# Kenilworth Public Schools Curriculum Guide

Content Area: AP Physics Grade: 12 BOE Approved: 4/6/20

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# Advanced Placement Physics Grade 12 Scope and Sequence

Unit 1- Kinematics	Unit 2- Dynamics	Unit 3- Circular Motion and Gravity	Unit 4- Energy	Unit 5- Momentum
Weeks 1-4	Weeks 5-9	Weeks 10-11	Weeks 12-16	Weeks 17-20
Unit Description: 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	Unit Description: In Unit 2, 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. This is accomplished by revisiting and building upon the representations presented in Unit 1, specifically the introduction to the free- body diagram. Translation, however, is key in this unit: Students must be able to portray the same	Unit Description: In Unit 3, students will continue to enhance their understanding of the physical world using models and representations to create a more complete and complex model of motion, particularly as it relates to gravitational mass and inertial mass. Again, translation and connections are essential—students must be able to use content and science practices from the previous two units and apply them in	Unit Description: In Unit 4, students will be introduced to the idea of conservation as a foundational model of physics, along with the concept of work as the agent of change for energy. As in earlier units, students will once again utilize both familiar and new models and representations to analyze physical situations, now with force or energy as major components. Students will be encouraged to call upon their knowledge of Units 1–4 to determine the most appropriate technique and will be challenged	Unit Description: Unit 5 introduces students to the relationship between force, time, and momentum via calculations, data analysis, designing experiments, and making predictions. Students will learn how to use new models and representations to illustrate the law of the conservation of momentum of objects and systems while simultaneously building on their knowledge of previously studied representations.

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narrative, graphical,	object-force	different ways.	to understand the	Using the law of the
and/or mathematical	interactions through	While it's essential	limiting factors of each.	conservation of
forms and from	different graphs,	that students are able	Describing, creating,	momentum to analyze
different frames of	diagrams, and	to calculate numerical	and using these	physical situations
reference. These	mathematical	answers to questions,	representations will also	gives students a more
representations will	relationships. Students	it is more important	help students grapple	complete picture of
help students analyze	will continue to make	that they can combine	with common	forces and leads them
the specific motion of	meaning from models	mathematical	misconceptions that	to revisit their
objects and systems	and representations that	representations to	they may have about	
while also dispelling	will help them further	-	energy, such as whether	misconceptions
some common	analyze systems, the	make new	or not a single object	surrounding
misconceptions they	interactions between	representations that	can "have" potential	Newton's third law.
may have about motion,	systems, and how these	more accurately	energy. A thorough	Students will also
such as exclusively	interactions result in	describe natural	understanding of these	have the opportunity
using negative	change.	phenomena. For	energy models will	to make connections
acceleration to describe	Alongside mastering	example, students	support students' ability	between the
an object slowing	the use of specific force	should be	to make predications—	conserved quantities
down. Additionally,	equations, Unit 2 also	comfortable	and ultimately justify	of momentum and
students will have the	encourages students to	combining equations	claims with evidence—	energy to determine
opportunity to go	derive new expressions	for uniform circular	about physical	under what conditions
beyond their traditional	from fundamental	motion with	situations. This is	each quantity is
understanding of	principles to help them		crucial, as the	conserved. It's
mathematics. Instead of	make predictions in	gravitational	mathematical models	
solving equations,	unfamiliar, applied	equations to describe	and representations	essential that students
students will use them	contexts. The skill of	the circular path of a	used in Unit 4 will	are not only
to support their	making predictions will	satellite circling a	mature throughout the	comfortable solving
reasoning and tighten	be nurtured throughout	planet.	course and appear in	numerical equations
their grasp on the laws	the course to help	It is also vital that	subsequent units.	(such as the speed of
of physics. Lastly,	students craft sound	students are given	As students'	a system after an
students will begin	scientific arguments.	opportunities to think	comprehension of	inelastic collision) but
making predictions		about and discuss the	energy (particularly	also confident in their
about motion and		impact that changes	kinetic, potential, and	ability to discuss
justifying claims with		or modifications have	microscopic internal	when momentum is
evidence by exploring			energy) evolves, they	
the relationships		on physical scenarios.	will begin to connect	conserved and how
between the physical		For example, students	and relate knowledge	the type of collision

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.		should be able to use mathematical and graphical representations to determine how doubling the distance of a satellite from a planet will change the period of orbit and then justify their answer with evidence and reasoning. Specific preconceptions will be addressed in this unit, such as the idea of a centrifugal force. Students will also have opportunities to wrestle with the idea of field models, which will be expanded upon in Unit 8.	across scales, concepts, and representations, as well as across disciplines, particularly physics, chemistry, and biology.	affects the outcome. Threading such connections between physical quantities is fundamental to understanding the broader relationship between this unit and the rest of the course. Students will have more opportunities to apply conservation laws to make predictions and justify claims in Unit 7 when they are introduced to rotational quantities.
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and tope of the system to analyze the mathematical, and graphicalfor collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.gravitation to calculate the gravitational forcesystems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.data needed to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.data needed to determine the relationship between the direction of the gravitation to calculate the stever day situations.data needed to determine the relationship between the direction of the gravitational force.Analyze esperimental an object and be able to results of the analysis using narrative, methematical, and graphicalRepresent forces in during the analysis of a situation.gravitational force appropriately labeled during the analysis of a situation.Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.Systems for everyday situations and apply conservation concepts fore energy of an objectdata needed to data needed to situations.Analyze a results of the analysis using of the center of mass of far system to analyze the motion of the system qualitatively and semi-gravitational force and the forces exerted on a object for different types of forces.Systems for everyday situations.data needed to data needed to 	Unit Targets:	Unit Targets:	Unit Targets:	Unit Targets:	Unit Targets:
anontitotivolv and and a solution an	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-	Design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration. 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.	Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital. Use Newton's law of gravitation to calculate the gravitational force. Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. Apply $F = mg$ to calculate gravitational force. Evaluate, using given data, whether all the forces on a system or whether all the parts of a system have been	Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations. Make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease, or remain unchanged. Use force and velocity vectors to determine qualitatively the net force exerted on an object and	Justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force. Justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction. Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. Analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval
quantitatively.force on itself.Design a plan to collectquantitatively whetherbesign a plan to collectthe kinetic energy ofDesign a plan for	quantitatively.			the kinetic energy of	Design a plan for
Make predictions about the motion of aDescribe a force as anand analyze data for motion (static, constant,that object would increase, decrease, orcollecting data to investigate the		Describe a force as an	•	5	

system based on the	interaction between	or accelerating) from	remain unchanged.	relationship between
fact that acceleration	two objects, and	force measurements,	remain unchanged.	changes in momentum
			Apply mothematical	
is equal to the change	identify both objects	and carry out an	Apply mathematical	and the average force
in velocity per unit	for any force.	analysis to determine	routines to determine	Calculate the change in
time, and velocity is		the relationship	the change in kinetic	linear momentum of a
equal to the change in	Construct explanations	between the net force	energy of an object	two-object system with
position per unit time.	of physical situations	and the vector sum of	given the forces on the	constant mass in linear
	involving the	the individual forces.	object	motion from a
Create mathematical	interaction of bodies		Calculate the total	representation of the
models and analyze	using Newton's third	Re-express a free-body	energy of a system and	system (data, graphs,
5	law and the	diagram representation	justify the mathematical	etc.).
graphical relationships	representation of	into a mathematical	routines used in the	
for acceleration,	action- reaction pairs of	representation, and	calculation of	Analyze data to find the
velocity, and position of the center of mass of a	forces.	solve the mathematical	component types of	change in linear
		representation for the	energy within the	momentum for a
system and use them to	Predict the motion of an	acceleration of the	system whose sum is	constant-mass system
calculate properties of	object subject to forces	object.	the total energy	using the product of the
the motion.	exerted by several		Predict changes in the	mass and the change in
	objects using an		total energy of the	velocity of the center of
	application of Newton's		system due to changes	mass.
	second law in a variety		in position and speed of	
	of physical situations,		objects or frictional	Apply mathematical
	with acceleration in one		interactions within the	routines to calculate the
	dimension.		system.	change in momentum of
	dimension.		Make predictions about	a system by analyzing
			the changes in the	the average force
			mechanical energy of a	exerted over a certain
			system when a	time on the system.
	Design a plan to collect		component of an	Perform an analysis on
	and analyze data for		external force acts	data presented as a
	motion (static, constant,		parallel or antiparallel	force-time graph and
	or accelerating) from		to the direction of the	predict the outcome.
	force measurement, and		displacement of the	*
	carry out an analysis to		center of mass.	Define open and closed
	determine the		Apply the concepts of	systems for everyday
			conservation of energy	situations and apply
	relationship between		conservation of energy	situations and appig

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	the net force and the	and the work-energy	conservation concepts
	vector sum of the	theorem to determine	for energy change and
	individual forces.	qualitatively and/or	linear motion
		quantitatively that work	
	Re-express a free-	done on a two-object	Make qualitative
	body diagram into a	system in linear motion	predictions about
	mathematical	will change the kinetic	natural phenomena
	representation, and	energy of the center of	based on conservation
	solve the	mass of the system, the	of linear momentum
	mathematical	potential energy of the	and restoration of
	representation for the	systems, and/or the	kinetic energy in elastic
	acceleration of the	internal energy of the	collisions.
	object.	system.	
		Create a representation	Apply the principles of
	Use representations of	or model showing that a	conservation of
	the center of mass of an	single object can only	momentum and
	isolated two-object	have kinetic energy and	restoration of kinetic
	system to analyze the	use information about	energy to reconcile a
	motion of the system	that object to calculate	situation that appears to
	qualitatively and semi-	its kinetic energy.	be isolated and elastic,
	quantitatively.		but in which data
		Translate between a	indicate that linear
	Apply Newton's second	representation of a	momentum and kinetic
	law to systems to	single object, which can	energy are not the same
	calculate the change in	only have kinetic	after the interaction, by
	the center-of-mass	energy, and a system	refining a scientific
	velocity when an	that includes the object,	question to identify
	external force is exerted	which may have both	interactions that have
	on the system.	kinetic and potential	not been considered.
		energies.	Students will be
	Use visual or	-	expected to solve
	mathematical	Describe and make	qualitatively and/or
	representations of the	qualitative and/or	quantitatively for one-
	forces between objects	quantitative predictions	dimensional situations
	in a system to predict	about everyday	and qualitatively in
	whether or not there	examples of systems	two-dimensional

