the ocean. |
| 5c2 | I can classify the major seafloor features based on their depth and slope (shelf, slope, abyssal plain, mid-ocean ridge, seamount, and trench). |
| **5d** | **I can describe and explain the evidence for the Theory of Plate Tectonics** |
| 5d1 | I can describe and explain the global distribution of earthquakes. |
| 5d2 | I can describe and explain the age of ocean floor crust and associated seafloor topography. |
| 5d3 | I can describe and explain how a hot spot can be used to determine the velocity (speed and direction) of plate motion. |
| 5d4 | I can differentiate the three types of plate boundaries and identify important geographic features that form at each. |
| 5d5 | I can synthesize data sets (depth, age, sediment thickness, EQ location - depth and intensity) to make a model of a tectonic boundary. |
| 5d6 | I can explain the relationship between age, temperature, and depth of ocean crust and how they relate to the thermal cycling of material in the Earth's interior. |

## 6. ACCELERATION AND GRAVITY

| OBJ | PITU: Students will be able to... |
|---|---|
| **6a** | **EXPERIMENTS. I can design, construct, and carry-out an experiment on an object moving at a constant acceleration using appropriate science practices.** |
| 6a1 | I can design, construct, and carry-out an experiment on a car gaining speed as it rolls down a ramp. |
| 6a2 | I can collect, analyze, & interpret data using technology: for example, Logger Pro/Graphical Analysis (video analysis & motion sensors) and photogates. |
| 6a3 | I can create and interpret an $a_{g,}$ vs. mass graph and table from lab data to show that all masses fall at 9.8 $m/s^2$, (slope is zero). |
| **6b** | **GRAPHS. I can create, interpret, and examine graphs of accelerated motion.** |
| 6b1 | I am able to interpret distance vs. time (x-t) and velocity vs. time (v-t). |
| 6b2 | I am able to interpret the meaning of the slope (as a rate); and more specifically, for position vs. time and velocity vs. time. |
| 6b3 | I am able to obtain numerical values for variables from x-t and v-t graphs, ($a$, $t$, $v_o$, $v$ and $\Delta x$). I.e., using (x, y) coordinates (& y-intercept), slope. |
| 6b4 | I am able to qualitatively describe motion given only an x-t or v-t graph (i.e., moving or stopped, gaining or losing speed, constant speed). |
| 6b5 | I can create and interpret angle vs. range graphs to determine the range when given an angle.. |
| **6c** | **ALGEBRA. I am able to make predictions by algebraically solving the 2 kinematic equations.** |
| 6c1 | I can solve for various variables in the $a = (v_f - v_i)/(t_f - t_i)$ formula |
| 6c2 | I can rearrange and solve for various variables in the $d_y = 4.9t^2$ Formula |
| 6c3 | I can solve for range (dx) of a projectile using the dx =v/t formula determining its time to drop given its height using the formula $t = \sqrt{H/4.9}$ |

## 7. FORCES

| OBJ | PITU: Students will be able to... |
|---|---|
| **7a** | **FORCE DIAGRAMS. I can draw force diagrams, (free-body diagrams).** |
| 7a1 | I can identify which forces are acting on an object. |
| 7a2 | I can draw each force acting on an object as a *labeled arrow* indicating what type of force it is and in which direction it points. |
| **7b** | **NEWTON'S LAWS. I can use Newton's Laws to make and justify claims about the forces acting on an object.** |
| 7b1 | I can apply *Newton's 1st law* to justify and make claims about balanced forces acting on an object if there is no acceleration, (i.e., inertia is the tendency of an object to maintain its current state of motion—either at rest or a constant speed; it's the tendency for an object to resist acceleration). |
| 7b2 | I can apply *Newton's 2nd law* to justify and make claims about unbalanced forces acting on an object if there is an acceleration, (i.e., a net force causes mass to accelerate). |
| 7b3 | I can apply *Newton's 3rd law* to identify and justify force pairs that are equal & opposite. (*By switching the "on___, by___" notation for a force, you can identify its force pair. Ex. There is a 10 N force "on the wall, by my hands" to the left, so there is also a 10 N force "on my hands, by the wall to the right.*) |
| 7b4 | Using a force diagram, I can write a mathematical and expression for Newton's 2nd law (also known as writing the "sum of forces"), by summing all positive and negative forces, and setting them equal to *ma* according to the relationship: $F_{net} = ma$.<br><br>*(PS2-1). I can analyze data to support the claim that Newton's second law describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration, (i.e., an unbalanced force causes acceleration based on the relationship: $F_{net} = ma$).* |
| **7c** | **ALGEBRA. I am able to make predictions by algebraically solving force equations.** |
| 7c1 | I can distinguish between *mass* and *force of gravity* (or *weight)*, and calculate each value using the following relationship: $F_g = (9.8N/kg)m$ |
| 7c2 | I can apply the net force equation $F_{net} = ma$, (Newton's 2nd Law) to solve for $F_{net}$, m, a. |
| **7d** | **EXPERIMENTS. I can design, construct, and carry-out an experiment on an object moving at a constant acceleration using appropriate science practices.** |
| 7d1 | I can design, construct, and carry-out an experiment to measure the force of friction. |
| 7d2 | I can design, construct, and carry-out an experiment that verifies Newton's 1st Law. |
| 7d3 | I can design, construct, and carry-out an experiment that verifies Newton's 2nd Law. |

