Unit 2: Dynamics
UNIT PLAN

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UNIT NARRATIVE

Unit 2 introduces students to the fundamental concepts of dynamics by building a deep understanding of Newton's Laws and the forces that govern motion. The unit begins with students developing an intuitive understanding of Newton's First Law through inquiry (Day 1) and direct exploration of real-world force interactions (Day 2). These initial lessons set the tone for emphasizing forces as interactions between objects and not inherent properties of objects, which is reinforced later in the unit with Newton's Third law. This foundation supports the introduction of key forces—force of gravity, normal force, tension, friction, and spring force—which are explored through a combination of interactive demonstrations and student-designed lab investigations (e.g., Day 3: Weight vs. Mass, Day 4: Spring Force Lab, Days 7–8: Friction Lab). Students also begin constructing and interpreting free-body diagrams (FBDs), with multiple scaffolded lessons (Days 2, 5, and 6) building student fluency in representing forces accurately and reasoning about net force.

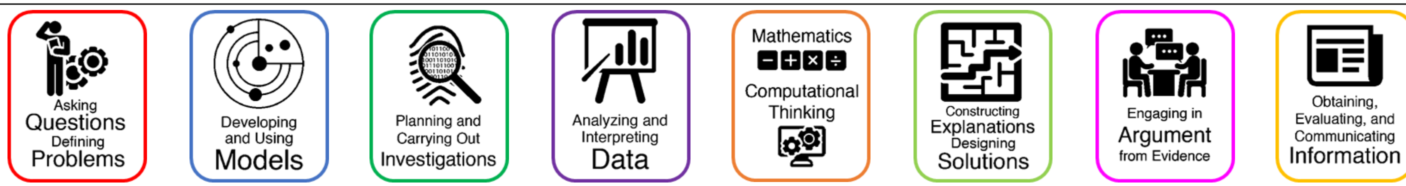
The next section of this unit focuses on Newton's Second and Third Laws. This section begins with lab activities (Days 9–10) and video analysis (Day 11) where students investigate how net force, mass, and acceleration are interrelated, Newton's Second Law, and then students are ready to apply the Second Law to vertical and horizontal scenarios (Day 12). Students then explore Newton's Third Law using real world setups of scenarios to practice identifying paired forces (Day 13), which leads to the conceptual distinction between internal and external forces in systems (Day 14). Students then apply these concepts to progressively more complex systems, including basic chained systems (Day 15), Atwood Machines (Day 16), and Modified Atwood Machines (Day 17). Each scenario builds on previous lessons and knowledge while leveraging new analytical tools, such as drawing FBD for these scenarios horizontally, and creating multiple FBD and Second Law equations, reinforcing algebraic reasoning within the physics context. This section culminates with the analysis of inclined planes, which require the synthesis of multiple prior concepts. Lessons on inclined planes (Days 18–19) emphasize vector resolution and the strategic tilting of axes in FBDs. Students must apply Newton's Second Law in both the horizontal and vertical directions to make qualitative and quantitative predictions about scenarios involving components of gravitational force, Normal Force and friction.

The final section of the unit shifts to exploring uniform circular motion on Earth and in orbital motion scenarios using the Newton's Laws. The circular motion lessons begin with an Anchoring Event (a compelling and puzzling hands-on activity) that students are asked to model and explain (Day 21: spinning a cup in a vertical circle). Students will then conduct a lab to describe the variable relationships that define centripetal force (Day 22) and practice analyzing circular motion scenarios using Newton's Second Law equations. During these lessons students will iteratively develop and revise explanations for the Anchoring Event using circular motion concepts and finally craft and Anchoring Event and Essential Question Seamless Explanation (Day 27). Next students explore circular motion scenarios where the centripetal force is provided by gravity, orbital motion. First students discover the variable relationships that define Universal Gravitation using a virtual lab. Next students derive an equation that to justify why astronauts in orbit feel weightless while still feeling the force of gravity. Finally, students derive and work with Kepler's Third Law to make claims and predictions about the motion and forces of objects in orbital motion.

The unit is intentionally scaffolded to move from concrete, observable phenomena to more abstract representations and theoretical models. Each section of the unit builds conceptual depth while reinforcing critical scientific thinking and problem-solving strategies. The emphasis on lab-based discovery, modeling using free-body diagrams, and equation derivation ensures that students are well-prepared for both the AP Physics 1 exam and future scientific study.

Focus on Disciplinary Literacy

In science, disciplinary literacy is synonymous with the science and engineering practices. The SEPs are the context through which all science concepts should be taught. In the lessons, you will find the Science and Engineering practices icons when the SEPs are being explicitly used by students.



UNPACKED STANDARDS

Below are the standards **taught** and **assessed** in this unit.

Topic #	Topic	LO #	Learning Objective	EO #	Essential Knowledge
2.1	**Systems and Conter of Mass**	2.1.A	Describe the properties and interactions of a system.	2.1.A.1	System properties are determined by the interactions between objects within the system.
				2.1.A.2	If the properties or interactions of the constituent objects within a system are not important in modeling the behavior of the macroscopic system, the system can itself be treated as a single object.
				2.1.A.3	Systems may allow interactions between constituent parts of the system and the environment, which may result in the transfer of energy or mass.
				2.1.A.4	Individual objects within a chosen system may behave differently from each other as well as from the system as a whole.
				2.1.A.5	The internal structure of a system affects the analysis of that system.
				2.1.A.6	As variables external to a system are changed, the system's substructure may change.
		2.1.B	Describe the location of a system's center of mass with respect to the system's constituent parts.	2.1.B.1	For systems with symmetrical mass distributions, the center of mass is located on lines of symmetry.
				2.1.B.2	The location of a system's center of mass along a given axis can be calculated using the **equation -->** $x_{cm} = \frac{\Sigma m_i x_i}{\Sigma m_i}$
				2.1.B.3	A system can be modeled as a singular object that is located at the system's center of mass.
		BOUNDARY STATEMENT: *AP Physics 1 only expects students to calculate the center of mass for systems of five or fewer particles arranged in a two-dimensional configuration or for systems that are highly symmetrical.*			
2.2	**Forces and Free-Body Diagrams**	2.2.A	Describe a force as an interaction between two objects or systems.	2.2.A.1	Forces are vector quantities that describe the interactions between objects or systems. i. A force exerted on an object or system is always due to the interaction of that object with another object or system. ii. An object or system cannot exert a net force on itself.
				2.2.A.2	Contact forces describe the interaction of an object or system touching another object or system and are macroscopic effects of interatomic electric forces.
		2.2.B	Describe the forces exerted on an object or system using a free-body diagram.	2.2.B.1	Free-body diagrams are useful tools for visualizing forces being exerted on a single object or system and for determining the equations that represent a physical situation.
				2.2.B.2	The free-body diagram of an object or system shows each of the forces exerted on the object by the environment.
				2.2.B.3	Forces exerted on an object or system are represented as vectors originating from the representation of the center of mass, such as a dot. A system is treated as though all of its mass is located at the center of mass.
				2.2.B.4	A coordinate system with one axis parallel to the direction of acceleration of the object or system simplifies the translation from free body diagram to algebraic representation. For example, in a free-body diagram of an object on an inclined plane, it is useful to set one axis parallel to the surface of the incline.

		BOUNDARY STATEMENT: *AP Physics 1 only expects students to depict the forces exerted on objects, not the force components on free-body diagrams. On the AP Physics exams, individual forces represented on a free-body diagram must be drawn as individual straight arrows, originating on the dot and pointing in the direction of the force. Individual forces that are in the same direction must be drawn side by side, not overlapping.*			
2.3	**Newton's Third Law**	2.3.A	Describe the interaction of two objects using Newton's third law and a representation of paired forces exerted on each object.	2.3.A.1	Newton's third law describes the interaction of two objects in terms of the paired forces that each exerts on the other. F(a on b) = - F (b on a)
				2.3.A.2	Interactions between objects within a system (internal forces) do not influence the motion of a system's center of mass.
				2.3.A.3	Tension is the macroscopic net result of forces that segments of a string, cable, chain, or similar system exert on each other in response to an external force. i. An ideal string has negligible mass and does not stretch when under tension. ii. The tension in an ideal string is the same at all points within the string. iii. In a string with nonnegligible mass, tension may not be the same at all points within the string. iv. An ideal pulley is a pulley that has negligible mass and rotates about an axle through its center of mass with negligible friction.
		BOUNDARY STATEMENT: *AP Physics 1 only expects students to describe tension qualitatively in a string, cable, chain, or similar system with mass. For example, students might note that the tension in a hanging chain is greater toward the top of the chain.* **BOUNDARY STATEMENT:** *The interaction between objects or systems at a distance is limited to gravitational forces in AP Physics 1. In AP Physics 2, gravitational, electric, and magnetic forces may be considered.*			
2.4	**Newton's First Law**	2.4.A	Describe the conditions under which a system's velocity remains constant.	2.4.A.1	The net force on a system is the vector sum of all forces exerted on the system.
				2.4.A.2	Translational equilibrium is a configuration of forces such that the net force exerted on a system is zero. **Derived equation →** $\Sigma F = 0$
				2.4.A.3	Newton's first law states that if the net force exerted on a system is zero, the velocity of that system will remain constant.
				2.4.A.4	Forces may be balanced in one dimension but unbalanced in another. The system's velocity will change only in the direction of the unbalanced force.
				2.4.A.5	An inertial reference frame is one from which an observer would verify Newton's first law of motion.
2.5	**Newton's Second Law**	2.5.A	Describe the conditions under which a system's velocity changes.	2.5.A.1	Unbalanced forces are a configuration of forces such that the net force exerted on a system is not equal to zero.
				2.5.A.2	Newton's second law of motion states that the acceleration of a system's center of mass has a magnitude proportional to the magnitude of the net force exerted on the system and is in the same direction as that net force. **Relevant equation -->** $a_{sys} = \frac{\Sigma F}{m_{sys}} = \frac{F_{net}}{m_{sys}}$
				2.5.A.3	The velocity of a system's center of mass will only change if a nonzero net external force is exerted on that system.