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	ter-of-mass velocity	energy.	situations.
	hat system.	energy.	Apply mathematical
011	nat system.	Maka quantitativa	
		Make quantitative calculations of the	routines appropriately
			to problems involving
		internal potential	elastic collisions in one
		energy of a system from	dimension and justify
		a description or diagram	the selection of those
		of that system.	mathematical routines
			based on conservation
		Apply mathematical	of momentum and
		reasoning to create a	restoration of kinetic
		description of the	energy.
		internal potential	
		energy of a system from	Design an experimental
		a description or diagram	test of an application of
		of the objects and	the principle of the
		interactions in that	conservation of linear
		system.	momentum, predict an
			outcome of the
		Describe and make	experiment using the
		predictions about the	principle, analyze data
		internal energy of	generated by that
		systems.	experiment whose
		5	uncertainties are
		Calculate changes in	expressed numerically,
		kinetic energy and	and evaluate the match
		potential energy of a	between the prediction
		system using	and the outcome.
		information from	
		representations of that	Classify a given
		system.	collision situation as
		Design an experiment	elastic or inelastic,
		and analyze data to	justify the selection of
		determine how a force	conservation of linear
		exerted on an object or	momentum and
		exerted on an object of	momentum and

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system does work on	restoration of kinetic
the object or system as	energy as the
it moves through a	appropriate principles
distance.	for analyzing an elastic
	collision, solve for
Design an experiment	missing variables, and
and analyze graphical	calculate their values.
data in which	Qualitatively predict, in
interpretations of the	terms of linear
area under a force-	momentum and kinetic
distance curve are	energy, how the
needed to determine the	outcome of a collision
work done on or by the	between two objects
object or system.	changes depending on
	whether the collision is
Predict and calculate	elastic or inelastic.
from graphical data the	
energy transfer to or	Plan data-collection
work done on an object	strategies to test the law
or system from	of conservation of
information about a	momentum in a two-
force exerted on the	object collision that is
object or system	elastic or inelastic and
through a distance.	analyze the resulting
through a distance.	•
Make claims about the	data graphically.
interaction between a	Apply the concernation
	Apply the conservation of linear momentum to
system and its	
environment in which	a closed system of
the environment exerts	objects involved in an
a force on the system,	inelastic collision to
thus doing work on the	predict the change in
system and changing	kinetic energy.
the energy of the	
system (kinetic energy	Analyze data that verify
plus potential)	conservation of

			Predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object.	momentum in collisions with and without an external frictional force. Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.
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#### navancea i lacement i hysics araac 12 scope and sequence

Simple Harmonic Motion	Torque and Rotational Motion	Electrical Charge and Electrical Force	DC Circuits	Mechanical Waves and Sound
Weeks 21-22	Weeks 23-26	Week 27-28	Weeks 29-32	Weeks 33-38
Unit Description:	Unit Description:	Unit Description:	Unit Description:	Unit Description:
In Unit 6, students	Unit 7 completes the	Although Unit 8	In Unit 9, students	In Unit 10, students
will continue to use	study of mechanical	presents students with	will draw on their	will move away from
the same tools,	physics by	physical phenomena	knowledge of	the main themes of
techniques, and	introducing students	that are difficult or	electricity and apply	the previous units and
models that they have	to torque and	impossible to directly	it to the conservation	learn about
been using	rotational motion.	observe, the concepts	of charge in electric	mechanical waves.
throughout this	Although these topics	of electric charge and	circuits. This unit will	Although concepts
course. However,	present more complex	electric force are the	push students to move	like oscillation,
they will now use	scenarios, the tools of	cornerstones of the	beyond	energy, and motion
them to analyze a new	analysis remain the	study of electricity	mathematically	carry over into the
type of motion:	same: The content	and magnetism. As in	solving for current,	study of waves,
simple harmonic	and models explored	earlier units, the	resistance, and	students will be
motion. Although	in the first six units of	foundation of this unit	voltage and will	introduced to new
simple harmonic	AP Physics 1 set the	includes the study of	challenge them to	tools to communicate
motion is unique,	foundation for Unit 7.	relationships and	make connections	scientific phenomena
students will learn	During their study of	change: Students are	between system	and solve scientific
that even in new	torque and rotational	expected to be able to	interactions and the	models. Standing
situations, the	motion, students will	discuss what happens	changes that result	wave models, for
fundamental laws of	be confronted with	to force when there is	from these	example, are applied
physics remain the	different ways of	a change in the	interactions. For	in Unit 10 to support
same. Energy bar	thinking about and	separation between	example, students	a more in-depth

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charts, as well as free-	modeling forces. As	charges or the	must not only be able	knowledge of musical
body diagrams,	in previous units, it's	magnitude of charges.	to calculate the	instruments and
become increasingly	critical that students	It's essential for	resistance of a light	sounds. Because
important as students	are given	students to be able to	bulb in a circuit; they	knowledge of
work toward	opportunities to create	use mathematics and	must also be able to	mechanical waves is
determining which	and use	mathematical	articulate the impact	essential for
model is most	representations and	relationships as	on other bulbs in the	understanding a wide
appropriate for a	models to make	evidence for claims,	circuit if that light	range of physical
given physical	predictions and	to analyze someone	bulb is removed.	phenomena
situation.	justify claims. It's	else's mathematical	Throughout the unit,	(including light and
Preconceptions—	equally important that	derivation, and/or to	it is essential that	the wave properties of
such as the	students are	explain their own	students have	matter), students will
relationship between	comfortable deriving	mathematical	opportunities to create	have several
the amplitude and	new expressions from	derivation in a	and use	opportunities in Unit
period of	fundamental	narrative.	representations and	10 to connect and
oscillation—will also	principles to help	Throughout this unit,	models, especially as	relate knowledge
be addressed to	them make	students will also	evidence to make	across various scales,
provide students with	predictions in	apply and make	predictions, justify	concepts, and
a more nuanced	unfamiliar, applied	predictions about	claims, and overcome	representations.
awareness of simple	contexts. Unit 7 also	conserved quantities,	any preconceived	Being able to identify
harmonic motion.	focuses on the	which will be further	notions about circuits.	and describe the
Students are expected	mathematical practice	developed and	It is also important	relationships between
to use the content	of estimating	applied in Unit 9.	that students develop	physical quantities
knowledge they	quantities that can	Helping students	an understanding of	and use these
gained in the first five	describe natural	practice the skill of	the language used in	relationships as
units to make and	phenomena. For	constructing scientific	Unit 8. Correctly	justification for
defend claims while	example, students	explanations of	using vocabulary	claims are equally
also making	need to be able to	phenomena based on	terms such as	essential. Although its
connections in and	estimate the torque on	scientific practices	"voltage," "current,"	content remains
across the content	an object caused by	should also be a focus	and "energy" is	distinct from earlier
topics and big ideas.	various forces in	of Unit 8, as it helps	essential to accurately	units, Unit 10
Because Unit 6 is the	comparison to other	students readily make	describe, analyze, and	presents concepts that
first unit in which	situations. Although	comprehensive	reason with content	will help students

students possess all	this particular science	predictions about new	presented in this	succeed in later
the tools of force,	practice doesn't	phenomena.	course. By helping	physics courses.
energy, and	appear often in AP	Students will also use	students relate	Students who take AP
momentum	Physics 1, it	familiar	theoretical models of	Physics 2 will further
conservation, it's	nonetheless is an	representations and	electricity to real	investigate the ideas
important that	important conceptual	models to make	circuits, Unit 9 sets	presented in Unit 10
teachers scaffold	skill for students to be	predictions and	the stage for AP	through their
lessons to help them	able to compare	justify claims. These	Physics C: Electricity	additional study of
develop a better	estimated values of	will help students	and Magnetism,	mechanical waves.
understanding of each	physical quantities.	dispel some of the	which explores	
fundamental physics	Throughout this unit,	common	circuits in greater	
principles as well as	students will have	misconceptions that	depth.	
its limitations.	opportunities to	they may continue to		
Throughout this unit,	compare and connect	have about forces,		
students will be asked	their understanding of	such as two charged		
to create force,	linear and rotational	objects with different		
energy, momentum,	motion, dynamics,	net charges applying		
and position versus	energy, and	different magnitude		
time graphs for a	momentum to make	forces on the other		
single scenario and to	meaning of these	object. The content		
make predictions	concepts as a whole,	and ideas presented in		
based on their	rather than as distinct	Unit 8 set a solid		
representations.	and separate units.	foundation for		
Students will enhance		students to be able to		
their study of motion		investigate and		
when they learn about		understand both DC		
oscillatory motion in		circuits, in Unit 9,		
Unit 10.		and the topics of		
		electricity and		
		magnetism, in AP		
		Physics 2.		