## 8. MOMENTUM

| OBJ | PITU: Students will be able to... |
|---|---|
| **8a** | **IMPULSE. I can create and utilize models to problem-solve situations involving the linear collision of an isolated object.** |
| 8a1 | I can analyze an *F-t* graph of a collision to determine information such as average/maximum force, and time of impact. |
| 8a2 | (PS2-3). I can apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force of impact on an object during a collision by increasing the time of impact . |
| 8a3 | I can apply the impulse equation: $Ft = mv_f - mv_i$, to solve for F, t, m, $v_f$, $v_i$ |
| 8a4 | I can use the impulse equation to qualitatively justify and make claims about the relationship between the net force acting on an object and time duration of that net force. |
| **8b** | **CONSERVATION OF LINEAR MOMENTUM. I can demonstrate the concept of conservation of total linear momentum, and utilize it to problem-solve situations involving the linear collision between two isolated objects.** |
| 8b1 | (PS2-2). I can 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. This means I can mathematically justify that the total momentum of two objects before and after any collision is always the same when the objects are free to move along a line, (e.g., no outside forces acting along the line motion). This law is called “conservation of total linear momentum.” |
| 8b2 | I can solve one variable equation to investigate momentum ($p = mv$). |
| 8b3 | I can apply the conservation of momentum equation to solve for the speed before or after a collision between two movable objects. |

## 9. ENERGY (KE/PE CONSERVATION AND PRODUCTION & CONSUMPTION)

| OBJ | PITU: Students will be able to... |
|---|---|
| **9a** | **I can identify the forms of energy present for objects at any particular moment**. |
| 9a1 | *Same as: (PS3-2). I can develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).* |
| 9a2 | I can identify that *gravitational potential energy* is dependent upon height/altitude. |
| 9a3 | I can identify that *kinetic energy* is dependent upon velocity. |
| 9a4 | I can identify that *elastic potential energy* is dependent upon spring's compression or stretching. |
| **9b** | **ALGEBRA. I am able to make predictions by algebraically solving the energy equations.** |
| 9b1 | I can apply the Grav. PE equation $E_g = mgh$, to solve for $E_g$, m, h. |
| 9b2 | I can apply the kinetic equation $E_k = ½mv^2$ , to solve for $E_k$, m, v. |
| 9b3 | I can apply the elastic potential energy equation $E_{el} = ½kx^2$ , to solve for $E_{el}$, k, x. |
| **9c** | **I can demonstrate the concept of conservation of total energy, and utilize it to problem-solve situations involving exchanges between height/distance and speed.** |
| 9c1 | (PS3-1). *I can 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.* This means I can mathematically justify that the total energy of all objects that are interacting with one another, and isolated from their environment, must remain the same at all times.<br>This law is called "conservation of energy," and it is represented mathematically by the following equation: $E_g + E_k = E_g + E_k + E_{lost}$ |
| 9c2 | I can apply the Conservation of Energy equation: $E_g + E_k = E_g + E_k$, to solve for *speed or height*. |
| 9c3 | I can utilize the law of conservation of energy to solve for the energy lost. |
| **9d** | **EXPERIMENTS. (PS 3-3). I can design, build, and refine an experimental setup that works within given constraints to convert one form of energy into another form of energy.** |
| 9d1 | I can design, construct, and carry-out an experiment on an object to determine the energy it loses during a collision. |
| 9d2 | I can design, construct, and carry-out an experiment on an object to determine the energy lost to friction. |

## 10 ORBITAL MOTION

| OBJ | PITU: Students will be able to... |
|---|---|
| **10a** | **I can explain how simple observations and measurements can be used to calculate and create an accurate model of the solar system.** |
| 10a1 | I can create a scaled model of Mercury's orbit given only measurements of Mercury's angular distance from the Sun (elongation), as seen from Earth. |
| 10a2 | I can make measurements and perform calculations that prove my model for Mercury's orbit confirms Kepler's 1st Law - The orbits of planets are ellipses with the Sun at one focus. |
| 10a3 | I can make measurements and perform calculations that prove my model for Mercury's orbit confirms Kepler's 2nd Law - Equal areas are swept out in equal times. |
| 10a4 | I can make measurements and perform calculations that prove my model for Mercury's orbit confirms Kepler's 3rd Law - The period of revolution is proportional to the semi-major axis. |
| 10a4 | I can use the Universal Law of Gravity equation between two objects, $F_g = \frac{GMm}{r^2}$, to solve for unknown variables. |
| **10b** | **I can describe how the night sky (visible stars and planets) changes due to the primary Earth motions (rotation and revolution) and the revolution of planets around the Sun.** |
| 10b1 | I can differentiate the observable phenomena caused by Earth's rotation and revolution. |
| 10b2 | I can determine the location of a planet in the night sky and when it will be visible given a model of the solar system. |

