Unit 1: Introduction to Mechanics (Physical Science, Engineering Design)

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Belleville Public Schools

Curriculum Guide

Physic A, Unit 1

Introduction to Mechanics

Belleville Board of Education

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Unit Overview

In this unit, students will be introduced to the world through the eyes of a physicist, whose principle goal is to study the underlying nature of everyday processes and to investigate the structure of the universe in terms of scientific analysis. Using the sciences of kinematics, or study of motion, and dynamics, or the study of forces, this unit requires the students to put into practice previously learned skills of hypothesis creation, experimental design, data collection and analysis in order to investigate how objects move through space. The quantities to be investigated include base units such as mass, length, and time, as well as derived units such as velocity and acceleration. The interrelation of these quantities will be discussed and problems will be solved using kinematics formulas. In addition, Newton's Laws of Motion will be used to analyze changes in motion, and Newton's Law of Universal Gravitation will be investigated.

The world is in a constant state of motion. To understand the world, students must first understand movement. Unit 1 introduces students to the study of motion and serves as a foundation for all of AP Physics 1 by beginning to explore the complex idea of acceleration and showing them how representations can be used to model and analyze scientific information as it relates to the motion of objects. By studying kinematics, students will learn to represent motion—both uniform and accelerating—in narrative, graphical, and/or mathematical forms and from different frames of reference. These representations will help students analyze the specific motion of objects and systems while also dispelling some common misconceptions they may have about motion, such as exclusively using negative acceleration to describe an object slowing down. Additionally, students will have the opportunity to go beyond their traditional understanding of mathematics. Instead of solving equations, students will use them to support their reasoning and tighten their grasp on the laws of physics. Lastly, students will begin making predictions about motion and justifying claims with evidence by exploring the relationships between the physical quantities of acceleration, velocity, position, and time. This is an important starting point for students, as these fundamental science practices will spiral throughout the course and appear in multiple units.

In this unit, students are introduced to the term force, which is the interaction of an object with another object. Part of the larger study of dynamics, forces are used as the lens through which students analyze and come to understand a variety of physical phenomena. Translation, however, is key in this unit: Students must be able to portray the same object–force interactions through different graphs, diagrams, and mathematical relationships. Students will continue to make meaning from models and representations that will help them further analyze systems, the interactions between systems, and how these interactions result in change. Alongside mastering the use of specific force equations, this unit also encourages students to derive new expressions from fundamental principles to help them make predictions in unfamiliar, applied contexts. The skill of making predictions will be nurtured throughout the course to help students craft sound scientific arguments.

Enduring Understanding

An observer in a reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
Displacement, velocity, and acceleration are all vector quantities.
Displacement is change in position.
Velocity is the rate of change of position with time.
Acceleration is the rate of change of velocity with time.
Changes in each property are expressed by subtracting initial values from final values.
A choice of reference frame determines the direction and the magnitude of each of these quantities.
There are three fundamental interactions or forces in nature: the gravitational force, the electroweak force, and the strong force.
The fundamental forces determine both the structure of objects and the motion of objects.
In inertial reference frames, forces are detected by their influence on the motion (specifically the velocity) of an object. So force, like velocity, is a vector quantity.
A force vector has magnitude and direction.
When multiple forces are exerted on an object, the vector sum of these forces, referred to as the net force, causes a change in the motion of the object.
The acceleration of the object is proportional to the net force.
The kinematic equations only apply to constant acceleration situations.
The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.
The variables x, v, and a all refer to the center-of-mass quantities.
The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change

of position with time.
The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
Force and acceleration are both vectors, with acceleration in the same direction as the net force.
The acceleration of the center of mass of a system is equal to the rate of change of the center of mass velocity with time, and the center of mass velocity is equal to the rate of change of position of the center of mass with time.
The variables x, v, and a all refer to the center-of-mass quantities.
Vector quantities have magnitude (how large the vector quantity is) and direction, while scalar quantities have magnitude only.
All motion must be compared to a frame of reference.
Many quantities in physics are rates of change of other quantities.
Vectors are specified by magnitude and direction while scalars are magnitude only.
Velocity is a change of position during a period of time.
Acceleration is the rate at which velocity changes.
In the absence of air resistance, all bodies fall with the same acceleration.
The slope of a distance vs. time graph is velocity.
The slope of a velocity vs. time graph is acceleration.
Area under the curve: of a v-t graph is the displacement; of an a-t graph is the velocity.
Projectile motion has vertical and horizontal components and is motion under the influence of gravity.

A gravitational field g at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.

On Earth, this gravitational force is called weight.
The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force.
If the gravitational force is the only force exerted on the object, the observed freefall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in Newtons/kilogram) at that location.
Contact forces result from the interaction of one object touching another object, and they arise from interatomic electric forces. These forces include tension, friction, normal, spring , and buoyant.
Inertial mass is the property of an object or system that determines how its motion changes when it interacts with other objects or systems.
Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
Forces are described by vectors.
Forces are detected by their influence on the motion of an object.
Forces have magnitude and direction.
A force exerted on an object is always due to the interaction of that object with another object.
An object cannot exert a force on itself.
Even though an object is at rest, there may be forces exerted on that object by other objects.
The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.
If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.
If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.
Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
An object can be drawn as if it were extracted from its environment and the interactions with the environment were identified.