	Unit Targets:	Unit Targets:	Unit Targets:	Unit Targets:
Unit Targets:	Express the motion of	Define open and closed	e	Use a visual
Predict which	an object using	systems for everyday	Make claims about	representation to
properties determine the	narrative, mathematical,	situations and apply	natural phenomena	construct an
motion of a simple	and graphical	conservation concepts	based on conservation	explanation of the
harmonic oscillator and	<b>U</b>		of electric charge.	distinction between
what the dependence of	representations.	for energy, charge, and	Make predictions, using	
the motion is on those	Express the motion of	linear momentum to	the conservation of	transverse and
properties.	an object using	those situations	electric charge, about	longitudinal waves by
	narrative, mathematical,	Make claims about	the sign and relative	focusing on the
Design a plan and	and apply to constant	natural phenomena	quantity of net charge	vibration that generates
collect data in order to	acceleration situations.	based on conservation	of objects or systems	the wave.
ascertain the	Compare the torques on	of electric charge.	after various charging	Describe
characteristics of the	an object caused by		processes, including	representations of
motion of a system	various forces.	Make predictions, using	conservation of charge	transverse and
undergoing oscillatory		the conservation of	in simple circuits.	longitudinal waves
motion caused by a	Estimate the torque on	electric charge, about	Choose and justify the	Describe sound in terms
restoring force.	an object caused by	the sign and relative	selection of data needed	of transfer of energy
restoring roles.	various forces in	quantity of net charge	to determine resistivity	and momentum in a
Analyze data to identify	comparison with other	of objects or systems	for a given material.	medium and relate the
qualitative and	situations.	after various charging	Construct or interpret a	concepts to everyday
quantitative		processes, including	graph of the energy	examples.
relationships between	Design an experiment	conservation of charge	changes within an	Use graphical
given values and	and analyze data testing	in simple circuits.	electrical circuit with	representation of a
variables (i.e., force,	a question about torques	-	only a single battery	periodic mechanical
displacement,	in a balanced rigid	Construct an	and resistors in series	wave to determine the
acceleration, velocity,	system.	explanation of the two-	and/or in, at most, one	amplitude of the wave.
period of motion,	-	charge model of electric	parallel branch as an	Explain and/or predict
<b>^</b>	Calculate torques on a	charge.	application of the	qualitatively how the
frequency, spring	two-dimensional system	Use Coulomb's Law	conservation of energy	energy carried by a
constant, string length,	in static equilibrium by	qualitatively and	(Kirchhoff's loop rule).	sound wave relates to
mass) associated with	examining a	quantitatively to make	(Reference).	the amplitude of the
objects in oscillatory	representation or model	predictions about	Apply conservation of	wave and/or apply this
motion and use those	(such as a diagram or	interactions between	energy concepts to the	concept to a real-world
data to determine the	physical construction).	collections of electric	design of an experiment	example.
value of an unknown.	r <i>J</i>	point charges.	that will demonstrate	Use a graphical
	Use representations of	Connect the concepts of	the validity of	representation of a
Construct a qualitative	ese representations of	connect the concepts of		representation of a

and/ an anomitation	the velotion ship	anaritational forma and	Vinable off's loss mile	nonio dia mantena inal
and/ or quantitative	the relationship	gravitational force and	Kirchhoff's loop rule	periodic mechanical
explanation of	between force and	electric force to	$(\sum \Delta V = 0)$ in a circuit	wave (position versus
oscillatory behavior	torque.	compare similarities	with only a battery and	time) to determine the
given evidence of a		and differences between	resistors either in series	period and frequency of
restoring force.	Make predictions about	forces.	or in, at most, one pair	the wave and describe
	the change in the		of parallel branches.	how a change in the
Calculate the expected	angular velocity about			frequency would
behavior of a system	an axis for an object		Apply conservation of	modify features of the
using the object model	when forces exerted on		energy (Kirchhoff's	representation
(i.e., by ignoring	the object cause a		loop rule) in	Use a visual
changes in internal	torque about that axis.		calculations involving	representation of a
structure) to analyze a	Plan data-collection and		the total electric	periodic mechanical
situation. Then, when	analysis strategies		potential difference for	wave to determine the
the model fails, the	designed to test the		complete circuit loops	wavelength of the wave
student can justify the	relationship between a		with only a single	Design an experiment
use of conservation of	torque exerted on an		battery and resistors in	to determine the
energy principles to	object		series and/or in, at	relationship between
calculate the change in	Predict the behavior of		most, one parallel	periodic wave speed
internal energy due to	rotational collision		branch.	wavelength, and
changes in internal	situations by the same		Apply conservation of	frequency and relate
structure because the	processes that are used		electric charge	these concepts to
object is actually a	to analyze linear		(Kirchhoff's junction	everyday examples
system.	collision situations		rule) to the comparison	Create or use a wave
	using an analogy		of electric current in	front diagram to
Describe and make	between impulse and		various segments of an	demonstrate or interpret
qualitative and/or	change of linear		electrical circuit with a	qualitatively the
quantitative predictions	momentum and angular		single battery and	observed frequency of a
about everyday	impulse and change of		resistors in series and	wave, dependent on
examples of systems	angular momentum		in, at most, one parallel	relative motions of
with internal potential			branch and predict how	source and observer
energy.	In an unfamiliar context		those values would	Use representations of
	or using representations		change if configurations	individual pulses and
Make quantitative	beyond equations,		of the circuit are	construct
calculations of the	justify the selection of a		changed.	representations to
internal potential	mathematical routine to			model the interaction of
energy of a system from	solve for the change in		Design an investigation	two wave pulses to

a description or diagram	angular momentum of	of an electrical circuit	analyze the
of that system.	an object caused by	with one or more	superposition of two
	torques exerted on the	resistors in which	pulses
Apply mathematical	object	evidence of	Design a suitable
reasoning to create a		conservation of electric	experiment and analyze
description of the	Plan data-collection and	charge can be collected	data illustrating the
internal potential	analysis strategies	and analyzed.	superposition of
energy of a system from	designed to test the	5	mechanical waves (only
a description or diagram	relationship between	Use a description or	for wave pulses or
of the objects and	torques exerted on an	schematic diagram of	standing waves
interactions in that	object and the change in	an electrical circuit to	Design a plan for
system	angular momentum of	calculate unknown	collecting data to
-	that object.	values of current in	quantify the amplitude
Describe and make		various segments or	variations when two or
predictions about the	Describe a	branches of the circuit	more traveling waves or
internal energy of	representation and use it		wave pulses interact in
systems.	to analyze a situation in		a given medium.
	which several forces		Analyze data or
Calculate changes in	exerted on a rotating		observations or evaluate
kinetic energy and	system of rigidly		evidence of the
potential energy of a	connected objects		interaction of two or
system using	change the angular		more traveling waves in
information from	velocity and angular		one or two dimensions
representations of that	momentum of the		(i.e., circular wave
system	system.		fronts) to evaluate the
			variations in resultant
	Plan data-collection		amplitudes
	strategies designed to		Refine a scientific
	establish that torque,		question related to
	angular velocity,		standing waves and
	angular acceleration,		design a detailed plan
	and angular momentum		for the experiment that
	can be predicted		can be conducted to
	accurately when the		examine the
	variables are treated as		phenomenon
	being clockwise or		qualitatively or

counterclockwise with		quantitatively
respect to a well-		Predict properties of
defined axis of rotation,		standing waves that
and refine the research		result from the addition
question based on the		of incident and reflected
examination of data.		waves that are confined
		to a region and have
Describe a model of a		nodes and antinodes.
rotational system and		Plan data-collection
use that model to		strategies, predict the
analyze a situation in		outcome based on the
which angular		relationship under test,
momentum changes due		perform data analysis,
to interaction with other		evaluate evidence
objects or systems.		compared with the
		prediction, explain any
Plan a data-collection		discrepancy, and, if
and analysis strategy to		necessary, revise the
determine the change in		relationship among
angular momentum of a		variables responsible
system and relate it to		for establishing
interactions with other		standing waves on a
objects and systems.		string or in a column of
		air.
Use appropriate		Describe
mathematical routines		representations and
to calculate values for		models of situations in
initial or final angular		which standing waves
momentum, or change		result from the addition
in angular momentum		of incident and reflected
of a system, or average		waves confined to a
torque or time during		region.
which the torque is		-
exerted in analyzing a		Challenge with
situation involving		evidence the claim that
torque and angular		the wavelengths of
torque and angular		the wavelenguis Of

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1	momentum.		standing waves are
1			determined by the
	Plan a data-collection		frequency of the source,
	strategy designed to test		regardless of the size of
	the relationship		the region.
	between the change in		Calculate wavelengths
	angular momentum of a		and frequencies (if
	system and the product		given wave speed) of
	of the average torque		standing waves based
	applied to the system		on boundary conditions
	and the time interval		and length of region
	during which the torque		within which the wave
	is exerted.		is confined and
			calculate numerical
	The change in angular		values of wavelengths
	momentum is given by		and frequencies.
	the product of the		Use a visual
	average torque and the		representation to
	time interval during		explain how waves of
	which the torque is		slightly different
	exerted.		frequency give rise to
			the phenomenon of
	Make qualitative		beats.
	predictions about the		
	angular momentum of a		
	system for a situation in		
	which there is no net		
	external torque.		
	1		
	Make calculations of		
	quantities related to the		
	angular momentum of a		
	system when the net		
	external torque on the		
	system is zero.		
L,	<u>ı                                    </u>		

th au a lo o	Describe or calculate he angular momentum and rotational inertia of a system in terms of the ocations and velocities of objects that make up he system.			
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### Unit Title: Kinematics