2.6	**Gravitational Force**	2.6.A	Describe the gravitational interaction between two objects or systems with mass.	2.6.A.1	Newton's law of universal gravitation describes the gravitational force between two objects or systems as directly proportional to each of their masses and inversely proportional to the square of the distance between the systems' centers of mass. **Relevant equation -->** $\left\|F_g\right\| = G\frac{m_1 m_2}{r^2}$ i. The gravitational force is attractive. ii. The gravitational force is always exerted along the line connecting the centers of mass of the two interacting systems. iii. The gravitational force on a system can be considered to be exerted on the system's center of mass.
				2.6.A.2	A field models the effects of a noncontact force exerted on an object at various positions in space. i. The magnitude of the gravitational field created by a system of mass M at a point in space is equal to the ratio of the gravitational force exerted by the system on a test object of mass m to the mass of the test object. **Derived equation -->** $\|g\| = \frac{\|F_g\|}{m} = G\frac{M}{r^2}$ ii. If the gravitational force is the only force exerted on an object, the observed acceleration of the object (in m/s2) is numerically equal to the magnitude of the gravitational field strength (in N/Kg) at that location.
				2.6.A.3	The gravitational force exerted by an astronomical body on a relatively small nearby object is called weight. **Derived Equation -->** $Weight = F_g = mg$
		2.6.B	Describe situations in which the gravitational force can be considered constant.	2.6.B.1	If the gravitational force between two systems' centers of mass has a negligible change as the relative position of the two systems changes, the gravitational force can be considered constant at all points between the initial and final positions of the systems.
				2.6.B.2	Near the surface of Earth, the strength of the gravitational field is **g = 10N/kg**
		2.6.C	Describe the conditions under which the magnitude of a system's apparent weight is different from the magnitude of the gravitational force exerted on that system.	2.6.C.1	The magnitude of the apparent weight of a system is the magnitude of the normal force exerted on the system.
				2.6.C.2	If the system is accelerating, the apparent weight of the system is not equal to the magnitude of the gravitational force exerted on the system.
				2.6.C.3	A system appears weightless when there are no forces exerted on the system or when the force of gravity is the only force exerted on the system.
				2.6.C.4	The equivalence principle states that an observer in a non-inertial reference frame is unable to distinguish between an object's apparent weight and the gravitational force exerted on the object by a gravitational field.
		2.6.D	Describe inertial and gravitational mass.	2.6.D.1	Objects have inertial mass, or inertia, a property that determines how much an object's motion resists changes when interacting with another object.
				2.6.D.2	Gravitational mass is related to the force of attraction between two systems with mass.
				2.6.D.3	Inertial mass and gravitational mass have been experimentally verified to be equivalent.

2.7	**Kinetic and Static Friction**	2.7.A	Describe kinetic friction between two surfaces	2.7.A.1	Kinetic friction occurs when two surfaces in contact move relative to each other. i. The kinetic friction force is exerted in a direction opposite to the motion of each surface relative to the other surface. ii. The force of friction between two surfaces does not depend on the size of the surface area of contact.
				2.7.A.2	The magnitude of the kinetic friction force exerted on an object is the product of the normal force the surface exerts on the object and the coefficient of kinetic friction. **Relevant equation -->** $\left\lvert F_{f,s} \right\rvert = \lvert \mu_k F_n \rvert$ i. The coefficient of kinetic friction depends on the material properties of the surfaces that are in contact. ii. Normal force is the perpendicular component of the force exerted on an object by the surface with which it is in contact; it is directed away from the surface.
		2.7.B	Describe static friction between two surfaces.	2.7.B.1	Static friction may occur between the contacting surfaces of two objects that are not moving relative to each other.
				2.7.B.2	Static friction adopts the value and direction required to prevent an object from slipping or sliding on a surface. **Relevant equation -->** $\left\lvert F_{f,s} \right\rvert \leq \lvert \mu_s F_n \rvert$ i. Slipping and sliding refer to situations in which two surfaces are moving relative to each other. ii. There exists a maximum value for which static friction will prevent an object from slipping on a given surface. **Derive Equation -->** $F_{f,s,max} = \mu_s F_n$
				2.7..3	The coefficient of static friction is typically greater than the coefficient of kinetic friction for a given pair of surfaces.
2.8	**Spring Forces**	2.8.A	Describe the force exerted on an object by an ideal spring	2.8.A.1	An ideal spring has negligible mass and exerts a force that is proportional to the change in its length as measured from its relaxed length.
				2.8.A.2	The magnitude of the force exerted by an ideal spring on an object is given by **Hooke's law** → $F_s = -k\Delta x$
				2.8.A.3	The force exerted on an object by a spring is always directed toward the equilibrium position of the object–spring system.
2.9	**Circular Motion**	2.9.A	Describe the motion of an object traveling in a circular path.	2.9.A.1	Centripetal acceleration is the component of an object's acceleration directed toward the center of the object's circular path. i. The magnitude of centripetal acceleration for an object moving in a circular path is the ratio of the object's tangential speed squared to the radius of the circular path. **Relevant equation -->** $a_c = \frac{v^2}{r}$ ii. Centripetal acceleration is directed toward the center of an object's circular path.

				2.9.A.2	Centripetal acceleration can result from a single force, more than one force, or components of forces exerted on an object in circular motion. i. At the top of a vertical, circular loop, an object requires a minimum speed to maintain circular motion. At this point, and with this minimum speed, the gravitational force is the only force that causes the centripetal acceleration. **Derived equation--> $v = \sqrt{gr}$** ii. Components of the static friction force and the normal force can contribute to the net force producing centripetal acceleration of an object traveling in a circle on a banked surface. iii. A component of tension contributes to the net force producing centripetal acceleration experienced by a conical pendulum.
				2.9.A.3	Tangential acceleration is the rate at which an object's speed changes and is directed tangent to the object's circular path.
				2.9.A.4	The net acceleration of an object moving in a circle is the vector sum of the centripetal acceleration and tangential acceleration.
				2.9.A.5	The revolution of an object traveling in a circular path at a constant speed (uniform circular motion) can be described using period and frequency. i. The time to complete one full circular path is defined as period T. ii. The rate at which an object is completing revolutions is defined as frequency, f. **Relevant equation--> $T = \frac{1}{f}$** iii. For an object traveling at a constant speed in a circular path, the period is given by the **Derived equation --> $T = \frac{2\pi r}{v}$**
		2.9.B	Describe circular orbits using Kepler's third law.	2.9.B.1	For a satellite in circular orbit around a central body, the satellite's centripetal acceleration is caused only by gravitational attraction. The period and radius of the circular orbit are related to the mass of the central body. **Derived equation --> $T^2 = \frac{4\pi^2}{GM}R^3$**
		BOUNDARY STATEMENT: *AP Physics 1 only expects students to quantitatively analyze banked curves in which no friction is required to maintain uniform circular motion. Analysis of situations in which friction is required on a banked curve is limited to qualitative descriptions.* **BOUNDARY STATEMENT:** *AP Physics 1 does not expect students to know Kepler's first or second laws of planetary motion.*			

UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

Key Understandings
❑ Balanced forces on an object result in no change to the object's motion ❑ Unbalanced forces change the motion of an object, which is called acceleration (speeding up, slowing down, changing direction) ❑ Forces are the result of interactions between objects ❑ Free body diagrams represent all forces acting on an object ❑ Variable relationships can be determined by creating graphs and analyzing shape and slope ❑ Weight and mass have a linear relationship (directly proportional). When one increases or decreases by a certain factor, the other will increase/decrease by the same factor ❑ The force of a spring is in the opposite direction of the spring's displacement ❑ The force of a spring is directly proportional to the spring's displacement ❑ The force of a spring is directly proportional to the spring constant ❑ Free body diagrams are analyzed independently in the horizontal or vertical directions ❑ Balanced and unbalanced forces must be represented on a free body diagram must correspond to the motion in the scenario ❑ Objects moving with constant velocity must have balanced forces acting on them ❑ Objects at rest must have balanced forces ❑ A single missing force can be calculated with a description of motion ❑ Friction is directly proportional to normal force ❑ Static friction applies to objects that are not moving (with a force attempting to move them) ❑ Static friction can be any value between 0 N and a maximum value based on the static friction equation ❑ Kinetic friction applies to objects that are moving ❑ Kinetic friction is always less than the maximum static friction ❑ Net force and acceleration are directly proportional ❑ Mass and acceleration are inversely related ❑ The slope of a v-t graph is the acceleration of an object, so it increases when net force increases or when mass decreases ❑ Force can be calculated by finding the product of acceleration and mass ❑ 2nd Law equations can be used to determine an unknown acceleration of an object ❑ 2nd Law equations have zero acceleration for constant velocity so forces must balance ❑ Forces always come in pairs as a result of interaction between two objects ❑ A "force-pair" is made up of a force acting on each object ❑ Force-pairs are equal in magnitude and opposite in direction ❑ Systems are a collection of objects that are of interest in a scenario ❑ Internal forces are the forces within a system and have no effect on the motion of the system ❑ External forces are the forces from the environment that act on the system and do affect the motion of the system

- ❑ In chained systems all objects in the system have the same acceleration
- ❑ A chained system can be analyzed as individual parts to find internal forces
- ❑ Atwood Machines are chained systems with the weight of hanging masses being the only external forces
- ❑ The acceleration of an Atwood Machine is proportional to the difference between the two masses
- ❑ The acceleration of an Atwood Machine is inversely proportional to the total mass of the system
- ❑ Modified Atwood systems have external forces of hanging mass weight and (sometimes) friction
- ❑ Modified Atwood systems can be drawn with horizontal FBD for easier analysis
- ❑ Normal force is directed perpendicular to the surface of contact
- ❑ Friction is directed parallel to incline and opposite direction of motion
- ❑ For inclined planes, the x- and y-axis is tilted to match the angle of incline
- ❑ Only the force of gravity needs to be broken into components
- ❑ As the angle of incline increases, the component of gravity pulling downhill increases and the component perpendicular to the surface decreases
- ❑ Anchoring Events are specific things or events that happen in a discrete time frame
- ❑ Phenomena scientific laws or processes that may be observable or unobservable
- ❑ A scientific question is a question that may lead to a hypothesis and help us in answering the explanation for an observation or event
- ❑ Velocity of an object in circular motion is always tangential to the circular path
- ❑ Centripetal force and acceleration are always directed toward the center of the circular motion
- ❑ Centripetal force does not increase the speed/velocity of the object
- ❑ Centripetal force is proportional to mass
- ❑ Centripetal force is proportional to velocity squared
- ❑ Centripetal for is inversely related to radius
- ❑ A centripetal force is any force that creates a circular motion
- ❑ A centripetal force always points toward the center of the circular path
- ❑ A centripetal force is always perpendicular to the instantaneous tangential velocity of the object
- ❑ When the circular force required for a circular motion scenario is larger than the force providing the centripetal force the circular motion will fall apart
- ❑ The centripetal force for vertical circular motion (on Earth) is created by a combination of gravity and another force
- ❑ The magnitude of the second force creating the centripetal force will vary at different points in the circle
- ❑ The second force that helps create the centripetal force can be described by creating a Second Law Equation
- ❑ Claims must have evidence and scientific reasoning as justification
- ❑ Orbital period is the time it takes for an object to complete one orbit (period of revolution)
- ❑ Orbital speed is the distance of one complete orbit divided by the orbital period
- ❑ The feeling of weightlessness arises when a person experiences zero velocity relative to their surroundings without a contact force holding them (like Normal force)
- ❑ Expressions to describe characteristics of orbital motion can be derived using Newton’s Second Law and the Law of Universal Gravitation
- ❑ A gravitational field is caused by any object with mass
- ❑ The period of an orbiting body has an inverse relationship with the radius of its orbit
- ❑

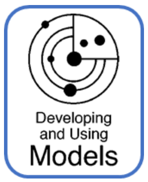
Key Questions
- How/when do objects move with constant velocity?   - How can we predict when an object will speed up or slow down?   - How do we describe all the forces acting on an object/system?   - Can a single force be created?   - How can we analyze the motion of systems of connected objects?   - How can we analyze the forces between objects in a system?   - What happens when a person on a boat (any frictionless box) tries to push the box in a direction?   - How do we analyze forces at angles?   - What causes objects to move in a circle?   - How can we predict the fastest safe speed a car can make a circular turn?   - Why do astronauts in orbit feel weightless?   - How/why do plants, moons and satellites more in circular orbits?

ROADMAP

AT A Glance: Unit #:				
Day	**Date**	**Lesson**	**Lesson Title**	**Lesson Notes**
1		01	First Law Deduction	
2		02	Introduction to Forces & FBD	
3		03	Lab - Weight vs Mass	
4		04	Lab – Spring Force	
5		05	FBD Practice	
6		06	Find the Missing Force	
7		07	Lab – Friction – Day 1	
8		08	Lab – Friction – Day 2	
9		09	Lab – Newton's Second Law – Day 1	
10		10	Lab – Newton's Second Law – Day 2	
11		11	Horizontal Forces – Video Analysis	
12		12	Practice – Vertical Forces	
13		13	Newton's Third Law	
14		14	Internal vs External Forces	
15		15	Chained Systems	
16		16	Atwood Machines	
17		17	Modified Atwood Machines	

18		18	Inclined Planes – Day 1	
19		19	Inclined Planes – Day 2	
20		20	**TX_SCI_APPhysics_F42_MUE2**	
21		21	Anchoring Event Introduction - Circular Motion	
22		22	Lab - Circular Motion	
23		23	Practice - Circular Motion	
24		24	Lab – Spinning Out	
25		25	Centripetal Force - Friction	
26		26	Vertical Circles	
27		27	Anchoring Event – Seamless Explanation	
28		28	Lab – Universal Gravitation	
29		29	Weightlessness in Space	
30		30	Practice – Circular Motion	
31		31	Practice – Circular Motion	
32	Unit Exam	32	**TX_SCI_APPhysics_F24_UE1**	
		Success Day	Time Permitting – review the most missed MC and the entire FRQ using	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 1 **First Law Deduction**	**STANDARD(s):** **Topic 2.4 – Newton's First Law** 2.4.A Describe the conditions under which a system's velocity remains constant. **SWBAT** describe constant velocity motion as the result of balanced forces and changing velocity motion as the result of unbalanced forces. **DISCIPLINARY LITERACY FOCUS:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ Balanced forces on an object result in no change to the object's motion ❑ Unbalanced forces change the motion of an object, which is called acceleration (speeding up, slowing down, changing direction) **LESSON CONTEXT FOR LESSON MASTERY** Students must understand that the state of motion of an object is a direct result of the net sum of the forces acting on that object. This lesson acts to introduce students to the concept of forces as "taps", or push and pulls between two objects. This lesson provides students with scenarios that require students to analyze either the forces present or the motion itself in order to determine Newton's First Law of Motion. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Producing rudimentary force diagrams • Identifying balanced vs unbalanced forces **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing the association between a common push or pull as a force • Arguing whether a scenario is experiencing balanced or unbalanced forces • Arguing whether a scenario is experiencing constant or accelerated motion **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming a net force is necessary to keep an object moving (not understanding inertia)	**Materials:** ▪ Bowling ball, or other ball with large mass ▪ Fan carts **Content Background Resources:** Newton's First Law of Motion PC- Balanced and Unbalanced Forces
Day 2 **Force Introductio n & Free-**	**STANDARD(s):** **Topic 2.2 – Forces & Free-Body Diagrams** 2.2.B Describe the forces exerted on an object or system using a free-body diagram.	**KEY UNDERSTANDINGS CHECKLIST** ❑ Forces are the result of interactions between objects ❑ Normal Force is present any time an object sits on the ground or a surface ❑ Tension is a pulling for a rope or string ❑ Force of gravity (weight) points towards the center of the Earth and is present any time an object is on or near the Earth	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Body Diagrams	**SWBAT**: Identify and Describe the different types of contact forces. **DISCIPLINARY LITERACY FOCUS:**  	❑ Free body diagrams represent all forces acting on an object **LESSON CONTEXT FOR LESSON MASTERY** Interactions between objects produce a force that acts on both objects, which have specific naming conventions based on the scenario. The prior lesson highlights the presence of forces during "collisions" between objects. This lesson builds on this idea by demonstrating that forces are always present during an interaction between objects. This lesson has students explore different physical scenarios to become familiar with common forces, then naming forces and identifying direction with practice problems. **LOOK-FORS (What to observe students doing or producing)** • Producing interaction diagrams for an object in a scenario • Translating the interaction diagram into a free body diagram **LISTEN-FORS (Examples of what students should be saying or explaining)** • Discussing the number of interactions present in a scenario • Determining direction of forces based on interaction **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Adding a force of motion in the direction of motion of the object when there should be none (not understanding inertia)	**Content Background Resources:** What are Forces? PC- The Meaning of Force Khan-Force Intro
Day 3 **Weight vs Mass**	**STANDARD(s):** **Topic 2.6 – Gravitational Force** 2.6.B Describe situations in which the gravitational force can be considered constant. **SWBAT** experimentally determine the mathematical relationship between the weight and mass of an object.	**KEY UNDERSTANDINGS CHECKLIST** ❑ Variable relationships can be determined by creating graphs and analyzing shape and slope ❑ Weight and mass have a linear relationship (directly proportional). When one increases or decreases by a certain factor, the other will increase/decrease by the same factor. **LESSON CONTEXT FOR LESSON MASTERY** Mass and weight are two different quantities that share a linear relationship. Students now have context that weight is a force and mass is not. This lesson has students design and perform an experiment to visualize the relationship between mass and weight.	APPhysicsU2-Day03.docx **Materials:** ▪ Various masses ▪ Force sensors or spring scales