A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation.
Free-body or force diagrams may be depicted in one of two ways—one in which the forces exerted on an object are represented as arrows pointing outward from a dot, and the other in which the forces are specifically drawn at the point on the object at which each force is exerted.
The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass. The variables x, v, and a all refer to the center-of-mass quantities.
The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
Force and acceleration are both vectors, with acceleration in the same direction as the net force.
The acceleration of the center of mass of a system is equal to the rate of change of the center of mass velocity with time, and the center of mass velocity is equal to the rate of change of position of the center of mass with time.
The variables x, v, and a all refer to the center-of-mass quantities.
Forces that the systems exert on each other are due to interactions between objects in the systems. If the interacting objects are parts of the same system, there will be no change in the center-of-mass velocity of that system.
An unbalanced force must be present to cause any change in an object's state of motion or rest.
Inertia is the property of matter that resists change in motion.
Gravitational force between two masses strengthens as the masses become more massive and rapidly weakens as the distance between them increases.
When one object exerts an action force on a second object, the second object exerts a reaction force on the first object. Forces always occur in action-reaction pairs.

Essential Questions

How are multiple representations used to describe an object's motion?
How do scalar measurements differ from vector measurements?
How are kinematic equations and graphs used to describe an object's motion in free-fall?
Why is it important to use vector quantities and not just scalar quantities to describe the motion of an object?
How does the resultant of two vectors change as the angle between the two changes?
How does the shape of graphs representing the relationship between displacement, velocity, or acceleration vs. time offer information about the motion of an object?
How is the motion of an object affected by the acceleration of gravity?
How can velocity be negative?
How can acceleration be negative?
Why is the initial acceleration of a sprint runner important in determining who will win the race?
How does the direction of the acceleration affect the direction of motion?
How is the distance a baseball travels before hitting the ground affected by the throwing conditions?
How does the description of motion of an object change depending of the reference frame used to describe it?
How can you prove that all objects fall at the same rate?
Why does a projectile make a parabolic path?

Explain how something can have no forces acting on it, yet still be moving.

If two cars of different masses had the same exact engine, which one would you want to buy and why?
If they both feel an equal and opposite force, why is a car not affected as much as a fly when they collide?
How does the presence of a net force determine the acceleration of an object?
What is the nature of friction and how does it factor into an object's acceleration?
How can an Atwood's machine be used to calculate the acceleration of gravity?
What is Newton's 1st Law and how does it explain static equilibrium?
How is knowledge of the net force essential to understanding an object's constant velocity?

Exit Skills

Unit Essential Questions:

How does the Scientific Method apply to physics?
How does Mathematics play a role in physics
What are the various forms of motion?
How do physicists describe and quantify motion?
How does one describe motion of an object in two dimensions?
What is the difference between weight and mass?

New Jersey Student Learning Standards (NJSLS-S)

NextGen Science Standards

SCI.9-12.HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
SCI.9-12.HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
SCI.9-12.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
SCI.9-12.HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
SCI.9-12.HS-PS2-2	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
SCI.9-12.HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
SCI.9-12.HS-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
SCI.9-12.HS-PS2-3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
SCI.9-12.HS-PS2-5	Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.
WRK.9.1.2.CAP.1	Make a list of different types of jobs and describe the skills associated with each job.
9-12.HS-PS2-4.1.1	students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
9-12.HS-PS2-1.2.1	students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.
9-12.HS-PS2-3.2.1	Systems can be designed to cause a desired effect.
9-12.HS-PS2-5.2.1	students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.
9-12.HS-PS2-5.3.1	Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
9-12.HS-PS2-1.4.1	Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
9-12.HS-PS2-2.4.1	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined.

9-12.HS-PS2-2.5.1	Use mathematical representations of phenomena to describe explanations.
9-12.HS-PS2-4.5.1	Use mathematical representations of phenomena to describe explanations.
9-12.HS-PS2-3.6.1	Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects.
9-12.HS-PS2-2.PS2.A.1	Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.
9-12.HS-PS2-3.PS2.A.1	If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
9-12.HS-PS2-1.PS2.A.1	Newton's second law accurately predicts changes in the motion of macroscopic objects.
9-12.HS-PS2-2.PS2.A.2	If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system.
9-12.HS-PS2-4.PS2.B.1	Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
9-12.HS-PS2-3.PS2.B.1	Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.
9-12.HS-PS2-1.PS2.B.1	Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects.
9-12.HS-PS2-5.PS2.B.1	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
9-12.HS-PS2-4.PS2.B.2	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
9-12.HS-PS2-5.PS3.A.1	"Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents.
9-12.HS-PS2-3.ETS1.A.1	Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them.
9-12.HS-PS2-3.ETS1.C.1	Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.
TECH.9.4.2.CI.1	Demonstrate openness to new ideas and perspectives (e.g., 1.1.2.CR1a, 2.1.2.EH.1, 6.1.2.CivicsCM.2).
TECH.9.4.2.CI.2	Demonstrate originality and inventiveness in work (e.g., 1.3A.2CR1a).
TECH.9.4.2.CT.1	Gather information about an issue, such as climate change, and collaboratively brainstorm ways to solve the problem (e.g., K-2-ETS1-1, 6.3.2.GeoGI.2).
TECH.9.4.2.CT.2	Identify possible approaches and resources to execute a plan (e.g., 1.2.2.CR1b, 8.2.2.ED.3).
TECH.9.4.2.CT.3	Use a variety of types of thinking to solve problems (e.g., inductive, deductive).
TECH.9.4.2.DC.7	Describe actions peers can take to positively impact climate change (e.g., 6.3.2.CivicsPD.1).
TECH.9.4.2.IML.3	Use a variety of sources including multimedia sources to find information about topics such as climate change, with guidance and support from adults (e.g., 6.3.2.GeoGI.2, 6.1.2.HistorySE.3, W.2.6, 1-LSI-2).
	Examples of data could include tables or graphs of position or velocity as a function of

time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.