## 11 APPLICATIONS OF ORBITAL MOTION: SEASONS AND CLIMATE

| OBJ | PITU: Students will be able to... |
|---|---|
| **11a** | **I can describe how energy is transferred from the Sun to the Earth and how that energy is modified before it reaches the surface.** |
| 11a1 | I can make a simple diagram that shows the fate of incoming solar radiation - how much is reflected/scattered vs absorbed by the atmosphere. |
| 11a2 | I can list the types of incoming solar radiation that are absorbed by the atmosphere and what types penetrate to the surface and cause heating. |
| **11b** | **I can explain why energy from the Sun is distributed unequally on the Earth's surface and how characteristics of the surface further contribute to unequal heating.** |
| 11b1 | I can explain why locations close to the Equator experience smaller seasonal temperature variations compared to locations closer to the Poles. |
| 11b2 | I can describe the two primary causes of seasonal temperature variation and how they result in unequal heating - duration of sunlight, angle of the Sun's rays. |
| 11b2a | I can interpret graphs of sun altitude and hours of daylight for locations at different latitudes (low, mid, high). |
| 11b3 | I can explain how proximity to water modifies seasonal temperature variations. |
| 11b3a | I can explain why land and water heat up and cool down at different rates and how that relates to different climatic conditions for coastal and continental locations. |
| 11b4 | I can describe how energy from the Sun, after being absorbed by the Earth's surface, is transferred to the air above and to the ground below. |
| 11b5 | I can explain why the hottest time of the day (2-3pm) is typically hours after the most intense solar radiation (local noon) and why the hottest month (July) of the year is after the time of most intense solar radiation (June 21st). |
| **11c** | **I can describe long term modifiers of Earth's climate; specifically how long term orbital properties of the Earth coupled with the position of continents can lead to climate change.** |
| 11c1 | I can describe how differences in solar output can result in climatic changes on Earth. |
| 11c2 | I can describe the three primary orbital properties of Earth that change and the resulting variations in solar energy received. |
| 11c3 | I can describe the conditions (orbital characteristics and position of continents) that result in long term climatic changes (specifically Ice Ages). |
| 11c4 | I can differentiate the three cyclical variations in Earth's orbital properties that influence the amount of solar radiation received. (ie - Milankovitch cycles) |

# Physics Honors: Physics in the Universe Units and Objectives

*This course covers the skills and content of a first year physics course with the context of the Earth and its place in the Universe. Topics include experimental design, waves, earthquakes, motion, plate tectonics, forces, energy, climate, momentum, gravity, planetary motion, projectiles and the solar system. In Honors, this course covers similar topics but at a deeper level and an accelerated pace. This course requires mastery of Algebra 1 and strong math critical thinking skills. (Fall 2019)*

| Physics Honors Units | NGSS |
|---|---|
| Science Practices | |
| Constant Velocity | |
| Forces & Motion (1-D) | PS2-1, PS2-4 |
| Forces & Motion (2-D) | |
| Circular Motion | |
| Momentum | PS2-2, PS2-3 |
| Waves | PS4-1 |
| Application of Waves: Big Bang | ESS1-2, ESS2-3 |
| Energy | PS3-2 |
| Circuits + Electromagnetic Energy Production | |
| Orbital Motion | ESS1-4 |
| Application of Orbital Motion:<br>Seasons and Climate | PS3-1, PS3-3,<br>ESS2-4, ESS3-5 |