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	DISCIPLINARY LITERACY FOCUS: Planning and Carrying Out Investigations	**LOOK-FORS (What to observe students doing or producing)** • Varying the masses and measuring the respective weight • Performing graphical analysis of their mass vs weight graph • Applying the linear relationship to extrapolate or interpolate data **LISTEN-FORS (Examples of what students should be saying or explaining)** • Discussing the trend present in their data • Discussing the slope of their data and what it may represent (gravitational acceleration on Earth) **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Assume that weight = mass x 10 for all planets, regardless of gravitational acceleration • Assume that mass and weight are interchangeable	**Content Background Resources:** Mass vs. Weight and Normal Force
Day 4 **Lab – Spring Force**	**STANDARD(s):** **Topic 2 … orces** 2.8.A … e force exerted … ct by an ideal sp… Planning and Carrying Out Investigations **SWBAT** experimentally determine the mathematical relationships that define the force from a spring. **DISCIPLINARY LITERACY FOCUS:**	**KEY UNDERSTANDINGS CHECKLIST** ❑ The force of a spring is in the opposite direction of the spring's displacement ❑ The force of a spring is directly proportional to the spring's displacement ❑ The force of a spring is directly proportional to the spring constant **LESSON CONTEXT FOR LESSON MASTERY** At this point in the unit, the student has become familiar with the concept of individual, specific forces. The student now has experience with designing an experiment. This lesson has students design and perform an experiment to visualize what affects the force produced inside a spring. By introducing this topic now, students will have time to internalize before revisiting springs in U3: Energy and U5: Oscillations **LOOK-FORS (What to observe students doing or producing)** • Varying the spring displacement and measuring the force (or vice versa) • Varying the spring constant and measuring the force • Performing graphical analysis of their data	**Materials:** ▪ Various masses ▪ Various springs ▪ Force sensors or spring scales ▪ Student computers **Content Background Resources:** Hooke's Law **Khan-Spring Force**

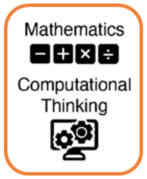
Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		LISTEN-FORS (Examples of what students should be saying or explaining) • Discussing the trends present in their data • Arguing why spring constant and displacement have a proportional relationship with spring force **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Assuming springs produce only one constant force, regardless of displacement • Assuming spring force points in the same direction as displacement	
Day 05 **Free-Body Diagram Practice**	**STANDARD(s):** **Topic 2.2 – Forces & Free-Body Diagrams** 2.2.B Describe the forces exerted on an object or system using a free-body diagram. **SWBAT** create accurate free body diagrams for physics scenarios. **DISCIPLINARY LITERACY FOCUS:** Planning and Carrying Out Investigations	**KEY UNDERSTANDINGS CHECKLIST** ❑ Free body diagrams show all the forces on an object ❑ Free body diagrams are often analyzed in the horizontal or vertical direction ❑ Balanced and unbalanced forces must be represented on a free body diagram appropriately **LESSON CONTEXT FOR LESSON MASTERY** Interactions between objects produce a force that acts on both objects, which have specific naming conventions based on the scenario. The student now has familiarity with forces as vectors and the concept that forces occur due to interactions. This lesson acts as a direct continuation of the Day 2 lesson: “Force Introduction and FBD”. This lesson asks students to analyze a scenario and create the matching interaction diagram and free body diagram with appropriate vector lengths. **LOOK-FORS (What to observe students doing or producing)** • Producing interaction diagrams for an object in a scenario • Translating the interaction diagram into a free body diagram **LISTEN-FORS (Examples of what students should be saying or explaining)** • Discussing the number of interactions present in a scenario • Determining direction of forces based on interaction **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Assuming that a normal force always points directly upward instead of perpendicular to the surface	**Content Background Resources:** System Schema (or Interaction Diagram) and translating to FBDs further down the webpage PC- Drawing Free-Body Diagrams

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Adding forces to a FBD that do not result from direct interactions (ex: a hand pulling the rope of a wagon; the student adds an applied force to the wagon instead of tension) • Adding no existing forces in the direction of motion of the object (not understanding inertia)	
Day 06 **Find the Missing Force**	**STANDARD(s):** **Topic 2.4 – Newton's First Law** 2.4.A Describe the conditions under which a system's velocity remains constant. **SWBAT** apply the concept of balanced forces to qualitatively solve for unknown forces. **DISCIPLINARY LITERACY FOCUS:** Mathematics Computational Thinking	**KEY UNDERSTANDINGS CHECKLIST** ❑ Objects moving with constant velocity must have balanced forces acting on them ❑ When only one force is missing from a scenario description it can be solved ❑ For objects at rest, the forces on the object must be balanced in both the vertical and horizontal **LESSON CONTEXT FOR LESSON MASTERY** At this point in the unit, the student has familiarity with: • Identifying interactions in real-world scenarios • Drawing interaction diagrams • Translating interaction diagrams into FBDs • Interpreting FBDs to determine the state of motion of an object This lesson builds off this topic by withholding complete information from real-world scenarios. Teachers create stations for students to observe objects interacting, however these stations will not provide full context (such as the magnitude of all forces present). Students must apply their understanding of Newton's 1st Law to solve for the missing forces by creating FBDs. This concept is crucial for upcoming lessons covering Newton's 2nd Law. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Creating FBDs that represent a given scenario • Algebraically analyzing vectors in horizontal or vertical directions, independently **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Justifying vector calculations based on algebra and the VAD (vector addition diagram) • Discussing Newton's First Law as a reason for forces being balanced	**Materials:** ▪ Force sensor or Spring scales ▪ Various masses ▪ Hoop spring ▪ Electronic balance ▪ Rind stands ▪ Dynamics Cart and Track ▪ Pulleys ▪ String

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings) • **Forgetting to include the direction when comparing forces in opposite direction** • **Attempting to sum forces in horizontal and vertical direction together**	
Day 07 **Lab – Friction Day 1**	**STANDARD(s):** **Topic 2.7 – Kinetic & Static Friction** 2.7.A Describe kinetic friction between two surfaces 2.7.B Describe static friction between two surfaces. **SWBAT** experimentally describe the relationship between the Normal Force and Friction force for an object pulled horizontally. **DISCIPLINARY LITERACY FOCUS:** Planning and Carrying Out Investigations	**KEY UNDERSTANDINGS CHECKLIST** ❑ **Static friction applies to objects that are not moving** ❑ **Static friction can be any value between 0 N and a maximum value based on the static friction equation** ❑ **Friction is directly proportional to the normal force on an object** **LESSON CONTEXT FOR LESSON MASTERY** Friction is a unique force that changes depending on the state of motion of the object. It may be one fixed value (kinetic friction) or it may fall within a threshold of values (static friction). Additionally, both types of friction have dependencies on factors that affect their magnitude. This lesson is a two-day lab that poses several questions about friction in order for students to design and perform an experiment. At this point in the lesson, students have had several opportunities to design and carry out an experimental procedure. To facilitate a successful lab, students should perform data analysis and draw conclusions by discussing with peers. This lesson will uncover the static and kinetic friction equations, which will return heavily throughout this unit as well as future units. LOOK-FORS 🔍 (What to observe students doing or producing) • Varying the weight of an object being dragged and measuring the force required to move it • Varying the surface area of an object being dragged and measuring the force required to move it • Performing graphical analysis of their data LISTEN-FORS 🗣 (Examples of what students should be saying or explaining) • Discussing trends present in their data / comparing to other groups • Arguing why weight (normal force) has a proportional relationship with friction but surface area does not • Discussing static friction's range of values	**Materials per lab group:** ▪ Textbook (or other flat object with significant mass) ▪ String ▪ Force sensor or spring scale ▪ Motion sensor Shared ▪ Electronic balance **Content Background Resources:** [Khan - Friction]