Interdisciplinary Connections

Upon completion of this section, please remove all remaining descriptions, notes, outlines, examples and/or illustrations that are not needed or used.

Please list all and any additional **Interdisciplinary Connections/Cross-Curricular** New Jersey Student Learning Standards that link to this unit, and which are not included in the NJSLS section above.

LA.RH.11-12.4	Determine the meaning of words and phrases as they are used in a text, including analyzing how an author uses and refines the meaning of a key term over the course of a text (e.g., how Madison defines faction in Federalist No. 10).
LA.RH.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, qualitatively, as well as in words) in order to address a question or solve a problem.
LA.RH.11-12.9	Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.
LA.RH.11-12.10	By the end of grade 12, read and comprehend history/social studies texts in the grades 11-CCR text complexity band independently and proficiently.
LA.WHST.11-12.2.A	Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
LA.WHST.11-12.2.B	Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
LA.WHST.11-12.2.D	Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
LA.WHST.11-12.2.E	Provide a concluding paragraph or section that supports the argument presented.
LA.WHST.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
LA.WHST.11-12.6	Use technology, including the Internet, to produce, share, and update writing products in response to ongoing feedback, including new arguments or information.
LA.WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation.

Learning Objectives

The student will be able to..

Express the motion of an object using narrative, mathematical, and graphical representations.
Design an experimental investigation of the motion of an object
Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations.
Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.
Make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.
Create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.
Develop a particle model to represent a moving object.
Define coordinate systems for motion problems.
Recognize that the chosen coordinate system affects the signs of the objects' positions.
Define Displacement.
Determine a time interval.
Develop position-time graphs for moving objects.
Use a position-time graph to interpret an object's position or displacement.
Define velocity.
Differentiate between speed and velocity.
Create pictorial, physical, and mathematical models of motion problems.
Recognize that the chosen coordinate system affects the signs of the objects' positions.
Create pictorial, physical, and mathematical models of motion problems.
Draw motion diagrams to describe motion.
Develop a particle model to represent a moving object.
Define coordinate systems for motion problems.
Define Displacement.
Determine a time interval.
Use a motion diagram to answer questions about an object's position or displacement.
Develop position-time graphs for moving objects.
Use a position-time graph to interpret an object's position or displacement.
Make motion diagrams, pictorial representations, and position time graphs that are equivalent representations describing an object's motion.
Define velocity.
Create pictorial, physical, and mathematical models of motion problems. (NPS) Define acceleration.
Relate velocity and acceleration to the motion of objects.
Create velocity-time graphs.
Determine mathematical relationships among position, velocity, acceleration, and time.
Define acceleration due to gravity.
Solve problems involving objects in free fall.
Model verbally or visually the properties of a system based on its substructure and relate this to changes in the system properties over time as external variables are changed.
Apply $F = mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.
Make claims about various contact forces between objects based on the microscopic cause of these forces.
Explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions.
Design an experiment for collecting data to determine the relationship between the net force exerted on an

object, its inertial mass, and its acceleration.
Design a plan for collecting data to measure gravitational mass and inertial mass and to distinguish between the two experiments.
Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
Analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.
Challenge a claim that an object can exert a force on itself.
Describe a force as an interaction between two objects, and identify both objects for any force.
Construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of actionreaction pairs of forces.
Use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.
Analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.
Predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations, with acceleration in one dimension.
Design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurement, and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces.
Re-express a free-body diagram into a mathematical representation, and solve the mathematical representation for the acceleration of the object.
Create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.
Evaluate, using given data, whether all the forces on a system or all the parts of a system have been identified.
Apply Newton's second law to systems to calculate the change in the center-of-mass velocity when an external force is exerted on the system.
Use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system.
Define force.
Use Newton's second law to solve problems.
Explain the meaning of Newton's first law.
Describe how the weight and the mass of an object are related.
Differentiate between actual weight and apparent weight.
Define Newton's third law.
Explain the tension in ropes and strings in terms of Newton's third law.
Define the Normal Force.
Determine the value of the normal force by applying Newton's second law.
Interpret position-time graphs for motion with constant acceleration.
Apply graphical and mathematical relationships to solve constant –acceleration problems.
Differentiate between actual weight and apparent weight.
Determine the value of the normal force by applying Newton's second law.
Evaluate the sum of two or more vectors in two dimensions, graphically.
Determine the components of vectors.
Solve for the sum of two or more vectors, algebraically, by adding the components of the vectors.
Define Friction Force.
Distinguish between static and kinetic friction.
Relate the height, time in the air, and initial vertical velocity of a projectile using its vertical motion.
Explain how the trajectory of the projectile depends upon the frame of reference from which it observed.
Determine the force that produces equilibrium when two to three forces act on an object.