# Physics Honors: Physics in the Universe Objectives

## 1. SCIENCE PRACTICES

| OBJ | PITU H: Students will be able to... |
|---|---|
| **1a** | **DATA COLLECTION. I can confidently collect quality data as part of a scientific investigation.** |
| 1a1 | I can apply the following three key techniques for obtaining data that accurately depicts a relationship: (i) maximize the domain of the independent variable, (ii) collect as many different data points as possible, and (iii) utilize repeated trials to obtain an average value and a measure of its *uncertainty*, (difference in the highest and lowest repeated trials). |
| 1a2 | I can distinguish between an independent variable and a dependent variable and plot them on the appropriate axes. |
| 1a3 | I can evaluate and critique other teams' data according to the three key techniques for collecting data (see 1a1). |
| **1b** | **DATA REPRESENTATION. I can organize, analyze, and interpret data.** |
| 1b1 | I can appropriately organize data into tables, and given a computer-generated graph, I can sketch a "free-hand graph" that has: labeled axes (variable and units), maximum values listed on each axis, and a best fit line/curve, (no data points). |
| 1b2 | I can calculate uncertainty using repeated trials, and use this value to determine if there is a trend or no trend in the data. |
| 1b3 | II can use a spreadsheet (e.g., GRAPHICAL ANALYSIS) to: (i) plot data sets on a scatter plot, (ii) generate an appropriate trendline (line or parabola), (iii) obtain values for slope and y-intercept, and (iv) perform a linear or quadratic curve-fit. |
| **1c** | **MATHEMATICAL MODELS. I can apply mathematical and computational thinking to datasets.** |
| 1c1 | Using a linear regression (by hand on graph paper or using graphing software), I can write a mathematical model, which includes determining the units on all coefficients such as slope. |
| 1c2 | I can make predictions using mathematical models or equations, [i.e., given constants for variables, I can algebraically solve for an unknown variable, (linear and quadratic functions)]. |
| 1c3 | Given a conversion factor, I can perform conversions using proportional reasoning. |

## 2. CONSTANT VELOCITY

| OBJ | PITU H: Students will be able to... |
|---|---|
| **2a** | **EXPERIMENTS. I can design, construct, and carry-out an experiment on an object moving at a constant velocity using appropriate science practices.** |
| 2a1 | I can obtain the following equation from position vs. time graphs: $x = vt + x_o$, or $\Delta x = vt$ |
| 2a2 | I can convert between metric measures, and between standard and nonstandard units, (e.g., meters ↔ feet & mph ↔ m/s). |
| **2b** | **GRAPHS. I can create, interpret, and examine graphs of constant velocity .** |
| 2b1 | I can use a position vs. time graph to quantitatively determine $\Delta x$ and $\Delta t$ from the x- and y-axes, and velocity by calculating the slope. |
| 2b2 | I can qualitatively describe the velocity of an object by examining the steepness of a position vs. time graph, or the y-axis of a v-t graph. |
| 2b3 | I can sketch a free-hand graph of an object's velocity vs. time when given its position vs. time graph, (and vice versa) for constant velocity motion . |
| 2b4 | I can plot numerical values on an object's velocity vs. time graph when given its quantitative graph of its position vs. time, and vice versa, for constant velocity motion . |
| **2c** | **ALGEBRA. I am able to make predictions by algebraically solving the constant velocity equation, ($\Delta x = vt$).** |
| 2c1 | I can identify what each of the following variables represent: $x, v, t, x_o$, $\Delta x$ and know each variables' standard units. |
| 2c2 | I can recognize that the forward direction is represented by positive values, and the backwards direction is represented by negative values; (+) & (-) implies direction. |

## 3. FORCES & MOTION (1-D)

| OBJ | PITU H: Students will be able to... |
|---|---|
| **3a** | **EXPERIMENTS. I can design, construct, and carry-out an experiment on an object moving at a constant acceleration using appropriate science practices.** |
| 3a1 | I can design, construct, and carry-out an experiment on a car gaining speed as it rolls down a ramp. |
| 3a2 | I can collect, analyze, & interpret data using technology: for example, Logger Pro/Graphical Analysis (video analysis & motion sensors) and photogates. |
| 3a3 | I can create and interpret an $a_{g,}$ vs. mass graph and table from lab data to show that all masses fall at 9.8 $m/s^2$, (slope is zero). |
| 3a4 | I can design, construct, and carry-out an experiment that verifies Newton's 1st Law. |
| 3a5 | I can design, construct, and carry-out an experiment that verifies Newton's 2nd Law. |
| 3a6 | I can design, construct, and carry-out an experiment to measure the force of friction. |
| 3a7 | I can design, construct, and carry-out an experiment to determine the coefficient of friction between the surfaces of two objects. |
| **3b** | **FORCE DIAGRAMS. I can draw force diagrams, (free-body diagrams).** |
| 3b1 | I can identify which forces are acting on an object. |
| 3b2 | I can draw each force acting on an object as a *labeled arrow* indicating what type of force it is and in which direction it points. |
| **3c** | **NEWTON'S LAWS. I can use Newton's Laws to make and justify claims about the forces acting on an object.** |
| 3c1 | I can apply *Newton's 1st law* to justify and make claims about balanced forces acting on an object if there is no acceleration, (i.e., inertia is the tendency of an object to maintain its current state of motion—either at rest or a constant speed; it's the tendency for an object to resist acceleration). |
| 3c2 | I can apply *Newton's 2nd law* to justify and make claims about unbalanced forces acting on an object if there is an acceleration, (i.e., a net force causes mass to accelerate). |
| 3c3 | I can apply *Newton's 3rd law* to identify and justify force pairs that are equal & opposite. (*By switching the "on___, by___" notation for a force, you can identify its force pair. Ex. There is a 10 N force "on the wall, by my hands" to the left, so there is also a 10 N force "on my hands, by the wall to the right.*) |
| 3c4 | Using a force diagram, I can write a mathematical and expression for Newton's 2nd law (also known as writing the "sum of forces"), by summing all positive and negative forces, and setting them equal to *ma* according to the relationship: $F_{net} = ma$.<br><br>*Same as: (PS2-1). I can analyze data to support the claim that Newton's second law describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration, (i.e., an unbalanced force causes acceleration according to the relationship:* $F_{net} = ma$*).* |