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings) • Assuming static friction can only be the maximum value • Assuming friction cannot be present because an object is not in motion	
Day 08 **Lab – Friction Day 2**	**Topic 2.7 – Kinetic & Static Friction** 2.7.A Describe kinetic friction between two surfaces 2.7.B Describe static friction between two surfaces. **SWBAT** Compare and contrast static and kinetic friction qualitatively and quantitatively. **Disciplinary Literacy Focus:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ **Kinetic friction applies to objects that are moving** ❑ **Kinetic friction is only one fixed value and is always less than the maximum static friction value** **LESSON CONTEXT FOR LESSON MASTERY** See previous "lesson context' on Day 7. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Varying the weight of an object being dragged and measuring the force required to keep it in constant motion • Performing graphical analysis of their data **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing trends present in their data / comparing to other groups • Comparing results from 1st and 2nd day of experiments **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming kinetic friction and static friction are the same value • Assuming that maximum static friction is the kinetic friction	
Day 09 **Lab – Second Law Deduction**	**STANDARD(s):** **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes.	**KEY UNDERSTANDINGS CHECKLIST** ❑ Net force and acceleration are directly proportional ❑ Mass and acceleration are inversely related **LESSON CONTEXT FOR LESSON MASTERY** Students have thus far seen examples of both constant velocity motion and constant acceleration motion, and have investigated how the nature of forces determines the	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	SWBAT analyze experimental data to determine the variable relationships that define acceleration (Newton's Second Law). **DISCIPLINARY LITERACY FOCUS:**  	state of motion. However, students have not yet discussed what affects the nature of accelerated motion. This lesson has students design an experiment and analyze experimental data determine what affects the acceleration of a moving object. The outcome of this lab is for students to uncover Newton's 2^{nd} Law and 2^{nd} Law equation. This equation is, arguably, the most important and recurring concept throughout this course. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Producing well-formatted graphs of given experimental data • Performing graphical analysis on given data **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing what equipment can be used to measure force and acceleration • Discussing trends present in the given data **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming net force is an individual force rather than the sum of all forces on an object • That an object moving with constant velocity requires a net force	**Materials per lab group:** • 1 Vernier Tracks and carts • 1 Fan cart or regular cart • Extra masses • Motion detectors (optional) • Textbooks (optional - to create inclines) Masking tape (optional) Shared ▪ Electronic balance **Content Background Resources:** **Khan – Newtons Second Law** **PC- Newton's Second Law**
Day 10 **Second Law Practice**	**STANDARD(s):** **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes. **SWBAT** make and justify claims about the motion and forces on in physics scenarios using Newtons Second Law. **DISCIPLINARY LITERACY FOCUS:**	**KEY UNDERSTANDINGS CHECKLIST** ❑ Acceleration and mass have an inverse relationship ❑ The slope of a v-t graph is the acceleration of an object, so it increases when net force increases or when mass decreases **LESSON CONTEXT FOR LESSON MASTERY** Students have now been introduced to Newton's 2^{nd} Law and the quantities that affect acceleration. Additionally, students have had plenty of practice interpreting motion graphs. This lesson focuses on students interpreting motion graphs and relating it to forces and Newton's Laws without being shown explicitly. This lesson teaches students to connect concepts between units together. The lesson begins with a review of skills learned in the previous lab. The second activity has students match forces with their respective v-t graphs. The final activity has students practice	**Content Background Resources:** **Khan-More Newtons Second Law** **Khan-Second Law Calculations**

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		all skills with a qualitative to quantitative translation with an equation derivation. This is a crucial skill tested on the AP exam. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Performing graphical analysis to determine the relationship between variables (mass and acceleration) • Interpreting velocity graphs to determine slope • Create FBDs that accurately represent a narrative **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Ranking slope of v-t graph and applying Newton's 2nd Law • Justifying force ranking and answer choices of Scenario 3 **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Adding non-existing forces in the direction of motion of the object (not understanding inertia) to an FBD • Assuming the "effects" of an unbalanced force persist after the force is removed (ex: the object will continue to accelerate for a while after being pushed)	
Day 11 **Horizontal Forces – Video Analysis**	**STANDARD(s):** **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** calculate and describe horizontal forces using slow motion video analysis for data analysis. **DISCIPLINARY LITERACY FOCUS:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ Force can be calculated by finding the product of acceleration and mass ❑ Acceleration can be determined by creating a v-t graph and finding the slope **LESSON CONTEXT FOR LESSON MASTERY** The prior lesson aimed to teach students to apply Newton's 2nd Law to motion diagrams through worksheet practice. This lesson builds on that concept by having students practice these skills with real-world examples. After observing a clip of an accelerating object, students are asked to model the scenario with a FBD and matching 2nd Law equation. Using the same clip, students are tasked with data collection and graphical analysis to predict the force applied to the object. The ability to predict forces based on the existing motion of an object is crucial to most topics in this course. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Collecting position and time data	**Content Background Resources:** **See Day 09-10**

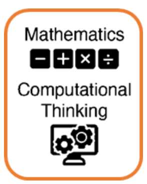
Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Producing well-formatted graphs of experimental data • Performing graphical analysis **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing whether collected data is accurate and comparing with neighboring groups **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Constant velocity requires a net force	
Day 12 Vertical Forces Practice	**Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT**: calculate unknown variables in vertical motion scenarios using Newton's Second Law. **DISCIPLINARY LITERACY FOCUS:** Mathematics Computational Thinking	**KEY UNDERSTANDINGS CHECKLIST** ❑ **2nd Law equations can be used to determine an unknown acceleration of an object** ❑ **2nd Lawe equations have zero acceleration for constant velocity so forces must balance** **LESSON CONTEXT FOR LESSON MASTERY** At this point in the unit, students have now applied Newton's 1st and 2nd law to objects constant velocity and constant acceleration in the horizontal direction. This lesson focuses on students making predictions about forces and motion in the vertical direction by applying Newton's 2nd law and setting up 2nd law equations. Students will be exposed to non-free fall situations, where the acceleration experienced by the object isn't equal to g. This lesson continues to build on student's ability to derive a 2nd law equation that can be used to make predictions. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Setting up proper FBDs with forces of relative magnitude acting in the correct direction • Using FBDs to create a 2nd Law equation • Performing mathematical routine to solve for missing quantity **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Comparing 2nd Law equations with peers	**Content Background Resources:** **See Day 09-10**

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings) • Assuming the acceleration is still equal to g, even when other vertical forces are present • Not taking the direction of the force into consideration when summing forces together • Cherry-picking a single force as the “net force” in the 2nd law equation	
Day 13 **Third Law Deduction**	**STANDARD(s):** **Topic 2.3 – Newton’s Third Law** 2.3.A Describe the interaction of two objects using Newton’s third law and a representation of paired forces exerted on each object. **SWBAT** identify and describe paired forces according to Newton’s Third Law. **DISCIPLINARY LITERACY FOCUS:**  	**KEY UNDERSTANDINGS CHECKLIST** ❑ Forces always come in pairs as a result of interaction between two objects ❑ A “force-pair” is made up of a force acting on each object ❑ Force-pairs are equal in magnitude and opposite in direction **LESSON CONTEXT FOR LESSON MASTERY** Interacting objects experience equal and opposite forces acting on each object. The resulting forces are called a force-pair, but do not happen on a singular object. Students have learned that forces happen as the result of interacting objects but have not dived into the action-reaction aspect of this interaction. This lesson has students observe and interact with real-world scenarios. Students learn to identify and explain the nature of action-reaction pairs. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Creating matching FBDs for interacting objects that include a “common force” (action-reaction pair) • Identifying the action-reaction pair from a diagram **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing the “cause and effect” of action-reaction pair on interacting objects **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming that both the action-reaction pair happen on the same object (This misconception is one of the most long-standing misunderstandings that can persist	**Materials:** ▪ **Canisters/boxes with magnets (requires setup)** ▪ **Force sensors/ spring scales** ▪ **Rubber bands** ▪ **Vernier carts with track & loop springs** ▪ **2 human dynamics carts** ▪ **Brick/textbook/ box** ▪ **Whiteboards** **Content Background Resources:** [Khan-Systems & Newtons Third Law] **PC-** [Newton's Third Law]