Unit Summary: 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. Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3, HSA-SSE.A.1, HSA-SSE.B.3, HSA-CED.A.1, HSA-CED.A.2, HSA-CED.A.4, HSF-IF.C.7, HSS-ID.A.1

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

### **Learning Targets**

NJSLS Standards: HS-PS2-1, HS-PS2-2, HS-PS2-3, HS-PS2-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, RST.11-12.7, WHST.9-12.2, WHST.9-12.7, WHST.11-12.8, WHST.11-12.9

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.
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.
3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
4	Communicate scientific and technical information about why the molecular-level structure is

important in the functioning of designed n	naterials.
Big Idea: The interactions of an object with	other objects can be described by forces and
interactions between systems can result in c	
Unit Essential Questions:	Unit Enduring Understandings:
<ul> <li>How can the motion of objects be predicted and/or explained?</li> <li>Can equations be used to answer questions regardless of the questions' specificity?</li> <li>How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports?</li> <li>How can we use models to help us understand motion?</li> <li>Why is the general rule for stopping your car "when you double your speed, you must give yourself four times as much distance to</li> </ul>	<ul> <li>All forces share certain common characteristics when considered by observers in inertial reference frames.</li> <li>The acceleration of the center mass of a system is related to the net force exerted on a system.</li> </ul>
<ul> <li>results of the analysis using narrative, a</li> <li>Use representations of the center of ma motion of the system qualitatively and</li> <li>Make predictions about the motion of a to the change in velocity per unit time, unit time.</li> <li>Create mathematical models and analy</li> </ul>	of the motion of an object. the motion of an object and be able to express the mathematical, and graphical representations. ass of an isolated two-object system to analyze the
Fridore	of Loorning
Summative Assessment: Labs, Unit Tests, B	e of Learning
Formative Assessments:	
• Quizzes	
-	
• Section Tests	
• Take home assignments	

Activities/Interdisciplinary Connections	Timeframe
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. 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.	4 weeks
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).	
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.	
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-by- frame 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.	
Teacher Resources	Teacher Note
Lab equipment, computers, analysis programs, projectors	

• Use of assisted technology

- Use of prompts
- Modification of content and student products
- Testing accommodations
- Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls
- •Sentence frames
- •Think-pair-share
- •Cooperative learning groups

### Unit Title: Dynamics

**Unit Summary:** In Unit 2, 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. This is accomplished by revisiting and building upon the representations presented in Unit 1, specifically the introduction to the free-body diagram. 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, Unit 2 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.

**Primary Interdisciplinary Connections:** MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3, HSA-SSE.A.1, HSA-SSE.B.3, HSA-CED.A.1, HSA-CED.A.2, HSA-CED.A.4, HSF-IF.C.7, HSS-ID.A.1

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

### Learning Targets

NJSLS Standards: HS-PS2-1, HS-PS2-2, HS-PS2-3, HS-PS2-4, HS-PS2-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, RST.11-12.7, WHST.9-12.2, WHST.9-12.7, WHST.11-12.8, WHST.11-12.9

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.
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.
3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
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.
5	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

**Big Idea:** Objects and systems have properties such as mass and charge. Systems may have internal structure. Fields existing in space can be used to explain interactions. The interactions of an object with other objects can be described by forces. Interactions between systems can result in changes in those systems.

Unit Essential Questions:	Unit Enduring Understandings:
<ul> <li>How can the properties of internal and gravitational mass be experimentally verified to be the same?</li> <li>How do you decide what to believe about scientific claims?</li> <li>How does something we cannot see determine how an object behaves?</li> <li>Why is the acceleration due to gravity constant on Earth's surface?</li> <li>Are different kinds of forces <i>really</i> different?</li> <li>How can Newton's laws of motion be used to predict the behavior of objects?</li> <li>Why does the same push change the motion of a shopping cart more than the motion of a car?</li> </ul>	<ul> <li>The internal structure of a system determines many properties of the system.</li> <li>A gravitational field is caused by an object with mass.</li> <li>At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.</li> <li>Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.</li> <li>All forces share certain common characteristics when considered by observers in inertial reference frames.</li> <li>Classically, the acceleration of an object interacting with other objects can be predicted by using a=F/m.</li> <li>The acceleration of the center of mass of a system.</li> </ul>

### Unit Learning Targets

Students will...

- Design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.
- 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 action- reaction pairs of 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.
- Use representations of the center of mass of an isolated two-object system to analyze the motion

of the system qualitatively and semi-quantitatively.

- 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.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

**Formative Assessments:** 

- Quizzes
- Section Tests
- Take home assignments

Lesson Plans	
Activities/Interdisciplinary Connections	Timeframe
• 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.	4 weeks
• 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.	
• 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.	
• 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.	
• 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 <i>one</i>	

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.	
Teacher Resources	Teacher Note
• Lab equipment, computers, analysis programs, projectors	
Differentiating Instruction Students with Disabilities, English Lang and Gifted & Talented Stude	uage Learners,
Examples of Strategies and Practices that Support Students with	Disabilities:
• Use of visual and multisensory formats	
• Use of assisted technology	
• Use of prompts	
• Modification of content and student products	
Testing accommodations	
• Authentic assessments	
Examples of Strategies and Practices that Support Gifted & Tale • Adjusting the pace of lessons • Curriculum compacting • Inquiry-based instruction • Independent study • Higher-order thinking skills • Interest-based content • Student-driven instruction • Real-world problems and scenarios	nted Students:
<ul> <li>Examples of Strategies and Practices that Support English Langu</li> <li>Pre-teaching of vocabulary and concepts</li> <li>Visual learning, including graphic organizers</li> <li>Use of cognates to increase comprehension</li> <li>Teacher modeling</li> </ul>	age Learners:
<ul> <li>Pairing students with beginning English language skills with st English language skills</li> <li>Scaffolding</li> <li>Word walls</li> <li>Sentence frames</li> <li>Think-pair-share</li> <li>Cooperative learning groups</li> </ul>	udents who have more advanced

### Unit Title: Circular Motion and Gravity

Unit Summary: In Unit 3, students will continue to enhance their understanding of the physical world using models and representations to create a more complete and complex model of motion, particularly as it relates to gravitational mass and inertial mass. Again, translation and connections are essential—students must be able to use content and science practices from the previous two units and apply them in different ways. While it's essential that students are able to calculate numerical answers to questions, it is more important that they can combine mathematical representations to make new representations that more accurately describe natural phenomena. For example, students should be comfortable combining equations for uniform circular motion with gravitational equations to describe the circular path of a satellite circling a planet. It is also vital that students are given opportunities to think about and discuss the impact that changes or modifications have on physical scenarios. For example, students should be able to use mathematical and graphical representations to determine how doubling the distance of a satellite from a planet will change the period of orbit and then justify their answer with evidence and reasoning. Specific preconceptions will be addressed in this unit, such as the idea of a centrifugal force. Students will also have opportunities to wrestle with the idea of field models, which will be expanded upon in Unit 8.

**Primary Interdisciplinary Connections:** MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3, HSA-SSE.A.1, HSA-SSE.B.3, HSA-CED.A.1, HSA-CED.A.2, HSA-CED.A.4, HSF-IF.C.7, HSS-ID.A.1

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

### **Learning Targets**

NJSLS Standards: HS-PS2-1, HS-PS2-2, HS-PS2-3, HS-PS2-4, HS-PS2-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, RST.11-12.7, WHST.9-12.2, WHST.9-12.7, WHST.11-12.8, WHST.11-12.9

	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.	
,	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.	
	3	Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.	
4	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.	
5	5	Communicate scientific and technical information about why the molecular-level structure is
	5	important in the functioning of designed materials.

**Big Idea:** Objects and systems have properties such as mass and charge. Systems may have internal structure. Fields existing in space can be used to explain interactions. The interactions of an object with other objects can be described by forces. Interactions between systems can result in changes in those systems.

Init Essential Questions:	Unit Enduring Understandings:
<ul> <li>How does changing the mass of an object affect the gravitational force?</li> <li>Why is a refrigerator hard to push in space?</li> <li>Why do we feel pulled toward Earth but not toward a pencil?</li> <li>How can the acceleration due to gravity be modified?</li> <li>How can Newton's laws of motion be used to predict the behavior of objects?</li> <li>How can we use forces to predict the behavior of objects and keep us safe?</li> <li>How is the acceleration of the center of mass of a system related to the net force exerted on the system?</li> <li>Why is it more difficult to stop a fully loaded dump truck than a small passenger car?</li> </ul>	<ul> <li>A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces), as well as a variety of other physical phenomena.</li> <li>Certain types of forces are considered fundamental.</li> <li>At the macroscopic level, forces can be categorized as either long-range (action-at- a-distance) forces or contact forces.</li> <li>A gravitational field is caused by an object with mass.</li> <li>Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.</li> <li>Classically, the acceleration of an object interacting with other objects can be predicted by using the formula a=F/m.</li> <li>All forces share certain common characteristics when considered by observers in inertial reference frames.</li> </ul>

### **Unit Learning Targets**

Students will...

- Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital.
- Use Newton's law of gravitation to calculate the gravitational force.
- Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces.
- Apply F = mg to calculate gravitational force.
- Evaluate, using given data, whether all the forces on a system or whether all the parts of a system

have been identified.