| | |
|---|---|
| **3d** | **ALGEBRA. I am able to make predictions by algebraically solving forces and motion equations.** |
| 3d1 | I can recognize that the forward direction is represented by positive values, and the backwards direction is represented by negative values; (+) & (-) implies direction for the following variables: $\Delta x$, $v_o$, $v$, $a$, $F$. |
| 3d2 | I can apply the friction equations, $(\max F_{fs}) = \mu_s F_N$ and $F_k = \mu_k F_N$, to solve for any unknown variable. |
| 3d3 | I am able to make predictions by algebraically solving the 4 kinematic equations. |
| 3d4 | I am able to recognize when objects are in free-fall and apply the free-fall acceleration (9.8 $m/s^2$ down) for those objects. This also includes understanding that ALL objects fall at the same acceleration regardless of mass or weight. |
| 3d5 | I can distinguish between *mass* and *<u>force</u> of gravity* (or *weight)*, and calculate each value using the following relationship: $F_g = (9.8N/kg)m$ |
| 3d6 | I can apply the net force equation $F_{net} = ma$, (Newton's 2nd Law) to solve for $F_{net}$, m, a. |
| **3e** | **GRAPHS. I can create, interpret, and examine graphs of accelerated motion.** |
| 3e1 | I am able to interpret the meaning of the y-intercept of any graph (lin. or quad.); and more specifically, for position vs. time (x-t) and velocity vs. time (v-t). |
| 3e2 | I am able to interpret the meaning of the slope (as a rate); and more specifically, for position vs. time and velocity vs. time. |
| 3e3 | I am able to obtain numerical values for variables from x-t and v-t graphs, ($a$, $t$, $v_o$, $v$ and $\Delta x$). I.e., using (x, y) coordinates (& y-intercept), slope, and coefficients from regressions. |
| 3e4 | I am able to qualitatively describe motion given only an x-t or v-t graph (i.e., moving or stopped, gaining or losing speed, constant speed, going forwards or backwards). |
| 3e5 | I am able to qualitatively recognize that acceleration is represented as both a parabola on a x-t graph, and slope of a v-t graph. |
| 3e6 | I can sketch a free-hand graph of an object's velocity vs. time when given its position vs. time graph, (and vice versa). |
| **3f** | **FRICTION. I can qualitatively explain the coefficients of friction, and quantitatively predict values using the friction equations, ($(\max F_{fs}) = \mu_s F_N$ and $F_k = \mu_k F_N$.).** |
| 3f1 | I can differentiate between static and kinetic friction. |
| 3f2 | I can differentiate between the force of friction and the coefficient of friction. |
| 3f3 | I can qualitatively explain the following relationships: $(\max F_{fs}) = \mu_s F_N$ and $F_k = \mu_k F_N$. |

## 4. FORCES & MOTION (2-D)

| OBJ | PITU H: Students will be able to... |
|---|---|
| **4a** | **I can create and utilize models to problem-solve situations involving angled forces and projectiles.** |
| 4a1 | I can qualitatively describe the horizontal motion and vertical motion of any projectile. |
| 4a2 | I am able to diagram the motion of a projectile that includes the following characteristics: before and after states, all relevant variables drawn as arrows labeled with variable letter, number and units. |
| 4a3 | I can apply and justify any projectile's horizontal acceleration as zero, $a_x = 0$ |
| 4a4 | I can recognize that the forward direction is represented by positive values, and the backwards direction is represented by negative values; (+) & (-) implies direction. |
| 4a5 | I am able to make predictions by algebraically solving kinematic equations. |
| 4a6 | I can solve quadratic equations by solving for its roots using a graphing calculator. |
| 4a7 | I can resolve angled vectors into horizontal and vertical components using right-triangle trigonometry. This includes the angled initial velocity for a projectile. |
| 4a8 | I can design, construct, and carry-out an experiment on a projectile to predict the position of its landing. |
| 4a9 | I can utilize that velocity must be momentarily zero when an object changes direction (e.g., $v_y = 0$ at the top of any projectile's path.) |
| 4a10 | I can resolve angled forces into horizontal and vertical components using right-triangle trigonometry. This includes the force of gravity for objects on an inclined surface. |