Analyze the motion of an object on an inclined plane with and without friction.
Recognize that the vertical and horizontal motions of a projectile are independent.
Relate the height, time in the air, and initial vertical velocity of a projectile using its vertical motion, and then determine the range using the horizontal motion.
Explain how the trajectory of the projectile depends upon the frame of reference from which it observed.
Solve relative velocity problems.

Develop a particle model to represent a moving object.
Define coordinate systems for motion problems.
Recognize that the chosen coordinate system affects the signs of the objects' positions.
Define Displacement.
Determine a time interval.
Develop position-time graphs for moving objects.
Use a position-time graph to interpret an object's position or displacement.
Define velocity.
Differentiate between speed and velocity.
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Relate velocity and acceleration to the motion of objects.
Create velocity-time graphs.
Determine mathematical relationships among position, velocity, acceleration, and time.
Define acceleration due to gravity.
Solve problems involving objects in free fall.
Define force.
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Differentiate between actual weight and apparent weight.
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Evaluate the sum of two or more vectors in two dimensions, graphically.
Determine the components of vectors.

Solve for the sum of two or more vectors, algebraically, by adding the components of the vectors.
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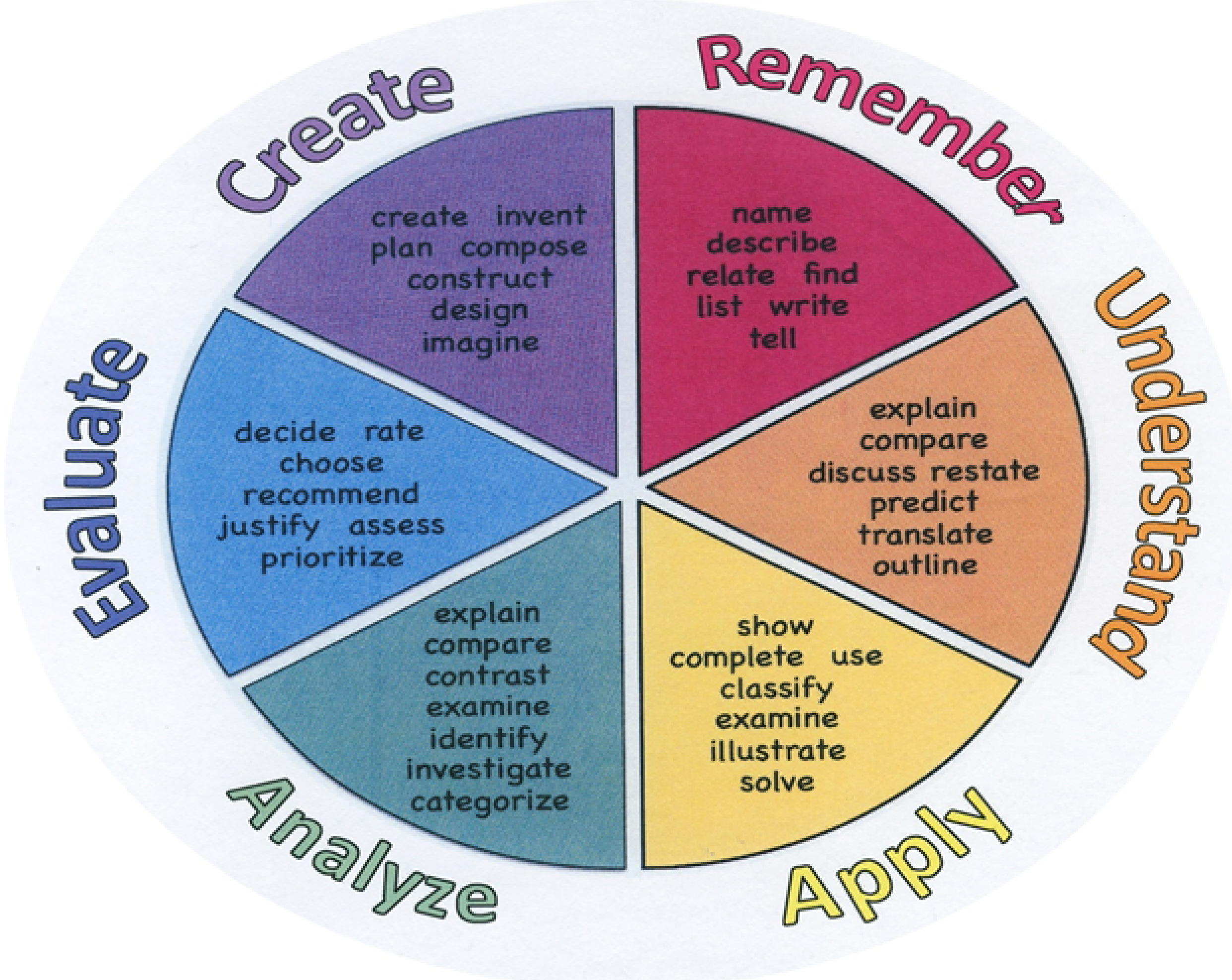
Explain how the trajectory of the projectile depends upon the frame of reference from which it observed.
Determine the force that produces equilibrium when two to three forces act on an object.
Analyze the motion of an object on an inclined plane with and without friction.
Recognize that the vertical and horizontal motions of a projectile are independent.
Relate the height, time in the air, and initial vertical velocity of a projectile using its vertical motion, and then determine the range using the horizontal motion.
Explain how the trajectory of the projectile depends upon the frame of reference from which it observed.
Solve relative velocity problems.
Explain why an object moving in a circle at a constant speed is accelerated.
Describe how centripetal acceleration depends up on the object's speed and the radius of the circle.
Identify the force that causes centripetal acceleration.
Describe angular displacement.
Describe torque and the factors that determine it.
Calculate net torque.
Define center of mass.
Use Newton's law of universal gravitation to solve problems.
Solve orbital motion problems.
Relate weightlessness to objects in free fall.
Describe gravitational fields.
Relate Kepler's laws to the law of universal gravitation.
Calculate orbital speeds and periods.