- Design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements, 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 representation into a mathematical representation, and solve the mathematical representation for the acceleration of the object.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

**Formative Assessments:** 

- Quizzes
- Section Tests
- Take home assignments

Lesson Plans	
Activities/Interdisciplinary Connections	Timeframe
<ul> <li>Have students use the "My Solar System" PhET applet to create circular orbits of varying radii around the central star and record radius, period, and planet mass for various trials. Next, have them calculate the speed using v = 2πr/T and force using F = mv<sup>2</sup>/r. Using the</li> </ul>	2 weeks
data, students show that gravitational force is directly proportional to mass and inversely proportional to radius.	
• Ask students to consider two identical objects moving in circles (or parts of circles) of different radii. Ask them to think of a situation where the object with the smaller radius has a greater net force and another situation where the object with the larger radius has a greater net force.	
• Describe something a driver could be doing in a car (e.g., "turning the steering wheel to the right while pressing the brake"). Have students walk out the motion while holding out one arm representing the velocity vector and the other arm representing the acceleration vector.	

<ul> <li>Find a data table on stopping distance. Have students determine the coefficient of static friction of the car's tires from this data and then create a new table of different car speeds and minimum turning radii to not skid.</li> <li>Attach a pendulum of known weight (say, 2 N) to a force sensor and cause the bob to swing in a 180-degree arc. Ask students, "At the bottom, the bob is neither speeding up nor slowing down, so what force is registered at the bottom?" Expect students to (incorrectly) answer, "2 N."</li> </ul>	
Teacher Resources	Teacher Note
• Lab equipment, computers, analysis programs, projectors	

# Differentiating Instruction:

## Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:

- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts
- Modification of content and student products
- Testing accommodations
- Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

• Pre-teaching of vocabulary and concepts

• Visual learning, including graphic organizers

• Use of cognates to increase comprehension

• Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

• Scaffolding

•Word walls

•Sentence frames

•Think-pair-share

•Cooperative learning groups

#### Unit Title: Momentum

**Unit Summary:** Unit 5 introduces students to the relationship between force, time, and momentum via calculations, data analysis, designing experiments, and making predictions. Students will learn how to use new models and representations to illustrate the law of the conservation of momentum of objects and systems while simultaneously building on their knowledge of previously studied representations. Using the law of the conservation of momentum to analyze physical situations gives students a more complete picture of forces and leads them to revisit their misconceptions surrounding Newton's third law. Students will also have the opportunity to make connections between the conserved quantities of momentum and energy to determine under what conditions each quantity is conserved. It's essential that students are not only comfortable solving numerical equations (such as the speed of a system after an inelastic collision) but also confident in their ability to discuss when momentum is conserved and how the type of collision affects the outcome. Threading such connections between this unit and the rest of the course. Students will have more opportunities to apply conservation laws to make predictions and justify claims in Unit 7 when they are introduced to rotational quantities.

Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

## **Learning Targets**

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of

thermodynamics).	
	teracting through electric or magnetic fields to e changes in energy of the objects due to the
<b>Big Idea:</b> The interactions of an object with Interactions between systems can result in cl result of interactions are constrained by conser	hanges in those systems. Changes that occur as a
<ul> <li>Unit Essential Questions:</li> <li>How does pushing an object change its momentum?</li> <li>How do interactions with other objects or systems change the linear momentum of a system?</li> <li>How is the physics definition of momentum different from how momentum is used?</li> <li>to describe things in everyday life?</li> <li>How does the law of the conservation of momentum govern interactions between objects or systems?</li> <li>How can momentum be used to</li> </ul>	<ul> <li>Unit Enduring Understandings:</li> <li>A force exerted on an object can change the momentum of the object.</li> <li>Interactions with other objects or systems can change the total linear momentum of a system.</li> <li>Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.</li> <li>The linear momentum of a system is conserved.</li> </ul>

- Justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.
- Justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.
- Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Analyze data to characterize the change in momentum of an object from the average force exerted on the object and the interval of time during collision.
- Design a plan for collecting data to investigate the relationship between changes in momentum and the average force.
- Calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).

- Analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.
- Apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.
- Perform an analysis on data presented as a force-time graph and predict the outcome
- Define open and closed systems for everyday situations and apply conservation concepts for energy change and linear motion.
- Make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.
- Apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and qualitatively in two-dimensional situations.
- Apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.
- Design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.
- Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.
- Qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.
- Plan data-collection strategies to test the law of conservation of momentum in a twoobject collision that is elastic or inelastic and analyze the resulting data graphically.
- Apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
- Analyze data that verify conservation of momentum in collisions with and without an external frictional force.
- Classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.

Evidence of Learning	
ummative Assessment: Labs, Unit Tests, Benchmarks	
ormative Assessments:	
Quizzes	
Section Tests	
Take home assignments	
Take nome assignments	
I organ Diana	
Lesson Plans	
Activities/Interdisciplinary Connections	Timeframe
• Ask students to imagine a pitcher throwing a	4 weeks
baseball and a catcher catching it. Students	
will debate who exerted more force on the ball	
(no way to know), who applied greater	
impulse (same for both), and who did a greater	
magnitude of net work on the ball (same).	
Repeat for a pitcher throwing the baseball and	
a batter hitting it back at the same speed.	
Connect a spring-loaded lanyard between a	
cart and force sensor, with a motion sensor on	
the other side of the cart. Have students take	
force and motion versus time data as the	
lanyard contracts and pulls, accelerating the	
cart. Show that impulse applied to the cart	
equals the cart's change in momentum.	
• Have students use momentum bar charts to	
explain why a dart bouncing off a cart makes	
the cart move faster than if the dart sticks to	
the cart, passes through the cart, or stops and	
drops after colliding with the cart.	
• Have a cart crash into a force sensor set to its	
highest setting in three different ways: cart	
sticks to sensor, cart bounces off the sensor on	
its hard side, and cart bounces off the sensor	
with its spring side. Have students predict in	
which case more force is registered, and	
explain why after each experiment is done.	
• Have two carts with different masses collide in	
a non-stick collision. Film the carts with a	
phone camera from above, with a meterstick	
next to the track. Have students use a frame-	
by-frame review app to determine the cart's	

initial/final speeds, whether momentum was conserved, and whether the collision was elastic.		
Teacher Resources	Teacher Note	
• Lab equipment, computers, analysis programs, projectors		
Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students		
Examples of Strategies and Practices that Support Students with Disabilities: • Use of visual and multisensory formats		
• Use of assisted technology		
<ul> <li>Use of prompts</li> <li>Modification of content and student products</li> <li>Testing accommodations</li> </ul>		
Authentic assessments		
Examples of Strategies and Practices that Support Gifted & Talented Students: • Adjusting the pace of lessons		

- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls
- •Sentence frames
- •Think-pair-share
- •Cooperative learning groups

# Advanced Placement Physics Grade 12 Framework

### Unit Title: Energy

**Unit Summary:** In Unit 4, students will be introduced to the idea of conservation as a foundational model of physics, along with the concept of work as the agent of change for energy. As in earlier units, students will once again utilize both familiar and new models and representations to analyze physical situations, now with force or energy as major components. Students will be encouraged to call upon their knowledge of Units 1–4 to determine the most appropriate technique and will be challenged to understand the limiting factors of each. Describing, creating, and using these representations will also help students grapple with common misconceptions that they may have about energy, such as whether or not a single object can "have" potential energy. A thorough understanding of these energy models will support students' ability to make predications—and ultimately justify claims with evidence—about physical situations. This is crucial, as the mathematical models and representations used in Unit 4 will mature throughout the course and appear in subsequent units. As students' comprehension of energy (particularly kinetic, potential, and microscopic internal energy) evolves, they will begin to connect and relate knowledge across scales, concepts, and representations, as well as across disciplines, particularly physics, chemistry, and biology.

Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

### Learning Targets

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

#### **Content Statements:**

1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
5	Develop and use a model of two objects interacting through electric or magnetic fields to

result of interactions are constrained by conser	nanges in those systems. Changes that occur as a vation laws.
Unit Essential Questions:	Unit Enduring Understandings:
<ul> <li>How does pushing something give it energy?</li> <li>How is energy exchanged and transformed within or between systems?</li> <li>How does the choice of system influence how energy is stored or how work is done?</li> <li>How does energy conservation allow the riders in the back car of a rollercoaster to have a thrilling ride?</li> <li>How can the idea of potential energy be used to describe the work done to move celestial bodies?</li> <li>How is energy transferred between objects or systems?</li> <li>How does the law of conservation of energy govern the interactions between objects and systems?</li> </ul>	<ul> <li>Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.</li> <li>A force exerted on an object can change the kinetic energy of the object.</li> <li>Interactions with other objects or systems can change the total energy of a system.</li> <li>The energy of a system is conserved.</li> </ul>

# **Unit Learning Targets**

Students will...

- Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
- Make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves.
- Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease, or remain unchanged.
- Use force and velocity vectors to determine qualitatively or quantitatively the net force exerted on an object and qualitatively whether the kinetic energy of that object would increase, decrease, or remain unchanged.
- Apply mathematical routines to determine the change in kinetic energy of an object given the forces on the object.

- Calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy.
- Predict changes in the total energy of the system due to changes in position and speed of objects or frictional interactions within the system.
- Make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass.
- Apply the concepts of conservation of energy and the work-energy theorem to determine qualitatively and/or quantitatively that work done on a two-object system in linear motion will change the kinetic energy of the center of mass of the system, the potential energy of the systems, and/or the internal energy of the system.
- Create a representation or model showing that a single object can only have kinetic energy and use information about that object to calculate its kinetic energy.
- Translate between a representation of a single object, which can only have kinetic energy, and a system that includes the object, which may have both kinetic and potential energies.
- Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.
- Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
- Apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
- Describe and make predictions about the internal energy of systems.
- Calculate changes in kinetic energy and potential energy of a system using information from representations of that system.
- Design an experiment and analyze data to determine how a force exerted on an object or system does work on the object or system as it moves through a distance.
- Design an experiment and analyze graphical data in which interpretations of the area under a force-distance curve are needed to determine the work done on or by the object or system.
- Predict and calculate from graphical data the energy transfer to or work done on an object or system from information about a force exerted on the object or system through a distance.
- Make claims about the interaction between a system and its environment in which the environment exerts a force on the system, thus doing work on the system and changing the energy of the system (kinetic energy plus potential).
- Predict and calculate the energy transfer to (i.e., the work done on) an object or system from information about a force exerted on the object).