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		for the rest of the course. This should always be addressed when discussing action-reaction pairs) • Assuming that action-reaction pairs cancel out (stemming from misconception 1)	
Day 14 **Internal vs External Forces**	**STANDARD(s):** **Topic 2.3 – Newton's Third Law** 2.3.A Describe the interaction of two objects using Newton's third law and a representation of paired forces exerted on each object. **SWBAT** identify and describe internal vs external forces for a system and their effect on the acceleration of the system. **DISCIPLINARY LITERACY FOCUS:** Constructing Explanations Designing Solutions	**KEY UNDERSTANDINGS CHECKLIST** ❑ Systems are a collection of objects that are of interest in a scenario ❑ Internal forces are the forces within a system and have no effect on the motion of the system ❑ External forces are the forces from the environment that act on the system and do affect the motion of the system **LESSON CONTEXT FOR LESSON MASTERY** Students have now become familiar with the following topics regarding forces: • They are caused by interactions between objects • They always come in equal and opposite pairs • They can cause changes in motion when unbalanced This lesson aims to differentiate **when** forces are responsible for changes in motion (when they are external to the system). This lesson introduces the topic of systems and internal vs external forces. Students will be tasked with analyzing a scenario with multiple interacting objects and drawing FBDs for various configurations of the system. They will also continue to build their skills, creating 2nd Law equations that accurately model a given scenario. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Creating multiple FBDs of a scenario to determine internal and external forces • Creating 2nd Law equations to predict acceleration **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing whether forces are classified as internal or external • Making predictions about acceleration based on FBDs **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)**	APPhysics-U2-Day14.docx **Content Background Resources:** **AP Classroom – Double Trouble**

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Assuming that both the action-reaction pair happen on the same object (This misconception is one of the most long-standing misunderstandings that can persist for the rest of the course. This should always be addressed when discussing action-reaction pairs) • Assuming that action-reaction pairs cancel out (stemming from misconception 1)	
Day 15 **Chained Systems**	**STANDARD(s):** **Topic 2.3 – Newton's Third Law** 2.3.A Describe the interaction of two objects using Newton's third law and a representation of paired forces exerted on each object. **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** make predictions about unknown forces and acceleration for horizontal chained systems **DISCIPLINARY LITERACY FOCUS:** Mathematics Computational Thinking	**KEY UNDERSTANDINGS CHECKLIST** ❑ In chained systems all objects in the system have the same acceleration ❑ Defining internal and external forces allow predictions about chained systems **LESSON CONTEXT FOR LESSON MASTERY** Students are tasked with solving for a specific internal force of a system. This lesson requires students to apply the problem-solving procedure practiced in the prior lesson and the procedure learned when practicing Newton's 2nd Law lessons. This lesson requires students to run the full gambit of: • Defining the system • Creating FBDs for multiple configurations of the system • Creating a 2nd Law equation for each FBD • Solve system of equations for the internal force and/or acceleration **LOOK-FORS 🔍 (What to observe students doing or producing)** • Using Newton's 3rd Law to create multiple FBDs to represent a single scenario • Using 2nd Law equation to make predictions about acceleration **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing whether forces are classified as internal or external • Justifying predictions about acceleration with FBDs **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming that both the action-reaction pair happen on the same object (This misconception is one of the most long-standing misunderstandings that can persist for the rest of the course. This should always be addressed when discussing action-reaction pairs) • Assuming that action-reaction pairs cancel out (stemming from misconception 1)	**Content Background Resources:** [AP Classroom – Double Trouble]()

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 16 **Atwood Machines**	**Topic 2.3 – Newton's Third Law** 2.3.A Describe the interaction of two objects using Newton's third law and a representation of paired forces exerted on each object. **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** make predictions with justification about the acceleration and forces of Atwood Machines. **DISCIPLINARY LITERACY FOCUS:** Mathematics Computational Thinking	**KEY UNDERSTANDINGS CHECKLIST** ❑ Atwood Machines are chained systems that have two external forces ❑ The acceleration of an Atwood Machine is proportional to the difference between the two masses ❑ The acceleration of an Atwood Machine is inversely proportional to the mass of the system **LESSON CONTEXT FOR LESSON MASTERY** This lesson offers a look into a real-world, specific type of chained system. Thus far, students have analyzed Newton's Third Law problems and chained systems undergoing horizontal motion. This lesson now has students approach these topics using vertical motion. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Using Newton's 3^{rd} Law to create multiple FBDs to represent a single scenario • Using 2^{nd} Law equation to make predictions about acceleration **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing whether forces are classified as internal or external • Justifying predictions about acceleration with FBDs **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming that both the action-reaction pair happen on the same object (This misconception is one of the most long-standing misunderstandings that can persist for the rest of the course. This should always be addressed when discussing action-reaction pairs) • Assuming that action-reaction pairs cancel out (stemming from misconception 1)	**Content Background Resources:** [Khan-Analyzing Systems]

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 17 **Modified Atwood Practice**	**STANDARD(s):** **Topic 2.3 – Newton's Third Law** 2.3.A Describe the interaction of two objects using Newton's third law and a representation of paired forces exerted on each object. **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** make qualitative and quantitative predictions about the forces and motion of a modified Atwood Machine. **DISCIPLINARY LITERACY FOCUS:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ Modified Atwood systems have one or two external forces accelerating the system ❑ Modified Atwood systems are analyzed like all other chained systems **LESSON CONTEXT FOR LESSON MASTERY** Students have now become familiar with applying Newton's 2nd and 3rd Law to chained systems in purely horizontal motion or purely vertical motion. This lesson offers students the opportunity to analyze a modified Atwood machine, which experiences motion in both horizontal and vertical direction. **LOOK-FORS (What to observe students doing or producing)** • Using 2nd Law equations to make predictions about acceleration • Creating claims (using CER format) about the motion of modified Atwood Machine **LISTEN-FORS (Examples of what students should be saying or explaining)** • Justifying their claims with reference to either a FBD, variable relationships of Atwood Machines, or 2nd / 3rd Law **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Assuming the acceleration is still equal to g, even when other vertical forces are present • Cherry-picking a single force as the "net force" in the 2nd law equation • Assuming that both the action-reaction pair happen on the same object (This misconception is one of the most long-standing misunderstandings that can persist for the rest of the course. This should always be addressed when discussing action-reaction pairs)	**Content Background Resources:** See Day 16
Day 18 **Inclined Planes - Lab**	**STANDARD(s):** **Topic 2.2 – Forces & Free-Body Diagrams** 2.2.B Describe the forces exerted on an object or system using a free-body diagram.	**KEY UNDERSTANDINGS CHECKLIST** ❑ Normal force is directed perpendicular to the surface ❑ For inclined planes, the x- and y-axis is tilted to match the angle of incline ❑ Only the force of gravity needs to be broken into components ❑ As the angle of incline increases, the component of gravity pulling downhill increases and the component perpendicular to the surface decreases	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	Topic 2.5 – Newton's Second Law 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** create and analyze free-body diagrams for an object on an incline **DISCIPLINARY LITERACY FOCUS:** Planning and Carrying Out Investigations Engaging in Argument from Evidence	**LESSON CONTEXT FOR LESSON MASTERY** Students have now been exposed to many different examples of accelerated motion in 1D. This lesson will now introduce objects subjected to 2D forces. This is a two day activity that begins with a lab for students to investigate how force vectors affect the acceleration of an object. Students will design and test how changing the angle of a ramp causes the force experienced by a cart on the ramp to change. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Varying the angle of a ramp and measuring the force required to keep an object stationary • Performing graphical analysis of their data **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing trends present in their data / comparing to other groups **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Not "tilting" the x and y axis to match the direction of motion down the ramp • Not breaking up F_g into components	**Materials (per group):** • **1 Vernier Dynamics Track** • **1 Vernier cart** • **1 Force sensor** • **1 motion sensor** • **1 protractor** • **Objects to make an incline with track** **Content Background Resources:** **Khan-Inclined Plane** **Khan – Resolving Forces into Components** **Khan-System on incline with Friction example**
Day 19 **Inclined Plane Practice**	**STANDARD(s):** **Topic 2.2 – Forces & Free-Body Diagrams** 2.2.B Describe the forces exerted on an object or system using a free-body diagram. **Topic 2.5 – Newton's Second Law** 2.5.A Describe the conditions under which a system's velocity changes **SWBAT** describe the motion of an object on an incline	**KEY UNDERSTANDINGS CHECKLIST** ❑ See key points above **LESSON CONTEXT FOR LESSON MASTERY** This lesson builds on the previous lab. Now that students have been introduced to the concept of forces at an angle, they will practice the following: • Creating FBDs for objects on an incline • Making predictions for individual forces or acceleration using 2^{nd} Law equations **LOOK-FORS 🔍 (What to observe students doing or producing)** • Correctly labeling x and y components of F_g with sine or cosine, respectively	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	qualitatively and quantitatively using Second Law Equations. **DISCIPLINARY LITERACY FOCUS:** Mathematics Computational Thinking	• Incorporating the x-component of F_g in the 2nd law equation as part of the net force **LISTEN-FORS (Examples of what students should be saying or explaining)** • Justifying their choices for the forces summed as the net force **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** • Choosing the wrong component of F_g to add to the net force • Mislabeling the components with the opposite trig function (students are used to using sine for the y-component and cosine for the x-component) • Forgetting to add any trig functions when using the components	
Day 20	**TX_SCI_APPhysics_F25_MUE2**		
Day 21 **Circular Motion Anchoring Event & Modeling**	**STANDARD(s):** **Topic 2.9 – Circular Motion** **2.9.A** Describe the motion of an object traveling in a circular path. **SWBAT:** create an initial explanatory model for the anchoring event. **DISCIPLINARY LITERACY FOCUS:** Asking Questions Defining Problems Constructing Explanations Designing Solutions	**KEY UNDERSTANDINGS CHECKLIST** ❑ Anchoring Events are specific things or events that happen in a discrete time frame ❑ Phenomena scientific laws or processes that may be observable or unobservable ❑ A scientific question is a question that may lead to a hypothesis and help us in answering the explanation for an observation or event **LESSON CONTEXT FOR LESSON MASTERY** This lesson introduces students first step into inquiry investigation and marks the second half of Unit 2. Students will be asked a question regarding an interactive, observable anchoring event. By playing with and making observations about the event, students form a hypothesis regarding the cause of the phenomenon. Their hypothesis will be tested and revised throughout the unit until a definitive conclusion is reached. This style of phenomenon based learning will return for other lessons within and beyond this unit. **LOOK-FORS (What to observe students doing or producing)** • Recording qualitative and quantitative observations and data	**Materials (per group):** • **1 plastic cup** • **1-2 yards string** • **Water or coins** • **Sticky notes**