Action Verbs: Below are examples of action verbs associated with each level of the Revised Bloom's Taxonomy.

Remember	Understand	Apply	Analyze	Evaluate	Create
Choose	Classify	Choose	Categorize	Appraise	Combine
Describe	Defend	Dramatize	Classify	Judge	Compose
Define	Demonstrate	Explain	Compare	Criticize	Construct
Label	Distinguish	Generalize	Differentiate	Defend	Design
List	Explain	Judge	Distinguish	Compare	Develop
Locate	Express	Organize	Identify	Assess	Formulate
Match	Extend	Paint	Infer	Conclude	Hypothesize
Memorize	Give Examples	Prepare	Point out	Contrast	Invent
Name	Illustrate	Produce	Select	Critique	Make
Omit	Indicate	Select	Subdivide	Determine	Originate
Recite	Interrelate	Show	Survey	Grade	Organize
Select	Interpret	Sketch	Arrange	Justify	Plan
State	Infer	Solve	Breakdown	Measure	Produce
Count	Match	Use	Combine	Rank	Role Play
Draw	Paraphrase	Add	Detect	Rate	Drive
Outline	Represent	Calculate	Diagram	Support	Devise
Point	Restate	Change	Discriminate	Test	Generate
Quote	Rewrite	Classify	Illustrate		Integrate
Recall	Select	Complete	Outline		Prescribe
Recognize	Show	Compute	Point out		Propose
Repeat	Summarize	Discover	Separate		Reconstruct
Reproduce	Tell	Divide			Revise
	Translate	Examine			Rewrite
	Associate	Graph			Transform

	Compute Convert Discuss Estimate Extrapolate Generalize Predict	Interpolate Manipulate Modify Operate Subtract			



Suggested Activities & Best Practices

Desktop Experiment Task: Have students find the acceleration of a yo-yo as it falls and unwinds using only a meterstick and stopwatch. Students then draw (with correct shapes and scales) distance, speed, and acceleration versus time graphs.
Identify Subtasks: Each group is given a spring-loaded ball launcher and a meterstick. Students launch the ball horizontally from a known height and then predict where it will land on the floor when fired at a given angle from the floor. Have students articulate subtasks and then perform each one.
Changing Representations: Show a curvy x versus t graph, a v versus t graph made of connected straight-line

segments, or an a versus t graph made of horizontal steps. Have students sketch the other two graphs and either walk them out along a line or move a cart on a track to demonstrate the motion (the track can be tilted slightly to provide constant acceleration in either direction).
Changing Representations: Students throw/project a ball from the second or third story to the ground and measure the ball's initial height, horizontal distance, and time in the air. From this, students calculate initial velocity components and draw (with scales) horizontal/vertical position/velocity/ acceleration versus time graphs.
Desktop Experiment Task: Give each group a pull-back toy car. Students lay out strips of paper 0.5 m apart and take a phone video of the car as it is released, speeds up, and slows down. Using a frame-byframe review app to get the time each strip is passed to get x versus t data, have students make v versus t data tables out of this, and graph both.

What situations in ordinary life could help to master this unit?

Measure horizontal velocity

Measure horizontal acceleration

Analyze Free Fall

Analyze Projectile motion

Build the highest tower with limited materials

Marshmallow challenge

Changing Representations; Have students consider an accelerating two-object system from everyday life (e.g., person pushes a shopping cart, car pulls a trailer). Have them draw the forces on one object, then on the other, and then the external forces acting on the two-object system.

Desktop Experiment Task; Have students measure the coefficient of static friction of their shoe on a wood plank or metal track. Level 1: Use a spring scale. Level 2: Use a pulley, a spring, a toy bucket, and an electronic balance. Level 3: Use a protractor.

Desktop Experiment Task; Give students a yo-yo, a low mass, low friction pulley, 50 paper clips, and a scale. Have them find the acceleration of the falling, unrolling yo-yo and then determine the mass of the paper clips to attach to the free end of the string so that the paper clips stay at rest even as the yo-yo falls and the string passes over the pulley.

Working Backward; Student A writes a Newton's second law equation either with symbols or plugged-in numbers including units. Student B must then describe a situation that the equation applies to, including the object's velocity direction and how velocity is changing, a diagram, and a free-body diagram.

Troubleshooting; Students take some force-related problem from the homework or textbook (one that requires setting up Newton’s second law and maybe more). Students write out a detailed solution that has exactly one mistake in it (not a calculation error). Post everyone’s problems/ solutions, and then ask students to identify everyone else’s errors. The last student to have his or her error found wins.

Students must be able to balance forces using force table.

Students must be able to measure coefficient of static friction.

Students must be able to measure coefficient of kinetic friction.