## 5. CIRCULAR MOTION

| OBJ | PITU H: Students will be able to... |
|---|---|
| 5a | **I can create and utilize models to problem-solve situations involving circular motion.** |
| 5a1 | I can recognize and apply the fact that velocity is always directed tangent to the circular path. |
| 5a2 | I can explain how inertia relates to objects in circular motion, (i.e., I can explain why one *feels* pushed outward when going around a bend in a car). |
| 5a3 | I can justify why an object moving in a circle at a constant speed is accelerating. |
| 5a4 | I can draw a force diagram to identify the net force inward force (i.e., the “centripetal” force), which always points along the radius toward the center of the circular path. |
| 5a5 | I can mathematically and conceptually utilize the equations of circular motion to make claims about the relationships among variables and solve for unknown quantities. These equations include: $F_{net} = \frac{mv^2}{r}$, $a_c = \frac{v^2}{r}$, $v_{avg} = \frac{2\pi r}{T}$ |

## 6. MOMENTUM

| OBJ | PITU H: Students will be able to... |
|---|---|
| **6a** | **IMPULSE. I can create and utilize models to problem-solve situations involving the linear collision of an isolated object.** |
| 6a1 | I am able to diagram the collision of an object(s) that includes the following characteristics: all relevant variables drawn as arrows labeled with variable letter, number and units. Emphasis on assignment of (+) and (-) signs to variables based upon direction. |
| 6a2 | I can analyze a *v-t, &/or F-t* graph of a collision to determine information such as impulse, velocity before/after a collision, average/maximum impact force, and time of impact. This includes understanding that area under an F-t graph can be used to calculate impulse delivered to an object. |
| 6a3 | I can apply the impulse equation: $Ft = mv - mv_o$, to solve for F, t, m, v , $v_o$ |
| 6a4 | I can use the impulse equation to qualitatively justify and make claims about the relationship between the net force acting on an object and time duration of that net force. |
| 6a5 | (PS2-3). I can apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force of impact on an object during a collision. |
| **6b** | **CONSERVATION OF LINEAR MOMENTUM. I can demonstrate the concept of conservation of total linear momentum, and utilize it to problem-solve situations involving the linear collision between two isolated objects.** |
| 6b1 | (PS2-2). I can 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. This means I can mathematically justify that the total momentum of two objects before and after any collision is always the same when the objects are free to move along a line, (e.g., no outside forces acting along the line motion). This law is called “conservation of total linear momentum.” |
| 6b2 | I can apply the conservation of momentum equation to algebraically solve for the speed before or after a collision between two movable objects. |

## 7. WAVES & OSCILLATION

| OBJ | PITU H: Students will be able to... |
|---|---|
| **7a** | **PROPERTIES. I understand the properties of waves.** |
| 7a1 | I understand a wave's energy is carried in its amplitude. |
| 7a2 | I understand wave motion: back and forth motion of source (particle/oscillation) moves in a straight-line through a medium away from source (pulse/propagation). |
| **7b** | **CHARACTERISTICS. I can define and measure characteristics of waves, and explain the interrelationships among them.** |
| 7b1 | I can measure and calculate the following wave characteristics: period, frequency, angular frequency, wavelength, amplitude, and propagational speed. |
| 7b2 | I understand relationships among all wave characteristics, and how changes to one characteristic affects the others. This includes comparing/contrasting period, frequency, and angular frequency using units. |
| 7b3 | I can identify wave characteristics from a position vs. time graph: period, frequency, angular frequency, and amplitude. |
| 7b4 | I can mathematically model a wave source's back-&-forth motion using a cosine function (i.e., convert between radians and cycles; determine amplitude, period, frequency, and angular frequency; and write an expression for y as a function of t). |
| **7c** | **EQUATION. (PS4-1). I can use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** (i.e., I can demonstrate an understanding of how the frequency and period of a wave depends on the source's motion, and move at a particular speed dependent only on the medium, and whose wavelength must adjust such that $v = f\lambda$). |
| 7c1 | Algebraic $v = f\lambda$. I am able to make predictions by algebraically solving the wave equation, ($v = f\lambda$). |
| 7c2 | Conceptual $v = f\lambda$. I can demonstrate an understanding of how the frequency and period of a wave depend on the source's motion, and move at a particular speed dependent only on the medium, and whose wavelength must adjust such that $v = f\lambda$. |