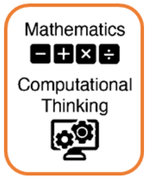
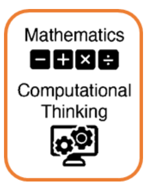
Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Create a model with annotations, questions, and ideas **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Using prior knowledge to justify their hypothesis **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Misconceptions will vary from student to student as this is their first exploration into circular motion (the key is to NOT dissuade these misconceptions as they will be addressed as they arise throughout the unit)	
Day 22 **Lab – Circular Motion**	**STANDARD(s):** **Topic 2.9 – Circular Motion** **2.9.A** Describe the motion of an object traveling in a circular path. **SWBAT:** Describe the velocity and net force of uniform circular motion qualitatively and quantitatively. **DISCIPLINARY LITERACY FOCUS:** Planning and Carrying Out Investigations Analyzing and Interpreting Data	**KEY UNDERSTANDINGS CHECKLIST** ❑ Velocity of an object in circular motion is always tangential to the circular path ❑ Centripetal force and acceleration are always directed toward the center of the circular motion ❑ Centripetal force does not increase the speed/velocity of the object ❑ Centripetal force is proportional to mass ❑ Centripetal force is proportional to velocity squared ❑ Centripetal for is inversely related to radius **LESSON CONTEXT FOR LESSON MASTERY** Previously, students have applied their knowledge of Dynamics to explain the state of motion of an object traveling in a straight line. This section of Unit 2 and onward ties these previous concepts with objects moving in circular motion. Additionally, this section prepares students for the upcoming unit: Rotational Motion which features circular motion heavily. This lesson features a hands-on lab for students to relate Newton's 2^{nd} Law to objects spinning in a circle. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Students graphing IV and DV data to determine their relationship • Student groups sharing and/or comparing data/results with other groups • Students using variable relationships discovered in the lab (or found in the centripetal force equation) to make quantitative predictions **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)**	**Content Background Resources:** Khan-Circular Motion

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Discussion explaining why the ball moves in a straight line when the hula hoop is lifted • Discussion about why the ball rises when the speed increases/radius decreases • Discussion about what force provides the centripetal force • Discussion about how to hold certain variables constant while manipulating an IV **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • The full force of the tension in the string is the centripetal force (rather than just the x-component • Centripetal force causes the ball/an object to accelerate	
Day 23 **Horizontal Circular Motion Practice 1** **Day 24** **Horizontal Circular Motion Practice 2**	**STANDARD(s):** **Topic 2.9 – Circular Motion** **2.9.A** Describe the motion of an object traveling in a circular path. **SWBAT:** identify the centripetal for in a circular motion physics scenario by drawing a free-body diagram. **SWBAT:** Support qualitative and quantitative claims about circular motion using variable relationships from derived equations.	**KEY UNDERSTANDINGS CHECKLIST** ❑ A centripetal force is any force that creates a circular motion ❑ A centripetal force always points toward the center of the circular path ❑ A centripetal force is always perpendicular to the instantaneous tangential velocity of the object ❑ When the circular force required for a circular motion scenario is larger than the force providing the centripetal force the circular motion will fall apart **LESSON CONTEXT FOR LESSON MASTERY** In the previous lab, students were introduced to a centripetal force by means of a tension force pulling an object in a circle in a lab experiment. This is a three day lesson aiming to drill the following concepts: • Identifying velocity and acceleration vectors for circular motion • Derive an equation using 2^{nd} Law equations **LOOK-FORS 🔍 (What to observe students doing or producing)** • Creating FBDs that reflect circular motion • Labeling the direction of velocity and acceleration	**Content Background Resources:** **See Day 22**

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 25 **Horizontal Circular Motion Practice 3**	**SWBAT:** derive an equation describing circular motion for a particular variable. **DISCIPLINARY LITERACY FOCUS:** Engaging in Argument from Evidence Mathematics Computational Thinking	• Using 2nd Law equation to make predictions about the state of motion of an object **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Justifying claims using Newton's 1st and 2nd Law **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming that the centripetal force acts tangent to the circular path (this misconception stems back to their misconception about inertia and the effect of forces on motion)	
Day 26 **Vertical Circles**	**STANDARD(s):** **Topic 2.9 – Circular Motion** **2.9.A** Describe the motion of an object traveling in a circular path. **SWBAT:** make claims about the forces acting on an object in vertical circular motion supported by evidence and physics reasoning. **DISCIPLINARY LITERACY FOCUS:** Engaging in Argument from Evidence Mathematics Computational Thinking	**KEY UNDERSTANDINGS CHECKLIST** • The centripetal force for vertical circular motion (on Earth) is created by a combination of gravity and another force • The magnitude of the second force creating the centripetal force will vary at different points in the circle • The second force that helps create the centripetal force can be described by creating a Second Law Equation **LESSON CONTEXT FOR LESSON MASTERY** At this point in the unit, students have become familiar with the key points of circular motion. Students will now be tasked with describing and predicting the net force and acceleration of objects swinging in vertical circles by using 2nd Law equations. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Creating FBDs that reflect vertical circular motion • Using 2nd Law equations to make predictions about the acceleration or centripetal force **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussing the direction of force vectors and acceleration vetors **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)**	**Content Background Resources:** [Khan-Ball in Vertical Loop Example]

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Assuming that centripetal force is constant throughout all points in the circular path • Cherry-picking a single force as the "net force" in the 2nd law equation • Assuming that centripetal acceleration is constant throughout all points in the circular path	
Day 27 **Anchoring Event Seamless Explanation**	**STANDARD(s):** **Topic 2.9 – Circular Motion** **2.9.A** Describe the motion of an object traveling in a circular path. **SWBAT:** develop a final explanatory model with evidence captured on the summary table for this unit. **DISCIPLINARY LITERACY FOCUS:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ Anchoring Events are specific things or events that happen in a discrete time frame ❑ Phenomena scientific laws or processes that may be observable or unobservable ❑ Claims must have evidence and scientific reasoning as justification **LESSON CONTEXT FOR LESSON MASTERY** This lesson acts as time for students to develop a final explanatory model for the original anchoring event. Students will review summary tables covering the lesson in this unit and discuss with their peers to develop an answer. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Organizing and analyzing information from the course of the unit using graphic organizer and summary table • Answering the essential question using evidence **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Discussion about identifying relevant evidence to explain the Anchoring Event & Essential Questions(s) • Discussion about how to use physics concepts and equations to connect the evidence with the claim **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Not making an explanation "Seamless" by skipping over required evidence or critical physics concepts that are needed to properly justify claims	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 28 **Lab - Universal Gravitation**	**STANDARD(s):** 2.6.A Describe the gravitational interaction between two objects or systems with mass. **SWBAT:** Determine and describe the variable relationships that define universal gravitation experimentally using a PhET simulation. **DISCIPLINARY LITERACY FOCUS:** 	**KEY UNDERSTANDINGS CHECKLIST** ❑ A gravitational field is caused by an object with mass Orbital period is the time it takes for an object to complete one orbit (period of revolution) ❑ Orbital speed is the distance of one complete orbit divided by the orbital period ❑ **LESSON CONTEXT FOR LESSON MASTERY** Students have now become familiar with analyzing objects in linear and circular motion on the small scale. The final lessons in Unit 2 focus on the forces and motion of celestial bodies and how Newton's Laws of Motion still govern their motion. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Collecting data and performing graphical analysis **LISTEN-FORS 🗣 (Examples of what students should be saying or explaining)** • Comparing data with peers for accuracy • Justifying claims with evidence from their experiment and key points from prior lessons **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Assuming larger bodies exert larger gravitational forces on smaller objects but only experience smaller reciprocating gravitational forces (not applying Newton's 3rd Law)	**PhET Simulation - Gravity Force Lab Basics** **Content Background Resources:** **Khan-Newtons Law of Gravitation**
Day 29 **Orbital Motion Derivations**	**STANDARD(s):** **Topic 2.9 – Circular Motion** 2.9.B Describe circular orbits using Kepler's third law. **SWBAT:** Derive equations to justify claims about orbital motion using the Universal Gravitation equation and the equation for centripetal force.	**KEY UNDERSTANDINGS CHECKLIST** ❑ The feeling of weightlessness arises when a person experiences zero velocity relative to their surroundings without a contact force holding them (like Normal force) ❑ The force of gravity is the centripetal force for satellites, moon and planets ❑ Expressions to describe characteristics of orbital motion can be derived using the Centripetal Force equations and the Law of Universal Gravitation **LESSON CONTEXT FOR LESSON MASTERY**	**Content Background Resources:** **Khan-Circular Orbits**