Calculate rate of change global temperature between 1980-2020, and assuming the same rate will continue, predict average global temperature in 2050

Assessment Evidence - Checking for Understanding (CFU)

Student must be able to graph fundamental quantities, acceleration, velocity, distance against time. (Formative)

Students must be able to read map and calculate velocity and speed of a moving object. (Formative)

Students must be able to convert polar quantities into cartesian quantities. (Formative)

Student must be able to graph fundamental quantities forces on Cartesian coordinate plane. (Formative)

Students must be able to read map and calculate tension in the rope between two moving object. (Formative)

Students must be able to calculate the net force after drawing a free body diagram. (Formative)

Common, Department Quarterly Benchmarks (Benchmark)

Oncourse Assessment Tools (Formative)

Unit Test/Quiz (Summative)

"Do Now/Exit Ticket" Activity (Formative)

- Admit Tickets
- Anticipation Guide
- Common Benchmarks
- Compare & Contrast
- Create a Multimedia Poster
- DBQ's
- Define
- Describe
- Evaluate
- Evaluation rubrics
- Exit Tickets
- Explaining
- Fist- to-Five or Thumb-Ometer
- Illustration
- Journals
- KWL Chart
- Learning Center Activities
- Multimedia Reports
- Newspaper Headline
- Outline
- Question Stems
- Quickwrite
- Quizzes
- Red Light, Green Light
- Self- assessments
- Socratic Seminar
- Study Guide
- Surveys
- Teacher Observation Checklist
- Think, Pair, Share
- Think, Write, Pair, Share
- Top 10 List
- Unit review/Test prep
- Unit tests
- Web-Based Assessments
- Written Reports

Primary Resources & Materials

Textbook: Conceptual Physics, Hewitt

Internet

Please list all district-provided Primary Resources & Materials and/or those outside that are accessed with district resources.

Ancillary Resources

Teacher Prepared Materials
Lab Materials
Study Guide Materials
United Streaming Videos
https://phet.colorado.edu/
STEM Lab

Please list all additional resources that will be used to strengthen this unit's lessons.

Technology Infusion

Students must be able to use the photogates to measure the speed of a falling object.

Students must be able to use projectile launcher to measure the range of a projectile.

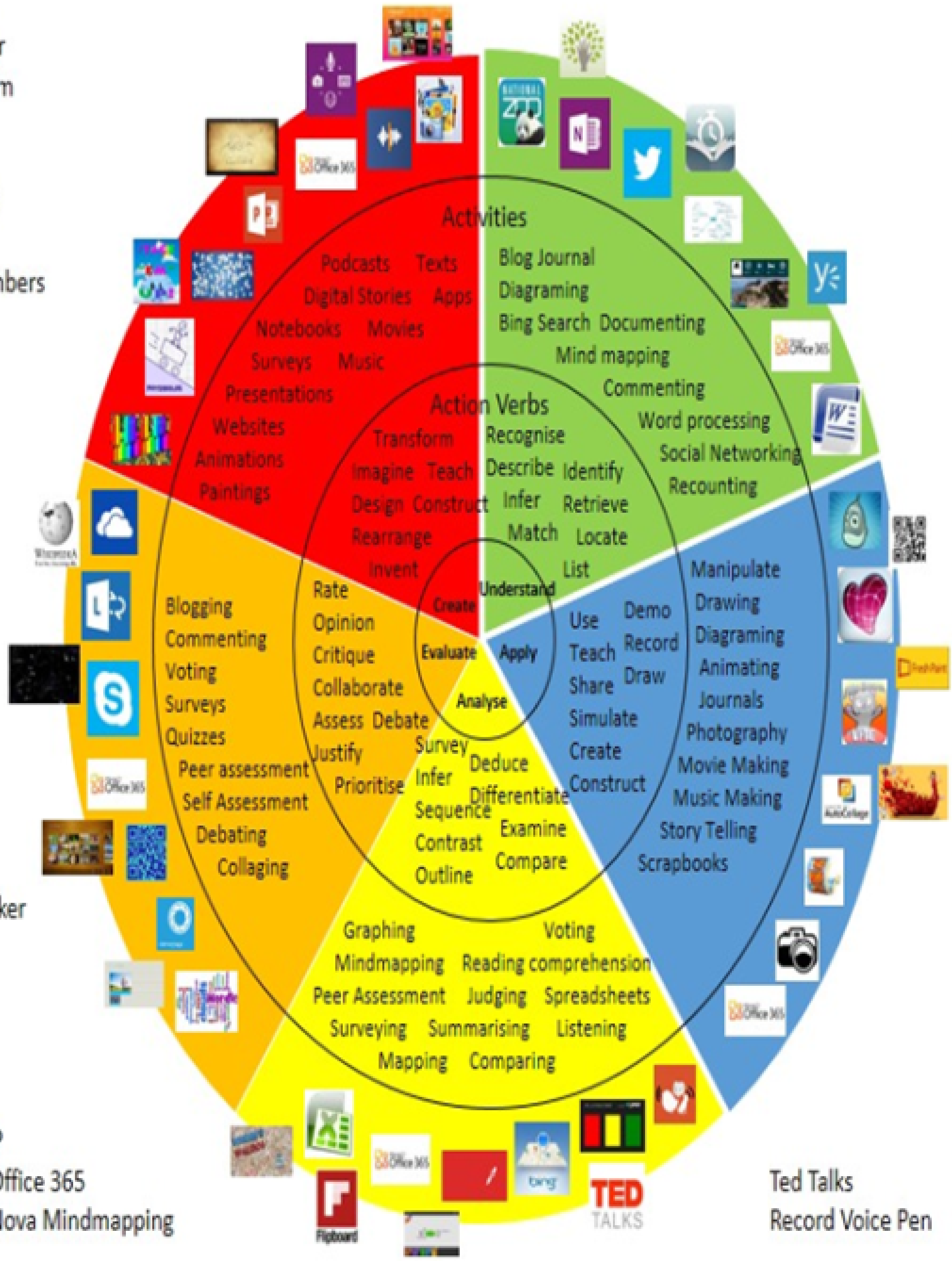
Students must be able to use virtual labs to solve kinematics problems.