# 8. APPLICATION OF WAVES: BIG BANG

| OBJ | PITU H: Students will be able to... |
|---|---|
| **8a** | **I understand how visible light spectra are produced and their applications to astronomy** |
| 8a1 | I can describe and differentiate emission, absorption and continuous spectra - including how they are formed and what information can be inferred from them. |
| 8a2 | I can describe and differentiate the emission spectra produced by charged hydrogen and helium - both the graphical (quantitative) and observable (qualitative). |
| **8b** | **I understand how distance affects wave properties** |
| 8b1 | I can apply the inverse square law qualitatively and quantitatively to measurements of both light and sound |
| **8c** | **I understand how movement of the source or observer affects wave properties** |
| 8c1 | I can apply the Doppler effect qualitatively and quantitatively to graphical and observable measurements of both light and sound |
| 8c2 | I can explain what the cosmic microwave background radiation tells us about the universe at its early stages |
| **8d** | **I can explain Hubble's Law and how it supports the idea of an expanding universe** |
| 8d1 | I can describe the process used by Hubble and other astronomers to determine the distance and recessional velocity of galaxies. |
| 8d2 | I can describe the relationship between recessional velocity and distance and how it is used to approximate the age of the universe. |

## 9. ENERGY (KE/PE CONSERVATION AND PRODUCTION & CONSUMPTION)

| OBJ | PITU H: Students will be able to... |
|---|---|
| **9a** | **WORK. I can conceptually and mathematically apply the concept of *work* as the *change in* energy due to a force acting along a distance.** |
| 9a1 | I can assess gains and losses in energy as positive or negative work. |
| 9a2 | I can algebraically solve for the unknown variables using the mathematical equation for work: $W = F \cdot x$ or $W = Fx \cos \theta$. |
| 9a3 | I can graphically solve for work done by a force by determining the area under an *F-x* graph. |
| 9a4 | I can describe the *type* of energy gained/lost depends on the *type* of force. |
| 9a5 | I can qualitatively and quantitatively apply the concept of power as the time rate of change in energy using the relationship: $P = \frac{W}{\Delta t}$. |
| 9a6 | I can design, construct, and carry-out an experiment on an object that examines the changes in energy it experiences due to a force. |
| **9b** | **FORMS OF ENERGY. I can identify the forms of energy present for objects at any particular moment**. |
| 9b1 | I can identify that *elastic potential energy* is dependent upon spring's compression or stretching, and is mathematically defined as: $E_{el} = ½kx^2$ |
| 9b2 | (PS3-2). I can develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects), (i.e., I can identify that *gravitational potential energy* is dependent upon height/altitude, and is mathematically defined as: $E_g = mgh$). |
| 9b3 | I can identify that *kinetic energy* is dependent upon velocity, and is mathematically defined as: $E_k = ½mv^2$ |
| 9b4 | I can identify that *work* is being done when there is a force acting along the displacement (e.g., friction, tension, push, etc.). |
| **9c** | **I can demonstrate the concept of conservation of total energy, and utilize it to problem-solve situations involving exchanges between height/distance and speed.** |
| 9c1 | (PS3-1). I can 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. This means I can mathematically justify that the total energy of all objects that are interacting with one another, and isolated from their environment, must remain the same at all times. This law is called "conservation of energy," and it is represented mathematically by the following equation: $\pm W_F + E_g + E_k + E_{el} = E_g + E_k + E_{el}$.. |
| 9c2 | (PS 3-3). I can design, build, and refine an experimental setup that works within given constraints to convert one form of energy into another form of energy. |

| | |
|---|---|
| 9c3 | I can utilize the law of conservation of energy to solve for the energy lost during a collision. |
| 9c4 | I can describe collisions as *elastic*, *inelastic*, or *perfectly inelastic*. |
| 9c5 | I can design, construct, and carry-out an experiment on an object to determine the energy it loses during a collision. |
| **9d** | **EXPERIMENTS. (PS 3-3). I can design, build, and refine an experimental setup that works within given constraints to convert one form of energy into another form of energy.** |
| 9d1 | I can design, construct, and carry-out an experiment on an object to determine the energy it loses during a collision. |
| 9d2 | I can design, construct, and carry-out an experiment on an object to determine the energy lost to friction. |

## 10. CIRCUITS

| OBJ | PITU H: Students will be able to... |
|---|---|
| 10a | **EXPERIMENTS. I can design, construct, and obtain measurements from circuits.** |
| 10a1 | I recognize that current only flows if there is a closed loop, and in the direction that positive charges would flow. |
| 10a2 | I can build circuits when given a circuit diagram, and draw circuit diagrams if given a circuit. |
| 10a3 | I can measure voltage, current, and resistance using a multimeter. |
| 10a4 | I can draw voltmeters and ammeters within circuit diagrams. |
| 10a5 | I can identify components in a circuit as being in either in series (same current) or parallel (presence of junctions) |
| 10b | **CIRCUIT LAWS. I can use Kirchhoff's and Ohm's Laws to make and justify claims about the voltages and currents within a circuit.** |
| 10b1 | I can conceptually and mathematically describe the equivalent resistance of a multiple resistor circuit that consists of series and parallel combinations of resistors. |
| 10b2 | I can determine which parallel branches receive the most (or least) current. |
| 10b3 | I can apply Ohm's Law (V = IR) to any closed circuit, and parts within a closed circuit, in order to calculate the total current through a power source and individual resistors, and the voltage across a power source and individual resistors. |
| 10b4 | I can apply Kirchhoff's Loop Rule, which states that voltages around any closed loop must add to zero, (conservation of energy). |
| 10b5 | I can apply Kirchhoff's Junction Rule, which states that currents through branches all add up to total current through the battery |
| 10b6 | I can calculate the power generated or dissipated by various circuit components. |
| 10b7 | I can qualitatively describe the voltage gains and losses throughout a closed circuit loop, as well as the changes to the current. |