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	DISCIPLINARY LITERACY FOCUS:  	This lesson focuses on building equation derivation skills using Newton's Second Law. This is a crucial skill that is tested on the AP exam and students need to be able to develop equations that reflect their claims about a topic. **LOOK-FORS (What to observe students doing or producing)** • Develop equations using algebraic manipulation • Create claims referencing the equations produced **LISTEN-FORS (Examples of what students should be saying or explaining)** • Discussing what information from a FBD or other model is needed to substitute into 2nd law equation • Discussing how the derived equation supports their claim **COMMON MISCONCEPTIONS (Historical/widespread misunderstandings)** •	
Day 30 **Gravitation & Circular Orbits Practice**	**STANDARD(s):** **Topic 2.9 – Circular Motion** 2.9.B Describe circular orbits using Kepler's third law. **SWBAT:** Derive equations to justify claims about Gravitational force and orbital motion using the Universal Gravitation equation and the equation for centripetal force. **DISCIPLINARY LITERACY FOCUS:**   	**KEY UNDERSTANDINGS CHECKLIST** ❑ The period of an orbiting body has an inverse relationship with the radius of its orbit **LESSON CONTEXT FOR LESSON MASTERY** This final lesson gives students practice using skills developed throughout this unit on orbiting bodies: • Creating FBDs of satellites • Labeling circular motion vectors with correct direction (velocity, acceleration, force) • Predicting forces using equations • Appling Newton's 3rd Law **LOOK-FORS (What to observe students doing or producing)** • See lesson context for list of look-fors **LISTEN-FORS (Examples of what students should be saying or explaining)** • Discussing direction of vectors with peers • Discussing how interaction between objects yields particular forces on a body	**Content Background Resources:** [Khan-Circular Orbits]

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings) • Assuming larger bodies exert larger gravitational forces on smaller objects but only experience smaller reciprocating gravitational forces (not applying Newton's 3rd Law)	
Day 31 Flex/ Review			
Day 32 **Unit Exam**	**Unit Exam – TX_SCI_APPhysics_F25_UE2** **All Students must have the AP Physics 1 Equation Table (revised for 24-25) for ALL Exams!**		ap-physics-1-Equation Table - 2024.pdf
Day 33 **Success Day**	Time Permitting.		

VERTICAL STANDARDS for Texas

This section details the **progression** of key student standards in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your students** for in the subsequent course.

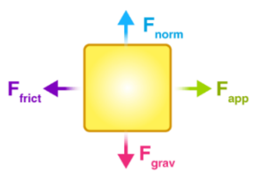
5th Grade Science	6/7 Grade Hybrid Science	8th Grade Science
5.7A investigate and explain how equal and unequal forces acting on an object cause patterns of motion and transfer of energy. 5(7)(B) design a simple experimental investigation that tests the effect of force on an object in a system such as a car on a ramp or a balloon rocket on a string.	**6(7) Force, motion, and energy. The student knows the nature of forces and their role in systems that experience stability or change. The student is expected to:** 6(7)(A) identify and explain how forces act on objects, including gravity, friction, magnetism, applied forces, and normal forces, using real-world applications. 6(7)(B) calculate the net force on an object in a horizontal or vertical direction using diagrams and determine if the forces are balanced or unbalanced; and 6(7)(C) identify simultaneous force pairs that are equal in magnitude and opposite in direction that result from the interactions between objects using Newton's Third Law of Motion. **7(7) Force, motion, and energy. The student describes the cause-and-effect relationship between force and motion. The student is expected to:** 7(7)(D) analyze the effect of balanced and unbalanced forces on the state of motion of an object using Newton's First Law of Motion. **7(9) Earth and space. The student understands the patterns of movement, organization, and characteristics of components of our solar system. The student is expected to:** 7(9)(B) describe how gravity governs motion within Earth's solar system; and	**8(7) Force, motion, and energy. The student understands the relationship between force and motion within systems. The student is expected to:** 8.7A calculate and analyze how the acceleration of an object is dependent upon the net force acting on the object and the mass of the object using Newton's Second Law of Motion. 8.7.B investigate and describe how Newton's three laws of motion act simultaneously within systems such as in vehicle restraints, sports activities, amusement park rides, Earth's tectonic activities, and rocket launches.

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary

Contact Force – any force the is the result of interaction by contact of two objects
Balanced forces – A net force of zero on an object
Unbalanced forces – A non-zero net force on an object
Force – Any push or pull on an object
Net Force – the vector sum of all the forces on an object or system (often calculated in horizontal and vertical vector components)
Mass - the quantity of matter in a physical body. It is also a measure of the body's inertia, the resistance to acceleration (change of velocity) when a net force is applied.[1] An object's mass also determines the strength of its gravitational attraction to other bodies.
Force of Gravity (weight) - the force acting on and object due to gravity.
Weight – synonym for the force of gravity, calculated using the equation $F_g = mg$
Tension (Force) – the force applied by a string or cable pulling on an object
Normal (Force) – the force of a surface that an object is touching that pushes perpendicularly to the surface (usually the ground, a table, etc. that an object is sitting on)
Applied Force – general term for a force applied by a person on an object
Friction - the force that opposes the motion between an object and a surface it is in contact with, directed parallel to the contact between object and surface and in the opposite direction of the attempted motion
Static Friction – Friction force that resists the motion of a stationary object. The force that must be overcome for an object to start moving.
Kinetic Friction - Friction force for an object that *is already moving.*
Interaction diagram – a diagram of the key objects in a scenario with lines between each pair of objects that interact with each other to create forces
Free body diagram (FBD)– diagram of a target object drawn free (without other objects from the scenario) and with all forces acting on the object draw as arrows pointing the direction the force acts and with length proportional to magnitude of the force



Vector Addition Diagram – a diagram where all the forces acting on a object are drawn to scale as vectors head-to-tail (direction and length):

- If the forces are balanced, then you should end up with nothing left over when you add them all together ($F_{NET} = 0$). That is, when you add all of the forces together, you should end up back at the same spot where you started (or a closed polygon). So with balanced forces, the vector addition diagram is a closed shape.
- If forces are unbalanced, there will be a gap in the diagram since the vectors will not add up to zero. The size of the gap represents how unbalanced the forces are. The direction of the gap represents the direction of the acceleration (same as the direction of the net force). We generally draw the net force vector as a bigger, outlined arrow to distinguish it from the forces acting on the object.

Acceleration – a vector measure of how the velocity of an object changes per unit of time (meters/second/second)
Free Fall - the movement of an object only under the influence of gravity.
Air Resistance - the force that air exerts on objects moving through it. Similar to friction caused by air molecules.

Newton's First Law – This law states that an object at rest remains at rest, and an object in motion remains in motion at a constant speed in a straight line unless acted on by a unbalanced forces (a net force).

Newton's Second Law – This law relates the net force on an object to the mass and acceleration of the object.

$$F_{NET} = ma \quad OR \quad a = \frac{F_{NET}}{m}$$

Newton's Third Law – This law of physics states "If an object A exerts a force on object B, then object B must exert a force of equal magnitude and opposite direction back on object A."

System - In physics, it is a portion of the physical universe chosen for analysis. Everything outside the system is known as the environment. The environment is ignored except for its effects on the system.

Internal Forces – forces that are the result of the interaction of objects within a system.

External Forces – forces that are the result of interaction between an object(s) outside of system (the environment) and an object(s) within the system

Ideal Pulley – a pulley that has no mass (and hence no rotational inertia) and no rotational friction

Ideal String – a string that has no mass and does no stretch

Related Vocabulary

Constant velocity Constant acceleration Slowing down Speeding up	Inertia "Law of Inertia" *Equal and Opposite Forces*			