What **Technology Infusion** and/or strategies are integrated into this unit to enhance learning? Please list all hardware, software and strategies. Please find a technology pedagogy wheel for assistance while completing this section.

Win 8.1 Apps/Tools Pedagogy Wheel

Podcasts
Photostory 3
Kid Story Builder
Music Maker Jam
Paint A Story
Office 365
MS PowerPoint
Stack 'Em Up
NqSquared Numbers
Physamajig
Xylophone 8

Wikipedia
Skydrive
Lync
SkyMap
Skype
Office 365
Puzzle Touch
Easy QR
Memorylage
Life Moments
Word Cloud Maker



Where's Waldo?
MS Excel
Flipboard
Office 365
Nova Mindmapping

Ted Talks
Record Voice Pen

Originally taken from http://www.coetail.com/vzimmer/files/2013/02/iPadagogy-Wheel.001.jpg
And adapted for Windows 8.1 devices by Charlotte Beckhurst @CharBeckhurst

Alignment to 21st Century Skills & Technology

Upon completion of this section, please remove all remaining descriptions, notes, outlines, examples and/or illustrations that are not needed or used.

Mastery and infusion of **21st Century Skills & Technology** and their Alignment to the core content areas is essential to student learning. The core content areas include:

- English Language Arts;
- Mathematics;
- Science and Scientific Inquiry (Next Generation);
- Social Studies, including American History, World History, Geography, Government and Civics, and Economics;
- World languages;
- Technology;
- Visual and Performing Arts.

CRP.K-12.CRP2.1	Career-ready individuals readily access and use the knowledge and skills acquired through experience and education to be more productive. They make connections between abstract concepts with real-world applications, and they make correct insights about when it is appropriate to apply the use of an academic skill in a workplace situation.
CRP.K-12.CRP5	Consider the environmental, social and economic impacts of decisions.
CAEP.9.2.12.C.3	Identify transferable career skills and design alternate career plans.
CAEP.9.2.12.C.6	Investigate entrepreneurship opportunities as options for career planning and identify the knowledge, skills, abilities, and resources required for owning and managing a business.
TECH.8.1.12.A	Technology Operations and Concepts: Students demonstrate a sound understanding of technology concepts, systems and operations.
TECH.8.1.12.A.3	Collaborate in online courses, learning communities, social networks or virtual worlds to discuss a resolution to a problem or issue.
TECH.8.1.12.A.CS1	Understand and use technology systems.
TECH.8.1.12.A.CS2	Select and use applications effectively and productively.

21st Century Skills/Interdisciplinary Themes

Upon completion of this section, please remove all remaining descriptions, notes, outlines, examples and/or illustrations that are not needed or used.

Please list only the **21st Century/Interdisciplinary Themes** that will be incorporated into this unit.

- Communication and Collaboration

- Creativity and Innovation
- Critical thinking and Problem Solving
- ICT (Information, Communications and Technology) Literacy
- Information Literacy
- Life and Career Skills
- Media Literacy

21st Century Skills

Upon completion of this section, please remove all remaining descriptions, notes, outlines, examples and/or illustrations that are not needed or used.

Please list only the **21st Century Skills** that will be incorporated into this unit.

- Civic Literacy
- Environmental Literacy
- Financial, Economic, Business and Entrepreneurial Literacy
- Global Awareness
- Health Literacy

Differentiation

Please remember: Effective educational **Differentiation** in a lesson lies within content, process, and/or product.

Please identify the ones that will be employed in this unit.

Differentiations:

- Small group instruction
- Small group assignments
- Extra time to complete assignments
- Pairing oral instruction with visuals
- Repeat directions
- Use manipulatives
- Center-based instruction
- Token economy
- Study guides

- Teacher reads assessments allowed
- Scheduled breaks
- Rephrase written directions
- Multisensory approaches
- Additional time
- Preview vocabulary
- Preview content & concepts
- Story guides
- Behavior management plan
- Highlight text
- Student(s) work with assigned partner
- Visual presentation
- Assistive technology
- Auditory presentations
- Large print edition
- Dictation to scribe
- Small group setting

Hi-Prep Differentiations:

- Alternative formative and summative assessments
- Choice boards
- Games and tournaments
- Group investigations
- Guided Reading
- Independent research and projects
- Interest groups
- Learning contracts
- Leveled rubrics
- Literature circles
- Multiple intelligence options
- Multiple texts
- Personal agendas
- Project-based learning
- Problem-based learning
- Stations/centers
- Think-Tac-Toes
- Tiered activities/assignments
- Tiered products
- Varying organizers for instructions

Lo-Prep Differentiations

- Choice of books or activities
- Cubing activities
- Exploration by interest
- Flexible grouping
- Goal setting with students
- Jigsaw
- Mini workshops to re-teach or extend skills
- Open-ended activities
- Think-Pair-Share
- Reading buddies

- Varied journal prompts
- Varied supplemental materials

Special Education Learning (IEP's & 504's)

Please identify the **Special Education Learning** adaptations that will be employed in the unit, using the ones identified below.