## 11. ORBITAL MOTION

| OBJ | PITU H: Students will be able to... |
|---|---|
| **11a** | **I can explain how simple observations and measurements can be used to calculate and create an accurate model of the solar system.** |
| 11a1 | I can create a scaled model of Mercury’s orbit given only measurements of Mercury’s angular distance from the Sun (elongation), as seen from Earth. |
| 11a2 | I can make measurements and perform calculations that prove my model for Mercury’s orbit confirms Kepler’s 1st Law - The orbits of planets are ellipses with the Sun at one focus. |
| 11a3 | I can make measurements and perform calculations that prove my model for Mercury’s orbit confirms Kepler’s 2nd Law - Equal areas are swept out in equal times. |
| 11a4 | I can make measurements and perform calculations that prove my model for Mercury’s orbit confirms Kepler’s 3rd Law - The period of revolution is proportional to the semi-major axis. |
| **11b** | **I can describe how the night sky (visible stars and planets) changes due to the primary Earth motions (rotation and revolution) and the revolution of planets around the Sun.** |
| 11b1 | I can differentiate the observable phenomena caused by Earth’s rotation and revolution. |
| 11b2 | I can determine the location of a planet in the night sky and when it will be visible given a model of the solar system. |
| 11b3 | I can differentiate the observable phenomena caused by rotation and revolution |
| 11b4 | I can explain which Earth motions are responsible for the ecliptic and changes in the location of the Sun on the ecliptic since the development of the astrological signs |
| 11b5 | I can use important stars and constellations to locate geographic North and find the ecliptic |
| 1b6 | I can use clues from the motions of stars and constellations to infer latitude and time of year |
| **11c** | **GRAVITATION. I apply Newton’s law of gravity and circular motion to orbiting bodies.** |
| 11c1 | I can use the Universal Law of Gravity equation between two objects, $F_g = \frac{GMm}{r^2}$ , to solve for unknown variables. |
| 11c2 | I can use the Universal Force of Gravity, $F_g = \frac{GMm}{r^2}$ , as the centripetal force that would cause circular orbits, and calculate orbital speed. |

## 12. APPLICATION OF ORBITAL MOTION: SEASONS AND CLIMATE

| OBJ | PITU H: Students will be able to... |
|---|---|
| **12a** | **I can describe how energy is transferred from the Sun to the Earth and how that energy is modified before it reaches the surface.** |
| 12a1 | I can make a simple diagram that shows the fate of incoming solar radiation - how much is reflected/scattered vs absorbed by the atmosphere. |
| 12a2 | I can list the types of incoming solar radiation that are absorbed by the atmosphere and what types penetrate to the surface and cause heating. |
| **12b** | **I can explain why energy from the Sun is distributed unequally on the Earth's surface and how characteristics of the surface further contribute to unequal heating.** |
| 12b1 | I can explain why locations close to the Equator experience smaller seasonal temperature variations compared to locations closer to the Poles. |
| 12b2 | I can describe the two primary causes of seasonal temperature variation and how they result in unequal heating - duration of sunlight, angle of the Sun's rays. |
| 12b2a | I can interpret graphs of sun altitude and hours of daylight for locations at different latitudes (low, mid, high). |
| 12b3 | I can explain how proximity to water modifies seasonal temperature variations. |
| 12b3a | I can explain why land and water heat up and cool down at different rates and how that relates to different climatic conditions for coastal and continental locations. |
| 12b4 | I can describe how energy from the Sun, after being absorbed by the Earth's surface, is transferred to the air above and to the ground below. |
| 11b5 | I can explain why the hottest time of the day (2-3pm) is typically hours after the most intense solar radiation (local noon) and why the hottest month (July) of the year is after the time of most intense solar radiation (June 21st). |
| **12c** | **I can describe long term modifiers of Earth's climate; specifically how long term orbital properties of the Earth coupled with the position of continents can lead to climate change.** |
| 11d1 | I can describe how differences in solar output can result in climatic changes on Earth. |
| 11d2 | I can describe the three primary orbital properties of Earth that change and the resulting variations in solar energy received. |
| 11d3 | I can describe the conditions (orbital characteristics and position of continents) that result in long term climatic changes (specifically Ice Ages). |
| 11d4 | I can differentiate the three cyclical variations in Earth's orbital properties that influence the amount of solar radiation received. (ie - Milankovitch cycles) |