- Students must be able to balances forces using inclined plane.

- printed copy of board work/notes provided
- additional time for skill mastery
- assistive technology
- behavior management plan
- Center-Based Instruction
- check work frequently for understanding
- computer or electronic device utilizes
- extended time on tests/ quizzes
- have student repeat directions to check for understanding
- highlighted text visual presentation
- modified assignment format
- modified test content
- modified test format
- modified test length
- multi-sensory presentation
- multiple test sessions
- preferential seating
- preview of content, concepts, and vocabulary
- Provide modifications as dictated in the student's IEP/504 plan
- reduced/shortened reading assignments
- Reduced/shortened written assignments
- secure attention before giving instruction/directions
- shortened assignments
- student working with an assigned partner
- teacher initiated weekly assignment sheet
- Use open book, study guides, test prototypes

English Language Learning (ELL)

Please identify the **English Language Learning** adaptations that will be employed in the unit, using the ones identified below.

- Students are provided with glossary in their native language.

- Spanish speaking students may utilize Spanish Edition of a Textbook

- teaching key aspects of a topic. Eliminate nonessential information
- using videos, illustrations, pictures, and drawings to explain or clarif
- allowing products (projects, timelines, demonstrations, models, drawings, dioramas, poster boards, charts, graphs, slide shows, videos, etc.) to demonstrate student's learning;
- allowing students to correct errors (looking for understanding)
- allowing the use of note cards or open-book during testing
- decreasing the amount of workpresented or required
- having peers take notes or providing a copy of the teacher's notes
- modifying tests to reflect selected objectives
- providing study guides
- reducing or omitting lengthy outside reading assignments
- reducing the number of answer choices on a multiple choice test
- tutoring by peers
- using computer word processing spell check and grammar check features
- using true/false, matching, or fill in the blank tests in lieu of essay tests

At Risk

Please identify Intervention Strategies that will be employed in the unit, using the ones identified below.

- Student provided access to virtual labs, presentations, videos, and practice questions.

- allowing students to correct errors (looking for understanding)
- teaching key aspects of a topic. Eliminate nonessential information
- allowing products (projects, timelines, demonstrations, models, drawings, dioramas, poster boards, charts, graphs, slide shows, videos, etc.) to demonstrate student's learning
- allowing students to select from given choices
- allowing the use of note cards or open-book during testing
- collaborating (general education teacher and specialist) to modify vocabulary, omit or modify items to reflect objectives for the student, eliminate sections of the test, and determine how the grade will be determined prior to giving the test.
- decreasing the amount of workpresented or required

- having peers take notes or providing a copy of the teacher's notes
- marking students' correct and acceptable work, not the mistakes
- modifying tests to reflect selected objectives
- providing study guides
- reducing or omitting lengthy outside reading assignments
- reducing the number of answer choices on a multiple choice test
- tutoring by peers
- using authentic assessments with real-life problem-solving
- using true/false, matching, or fill in the blank tests in lieu of essay tests
- using videos, illustrations, pictures, and drawings to explain or clarify

Talented and Gifted Learning (T&G)

Please identify the **Talented and Gifted** adaptations that will be employed in the unit, using the ones identified below.

- Students must be able to solve algebra based problems.

- Above grade level placement option for qualified students
- Advanced problem-solving
- Allow students to work at a faster pace
- Cluster grouping
- Complete activities aligned with above grade level text using Benchmark results
- Create a blog or social media page about their unit
- Create a plan to solve an issue presented in the class or in a text
- Debate issues with research to support arguments
- Flexible skill grouping within a class or across grade level for rigor
- Higher order, critical & creative thinking skills, and discovery
- Multi-disciplinary unit and/or project
- Teacher-selected instructional strategies that are focused to provide challenge, engagement, and growth opportunities
- Utilize exploratory connections to higher-grade concepts
- Utilize project-based learning for greater depth of knowledge

Sample Lesson

Unit Name: Introduction to Mechanics

NJSLS: HS-PS2-1, HS-PS2-2, HS-PS2-3, LA.RH.11-12.4, LA.RH.11-12.7, LA.RH.11-12.9, LA.RH.11-

12.10,

Interdisciplinary Connection: Vocabulary and algebra contents

Statement of Objective: The students will demonstrate the ability to apply the four kinematic equations for falling objects by solving problems with 90% accuracy.

Anticipatory Set/Do Now: from m/s to mil/h

Learning Activity:

Lecture – the four kinematic equations using a and g
Classroom activity: to apply the four kinematic equations to everyday life situations.

Student Assessment/CFU's: Surveying, written report, and exit ticket

Materials: Photogates, stands, clumps, light and heavy objects

21st Century Themes and Skills: Critical thibking and problem solving

Differentiation/Modifications:

Students must be able to solve algebra based problems. (Gifted and Talented)

Students must be able to set the apparatus to perform the lab. (Special Ed)

Integration of Technology:

Using photogates, and chromebook for exit ticket