# **Evidence of Learning**

## **Formative Assessments:**

- Quizzes
- Section Tests
- Take home assignments

Lesson Plans		
Activities/Interdisciplinary Connection	ns Timeframe	
<ul> <li>Release a low-friction cart (mass <i>m</i>) for a ramp, have students time (<i>t</i>) how takes to reach the bottom, and meass release height <i>h</i> and track length <i>L</i>. students calculate velocity using v = 4 then calculate <i>mgh</i> and ½<i>mv</i><sup>2</sup>. The tw are different; explain what incorrect assumptions lead to the difference i</li> <li>First square: Describe an everyday sit (e.g., "a car goes downhill, speeding the brakes are pressed") along with a Second square: Free-body diagram v arrow off to the side representing the displacement. Third square: Energy (initial and final). Fourth square: For force on the free-body diagram, stat that force performs positive or negat and what energy transformation that responsible for.</li> <li>Give each group a spring-loaded bat scale, and meterstick. Ask them to compare the state of the state o</li></ul>	rom the top long it ure the Have L/t, and vo energies     2 weeks       and vo energies     2       an energies.     2       uation up even as diagram.     2       vith an e object's bar charts r each e whether tive work t force is     2	
the spring constant of the spring in launcher.		
<ul> <li>Ask students to consider a cart that r rest down a ramp and then around a loop. For the cart to complete the lot falling out, the cart must be released height higher than the top of the loc students explain why this is the case energy and circular motion principle</li> <li>Student A writes a conservation of energy and circular the loc students around a student of the loc student A writes a conservation of energy and circular the loc student of the loc student A writes a conservation are student A writes a conservation of the loc student A writes a conservation of the loc student A writes a conservation are student A writes</li></ul>	vertical op without l at a p. Have e using es. energy	
equation (either symbolically or wit and units plugged in). Student B the		

describes a situation that the equation could apply to, draws a diagram, and draws energy bar charts.	
Teacher Resources	Teacher Note
• Lab equipment, computers, analysis programs, projectors	
Differentiating Instructio Students with Disabilities, English Lang and Gifted & Talented Stud	guage Learners, lents
Examples of Strategies and Practices that Support Students with • Use of visual and multisensory formats • Use of assisted technology • Use of prompts • Modification of content and student products • Testing accommodations • Authentic assessments Examples of Strategies and Practices that Support Gifted & Tal • Adjusting the pace of lessons • Curriculum compacting • Inquiry-based instruction • Independent study • Higher-order thinking skills • Interest-based content • Student-driven instruction • Real-world problems and scenarios	
<ul> <li>Examples of Strategies and Practices that Support English Lang</li> <li>Pre-teaching of vocabulary and concepts</li> <li>Visual learning, including graphic organizers</li> <li>Use of cognates to increase comprehension</li> <li>Teacher modeling</li> <li>Pairing students with beginning English language skills with see English language skills</li> <li>Scaffolding</li> <li>Word walls</li> <li>Sentence frames</li> <li>Think-pair-share</li> <li>Cooperative learning groups</li> </ul>	

# Advanced Placement Physics Grade 12 Framework

### Unit Title: Simple Harmonic Motion

Unit Summary: In Unit 6, students will continue to use the same tools, techniques, and models that they have been using throughout this course. However, they will now use them to analyze a new type of motion: simple harmonic motion. Although simple harmonic motion is unique, students will learn that even in new situations, the fundamental laws of physics remain the same. Energy bar charts, as well as free-body diagrams, become increasingly important as students work toward determining which model is most appropriate for a given physical situation. Preconceptions—such as the relationship between the amplitude and period of oscillation—will also be addressed to provide students with a more nuanced awareness of simple harmonic motion. Students are expected to use the content knowledge they gained in the first five units to make and defend claims while also making connections in and across the content topics and big ideas. Because Unit 6 is the first unit in which students possess all the tools of force, energy, and momentum conservation, it's important that teachers scaffold lessons to help them develop a better understanding of each fundamental physics principles as well as its limitations. Throughout this unit, students will be asked to create force, energy, momentum, and position versus time graphs for a single scenario and to make predictions based on their representations. Students will enhance their study of motion when they learn about oscillatory motion in Unit 10. Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

## **Learning Targets**

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

Co	ontent Statements:
1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results

in a more uniform energy distribution among the components in the system (second law of thermodynamics).
Develop and use a model of two objects interacting through electric or magnetic fields to

5 illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**Big Idea:** The interactions of an object with other objects can be described by forces. Changes that occur as a result of interactions are constrained by conservation laws.

Unit Essential Questions:	Unit Enduring Understandings:
<ul> <li>How does a restoring force differ from a "regular" force?</li> <li>How does the presence of restoring forces predict and lead to harmonic motion?</li> <li>How does a spring cause an object to oscillate?</li> <li>How can oscillations be used to make our lives easier?</li> <li>How does the law of conservation of energy govern the interactions between objects and systems?</li> <li>How can energy stored in a spring be used to create motion?</li> </ul>	<ul> <li>Classically, the acceleration of an object interacting with other objects can be predicted by using a=F/m.</li> <li>The energy of a system is conserved.</li> </ul>

## **Unit Learning Targets**

Students will...

- Predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties.
- Design a plan and collect data in order to ascertain the characteristics of the motion of a system undergoing oscillatory motion caused by a restoring force.
- Analyze data to identify qualitative and quantitative relationships between given values and variables (i.e., force, displacement, acceleration, velocity, period of motion, frequency, spring constant, string length, mass) associated with objects in oscillatory motion and use those data to determine the value of an unknown.
- Construct a qualitative and/ or quantitative explanation of oscillatory behavior given evidence of a restoring force.
- Calculate the expected behavior of a system using the object model (i.e., by ignoring changes in internal structure) to analyze a situation. Then, when the model fails, the student can justify the use of conservation of energy principles to calculate the change in internal energy due to changes in internal structure because the object is actually a system.

- Describe and make qualitative and/or quantitative predictions about everyday examples of systems with internal potential energy.
- Make quantitative calculations of the internal potential energy of a system from a description or diagram of that system.
- Apply mathematical reasoning to create a description of the internal potential energy of a system from a description or diagram of the objects and interactions in that system.
- Describe and make predictions about the internal energy of systems.
- Calculate changes in kinetic energy and potential energy of a system using information from representations of that system.

## **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

Formative Assessments:

- Quizzes
- Section Tests
- Take home assignments

Lesson PlansActivities/Interdisciplinary ConnectionsTimeframe• Have students determine the spring constant of a spring using (1) known masses and meterstick only and then (2) known masses and stopwatch only.2 weeks		
<ul> <li>Have students determine the spring constant of a spring using (1) known masses and meterstick only and then (2) known masses and stopwatch only.</li> </ul>	Lesson Plans	
a spring using (1) known masses and meterstick only and then (2) known masses and stopwatch only.	Activities/Interdisciplinary Connections	Timeframe
<ul> <li>Have students use a pendulum to measure the acceleration of gravity. Ask them to refine the experiment from single-trial calculation, to taking an average, to making a graph of linearized data.</li> <li>Make a pendulum bob oscillate with the other end of the string "clamped" between your fingers. While the bob oscillates, pull the string through your fingers so that the string length is shortened. Before doing this, ask students what will happen to the period of the oscillation and the amplitude (measured in degrees), and then explain why the period decreases and the amplitude angle increases.</li> <li>A cart wiggles on a horizontal spring. A blob of clay is dropped on the cart and sticks (could be</li> </ul>	<ul> <li>Have students determine the spring constant of a spring using (1) known masses and meterstick only and then (2) known masses and stopwatch only.</li> <li>Have students use a pendulum to measure the acceleration of gravity. Ask them to refine the experiment from single-trial calculation, to taking an average, to making a graph of linearized data.</li> <li>Make a pendulum bob oscillate with the other end of the string "clamped" between your fingers. While the bob oscillates, pull the string through your fingers so that the string length is shortened. Before doing this, ask students what will happen to the period of the oscillation and the amplitude (measured in degrees), and then explain why the period decreases and the amplitude angle increases.</li> <li>A cart wiggles on a horizontal spring. A blob of</li> </ul>	v

students to explain what happened to the	
period, total energy, amplitude of motion, and	
maximum speed?	
• Students choose a song and find its tempo	
(beats per minute). Students then must build a	
pendulum so that it swings back and forth on	
each beat. Students are then given a spring.	
They must find the spring's constant and then	
find the amount of mass necessary to make the	
spring-mass oscillate on each beat.	
Teacher Resources	Teacher Note
• Lab equipment, computers, analysis programs, projectors	

## Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:

- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts
- Modification of content and student products
- Testing accommodations
- Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced

- English language skills
- Scaffolding

Word wallsSentence framesThink-pair-shareCooperative learning groups

# Advanced Placement Physics Grade 12 Framework

### Unit Title: Torque and Rotational Motion

Unit Summary: Unit 7 completes the study of mechanical physics by introducing students to torque and rotational motion. Although these topics present more complex scenarios, the tools of analysis remain the same: The content and models explored in the first six units of AP Physics 1 set the foundation for Unit 7. During their study of torque and rotational motion, students will be confronted with different ways of thinking about and modeling forces. As in previous units, it's critical that students are given opportunities to create and use representations and models to make predictions and justify claims. It's equally important that students are comfortable deriving new expressions from fundamental principles to help them make predictions in unfamiliar, applied contexts. Unit 7 also focuses on the mathematical practice of estimating quantities that can describe natural phenomena. For example, students need to be able to estimate the torque on an object caused by various forces in comparison to other situations. Although this particular science practice doesn't appear often in AP Physics 1, it nonetheless is an important conceptual skill for students to be able to compare estimated values of physical quantities. Throughout this unit, students will have opportunities to compare and connect their understanding of linear and rotational motion, dynamics, energy, and momentum to make meaning of these concepts as a whole, rather than as distinct and separate units.

Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

## **Learning Targets**

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

Co	ontent Statements:
1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*
4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results

<ul><li>in a more uniform energy distribution among the components in the system (second law of thermodynamics).</li><li>Develop and use a model of two objects interacting through electric or magnetic fields to</li></ul>	
illustrate the forces between objects and the changes in energy of the objects due to the interaction.	
<b>Big Idea:</b> The interactions of an object with Interactions between systems can result in result of interactions are constrained by cons <b>Unit Essential Questions:</b>	changes in those systems. Changes that occur as a
<ul> <li>How does a system at rotational equilibrium compare to a system in translational equilibrium?</li> <li>How does the choice of system and rotation point affect the forces that can cause a torque on an object or a system?</li> <li>How can balanced forces cause rotation?</li> <li>Why does it matter where the door handle is placed?</li> <li>Why are long wrenches more effective?</li> <li>How can an external net torque change the angular momentum of a system?</li> <li>Why is a rotating bicycle wheel more stable than a stationary one?</li> <li>How does the conservation of angular momentum govern interactions between objects and systems?</li> <li>Why do planets move faster when they travel closer to the sun?</li> </ul>	<ul> <li>All forces share certain common characteristics when considered by observers in inertial reference frames.</li> <li>A force exerted on an object can cause a torque on that object.</li> <li>A net torque exerted on a system by other objects or systems will change the angular momentum of the system.</li> <li>The angular momentum of a system is conserved.</li> </ul>

### **Unit Learning Targets**

Students will...

- Express the motion of an object using narrative, mathematical, and graphical representations.
- Express the motion of an object using narrative, mathematical, and apply to constant acceleration situations.
- Compare the torques on an object caused by various forces.
- Estimate the torque on an object caused by various forces in comparison with other

situations.

- Design an experiment and analyze data testing a question about torques in a balanced rigid system.
- Calculate torques on a two-dimensional system in static equilibrium by examining a representation or model (such as a diagram or physical construction).
- Use representations of the relationship between force and torque.
- Make predictions about the change in the angular velocity about an axis for an object when forces exerted on the object cause a torque about that axis.
- Plan data-collection and analysis strategies designed to test the relationship between a torque exerted on an object.
- Predict the behavior of rotational collision situations by the same processes that are used to analyze linear collision situations using an analogy between impulse and change of linear momentum and angular impulse and change of angular momentum.
- In an unfamiliar context or using representations beyond equations, justify the selection of a mathematical routine to solve for the change in angular momentum of an object caused by torques exerted on the object.
- Plan data-collection and analysis strategies designed to test the relationship between torques exerted on an object and the change in angular momentum of that object.
- Describe a representation and use it to analyze a situation in which several forces exerted on a rotating system of rigidly connected objects change the angular velocity and angular momentum of the system.
- Plan data-collection strategies designed to establish that torque, angular velocity, angular acceleration, and angular momentum can be predicted accurately when the variables are treated as being clockwise or counterclockwise with respect to a well-defined axis of rotation, and refine the research question based on the examination of data.
- Describe a model of a rotational system and use that model to analyze a situation in which angular momentum changes due to interaction with other objects or systems.
- Plan a data-collection and analysis strategy to determine the change in angular momentum of a system and relate it to interactions with other objects and systems.
- Use appropriate mathematical routines to calculate values for initial or final angular momentum, or change in angular momentum of a system, or average torque or time during which the torque is exerted in analyzing a situation involving torque and angular momentum.
- Plan a data-collection strategy designed to test the relationship between the change in angular momentum of a system and the product of the average torque applied to the system and the time interval during which the torque is exerted.
- The change in angular momentum is given by the product of the average torque and the time interval during which the torque is exerted.
- Make qualitative predictions about the angular momentum of a system for a situation in which there is no net external torque.
- Make calculations of quantities related to the angular momentum of a system when the net external torque on the system is zero.

• Describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

### **Formative Assessments:**

- Quizzes
- Section Tests
- Take home assignments

Lesson Plans		
Activities/Interdisciplinary Connections	Timeframe	
• Spin a bike wheel (preferably with the tire	4 weeks	
removed so that it will roll on its metal rims),		
and release it from rest on a floor or long table.		
Have students predict what will happen to the		
wheel's linear velocity (will increase) and its		
angular velocity (will decrease) as the wheel		
"peels out." Then explain why this happens		
using a force diagram.		
• Have students release a yo-yo from rest,		
calculate its acceleration from distance and		
time measurements, and then determine the		
yo-yo's rotational inertia (requires the yo-yo's		
mass and the radius at which the string		
connects to the yo-yo). Next, have them roll		
the yo-yo down a ramp and use distance and		
time data to construct a conservation of energy		
equation that can be solved for the yo-yo's		
rotational inertia.		
• Obtain a ring and a disk of equal mass and		
radius, and load up a low-friction cart with		
weights to make it the same mass. "Race" the		
three objects from rest down identical inclines		
to show students the cart wins, then the disk,		
and then the ring. Have students explain why,		
with forces and then with energy.		
• A wheel rolls down an incline from rest and		
across a flat surface. Case 1: Tracks are rough		

Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students		
• Lab equipment, computers, analysis programs, projectors		
Teacher Resources	Teacher Note	
$E_3 > E_2$ ).		
$K_{T2} > K_{T1}$ ), ( $K_{R1} > K_{R2} > K_{R3}$ ), and ( $E_1 =$		
wheel at the end as three separate tasks. ( $K_{T3}$ >		
energies at the end, rotational kinetic energies at the end, and total mechanical energies of the		
friction. Have students rank translational kinetic		
slipping. Case 3: Tracks have negligible		
Tracks have some friction, but there is		
enough that there is no slipping. Case 2:		

Examples of Strategies and Practices that Support Students with Disabilities:

- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts
- Modification of content and student products
- Testing accommodations
- Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls

Sentence framesThink-pair-shareCooperative learning groups

# Advanced Placement Physics Grade 12 Framework

### Unit Title: Electrical Charge and Electrical Force

Unit Summary: Although Unit 8 presents students with physical phenomena that are difficult or impossible to directly observe, the concepts of electric charge and electric force are the cornerstones of the study of electricity and magnetism. As in earlier units, the foundation of this unit includes the study of relationships and change: Students are expected to be able to discuss what happens to force when there is a change in the separation between charges or the magnitude of charges. It's essential for students to be able to use mathematics and mathematical relationships as evidence for claims, to analyze someone else's mathematical derivation, and/or to explain their own mathematical derivation in a narrative. Throughout this unit, students will also apply and make predictions about conserved quantities, which will be further developed and applied in Unit 9. Helping students practice the skill of constructing scientific explanations of phenomena based on scientific practices should also be a focus of Unit 8, as it helps students readily make comprehensive predictions about new phenomena. Students will also use familiar representations and models to make predictions and justify claims. These will help students dispel some of the common misconceptions that they may continue to have about forces, such as two charged objects with different net charges applying different magnitude forces on the other object. The content and ideas presented in Unit 8 set a solid foundation for students to be able to investigate and understand both DC circuits, in Unit 9, and the topics of electricity and magnetism, in AP Physics 2.

Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

## **Learning Targets**

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

### **Content Statements:**

1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).
5	Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**Big Idea:** Objects and systems have properties such as mass and charge. Systems may have internal structure. The interactions of an object with other objects can be described by forces. Changes that occur as a result of interactions are constrained by conservation laws.

Unit Essential Questions:	Unit Enduring Understandings:
<ul> <li>How does electric charge change the way that something interacts with its surroundings?</li> <li>How do you decide what to believe about scientific claims?</li> <li>How does something we cannot see determine how an object behaves?</li> <li>How do charges exert forces on each other?</li> <li>How does the conservation of charge help us understand how charged objects behave?</li> <li>Why can you stick a balloon on the ceiling, if rubber is an insulator?</li> </ul>	<ul> <li>Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.</li> <li>Electric charge is a property of an object or a system that affects its interactions with other objects or systems containing charge.</li> <li>At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.</li> </ul>

## **Unit Learning Targets**

Students will...

- Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
- Make claims about natural phenomena based on conservation of electric charge
- Make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.
- Construct an explanation of the two-charge model of electric charge.
- Use Coulomb's Law qualitatively and quantitatively to make predictions about interactions between collections of electric point charges.
- Connect the concepts of gravitational force and electric force to compare similarities and

differences between forces.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

## Formative Assessments:

- Quizzes
- Section Tests
- Take home assignments

Lesson Plans	
Activities/Interdisciplinary Connections	Timeframe
• Charge two identical balloons connected to the ceiling by 1 to 2 m long strings. (It may need to be rubbed against a Van de Graaf generator.) As they repel each other and cause their strings to angle, have students make the necessary measurements to be able to calculate the charge on each balloon (assuming they have the same charge).	4 weeks
• Object 1 is fixed in place, and object 2 is free to move; both are charged. Have students explain how the velocity and acceleration of object 2 are changing (increasing or decreasing) as object 2 moves toward (or away from) object 1 if both have the same (or different) sign and magnitude of charge.	
• Two charged balloons hang at equal heights from strings attached at the same point on the ceiling. However, balloon 1's string makes a greater angle with the vertical. Student A thinks that balloon 2 has more charge than balloon 1, and Student B thinks that balloon 2 has more mass than balloon 1. Have students discuss the predictions and outline which parts of each argument are correct or incorrect.	
• Two identical spheres made of carbon-12 are in	

space. An equal number of electrons are removed from both spheres so that the spheres remain at rest, with electric and gravitational forces balanced. Have students determine what fraction of the total electrons on each sphere were removed. (Answer: One out of every 5.56 • 10 <sup>17</sup> electrons was removed.)	
• Have students calculate the electric force repelling two protons in a helium nucleus (230.4 N if $r = 10^{-15}$ m), then predict whether it is gravity that holds the nucleus together. Next, have students calculate the gravitational force attracting the protons (1.86 • 10 <sup>-34</sup> N).	
Teacher Resources	Teacher Note
<ul> <li>Lab equipment, computers, analysis programs, projectors</li> <li>Differentiating Instruction</li> <li>Students with Disabilities, English Lagrand Gifted &amp; Talented Statement</li> </ul>	anguage Learners,
Examples of Strategies and Practices that Support Students	
<ul> <li>Use of visual and multisensory formats</li> <li>Use of assisted technology</li> <li>Use of prompts</li> <li>Modification of content and student products</li> <li>Testing accommodations</li> <li>Authentic assessments</li> </ul>	
Examples of Strategies and Practices that Support Gifted & Talented Students: • Adjusting the pace of lessons • Curriculum compacting • Inquiry-based instruction • Independent study • Higher-order thinking skills	

- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers

• Use of cognates to increase comprehension

• Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls
- •Sentence frames
- •Think-pair-share
- •Cooperative learning groups

# Advanced Placement Physics Grade 12 Framework

#### Unit Title: DC Circuits

**Unit Summary:** In Unit 9, students will draw on their knowledge of electricity and apply it to the conservation of charge in electric circuits. This unit will push students to move beyond mathematically solving for current, resistance, and voltage and will challenge them to make connections between system interactions and the changes that result from these interactions. For example, students must not only be able to calculate the resistance of a light bulb in a circuit; they must also be able to articulate the impact on other bulbs in the circuit if that light bulb is removed. Throughout the unit, it is essential that students have opportunities to create and use representations and models, especially as evidence to make predictions, justify claims, and overcome any preconceived notions about circuits. It is also important that students develop an understanding of the language used in Unit 8. Correctly using vocabulary terms such as "voltage," "current," and "energy" is essential to accurately describe, analyze, and reason with content presented in this course. By helping students relate theoretical models of electricity to real circuits, Unit 9 sets the stage for AP Physics C: Electricity and Magnetism, which explores circuits in greater depth.

Primary Interdisciplinary Connections: MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

### **Learning Targets**

NJSLS Standards: HS-PS3-1, HS-PS3-2, HS-PS3-3, HS-PS3-4, HS-PS3-6

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

**ELA Companion Standards:** RST.11-12.1, WHST.9-12.7, WHST.11-12.8, WHST.9-12.9, SL.11-12.5

#### **Content Statements:**

1	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
4	Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

**Big Idea:** Objects and systems have properties such as mass and charge. Systems may have internal structure. Changes that occur as a result of interactions are constrained by conservation laws.

Unit Essential Questions:	Unit Enduring Understandings:
• How do you decide what to believe	• Electric charge is a property of an object
about scientific claims?	or a system that affects its interactions
• How does something we cannot see	with other objects or systems containing
determine how an object behaves?	charge.
• How do the laws of conservation of	Materials have many macroscopic
charge and energy allow us to light	properties that result from the
our homes and businesses?	arrangement and interactions of the
• How does the conservation of	atoms and molecules that make up the
charge govern interactions between	material.
objects and systems?	• The energy of a system is conserved.
• How does the law of conservation	• The electric charge of a system is
of energy govern the interactions	conserved.
between objects and systems?	

### **Unit Learning Targets**

Students will...

- Make claims about natural phenomena based on conservation of electric charge.
- Make predictions, using the conservation of electric charge, about the sign and relative quantity of net charge of objects or systems after various charging processes, including conservation of charge in simple circuits.
- Choose and justify the selection of data needed to determine resistivity for a given material.
- Construct or interpret a graph of the energy changes within an electrical circuit with only a single battery and resistors in series and/or in, at most, one parallel branch as an application of the conservation of energy (Kirchhoff's loop rule).
- Apply conservation of energy concepts to the design of an experiment that will demonstrate the validity of Kirchhoff's loop rule ( $\sum \Delta V = 0$ ) in a circuit with only a battery and resistors either in series or in, at most, one pair of parallel branches.
- Apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch.
- Apply conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed.

- Design an investigation of an electrical circuit with one or more resistors in which evidence of conservation of electric charge can be collected and analyzed.
- Use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

#### **Formative Assessments:**

- Quizzes
- Section Tests
- Take home assignments

Activities/Interdisciplinary Connections
Ask students to imagine a wire immersed in water with both ends connected to a battery to short the wire and heat the water. Ask, "What heats the water faster: thick or thin wire? Long or short wire?"
Have students choose an object or a substance that somewhat conducts electricity but is not normally used in a circuit (e.g., cylinder of modeling dough, cup of water). Students determine whether this substance is ohmic using five batteries and a multimeter.
Student A draws a two- or three-resistor circuit with resistors labeled X, Y, and (maybe) Z. There are also a voltmeter and an ammeter in the circuit, correctly connected (voltmeter is connected in parallel to only one of the resistors). Student A says, "the voltmeter reading needs to increase" (or decrease) and "the ammeter reading needs to decrease" (or increase). It is up to Student B to determine which resistor needs to change (and how: increase or decrease) to make the meters both change in that way.

• Resistors $R_s$ and $r_s$ are in series with a battery, and		
$R_p$ and $r_p$ are in parallel with an identical battery,		
where $R_s = R_p > r_s = r_p$ . Have students rank		
potential difference, current, and power		
dissipated for all four resistors. (Voltage: $R_p =$		
$r_p > R_S > r_S$ , Current: $r_p > R_p > R_S = r_S$ , Power:		
$\mathbf{r}_{\mathbf{p}} > \mathbf{R}_{\mathbf{p}} > \mathbf{R}_{\mathbf{S}} > \mathbf{r}_{\mathbf{S}}).$		
Teacher Resources	Teacher Note	
• Lab equipment, computers, analysis programs,		
projectors		
Differentiating Instruction:		
Students with Disabilities, English Language Learners,		

and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:

- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts
- Modification of content and student products
- Testing accommodations
- Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls

Sentence framesThink-pair-shareCooperative learning groups

# Advanced Physics Physics Grade 12 Framework

### Unit Title: Mechanical Waves and Sounds

**Unit Summary:** In Unit 10, students will move away from the main themes of the previous units and learn about mechanical waves. Although concepts like oscillation, energy, and motion carry over into the study of waves, students will be introduced to new tools to communicate scientific phenomena and solve scientific models. Standing wave models, for example, are applied in Unit 10 to support a more in-depth knowledge of musical instruments and sounds. Because knowledge of mechanical waves is essential for understanding a wide range of physical phenomena (including light and the wave properties of matter), students will have several opportunities in Unit 10 to connect and relate knowledge across various scales, concepts, and representations. Being able to identify and describe the relationships between physical quantities and use these relationships as justification for claims are equally essential. Although its content remains distinct from earlier units, Unit 10 presents concepts that will help students succeed in later physics courses. Students who take AP Physics 2 will further investigate the ideas presented in Unit 10 through their additional study of mechanical waves.

**Primary Interdisciplinary Connections:** MP.2, MP.4, HSA-SSE.A.1, HSA-SSE.B.3, HSA.CED.A.4

**21<sup>st</sup> Century Career and Life Themes:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration, Information Literacy, Media Literacy

# Learning Targets

### NJSLS Standards: HS-PS4-1.

**Technology Standards:** 8.1.12.A.1, 8.1.12.A.2, 8.1.12.A.3, 8.1.12.A.4, 8.1.12.A.5, 8.1.P.B.1, 8.1.2.B.1, 8.1.5.B.1, 8.1.8.B.1, 8.1.2.C.1, 8.1.12.C.1, 8.1.12.D.5, 8.1.12.E.1, 8.1.12.F.1, 8.2.12.A.1, 8.2.12.C.3, 8.2.12.C.4, 8.2.12.C.5, 8.2.12.E.1

### ELA Companion Standards: RST.11-12.7

### **Content Statements:**

1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

**Big Idea:** Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

Unit Essential Questions:	Unit Enduring Understandings:
• How can data be used to help us	• A wave is a traveling disturbance that
create models of phenomena we	transfers energy and momentum.
see around us?	• A periodic wave is one that repeats as a
• Why does a police siren sound	function of both time and position and can be described by its amplitude,
different when it is moving	frequency, wavelength, speed, and
	energy.

toward you than when it is moving away from you?	• Interference and superposition lead to standing waves and beats.
	standing waves and boats.
• What happens when two waves	
meet?	
How is resonance responsible	
for the Tacoma Narrows	
Bridge collapse?	
• How is sound produced?	

# **Unit Learning Targets**

Students will...

- Use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.
- Describe representations of transverse and longitudinal waves.
- Describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.
- Use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.
- Explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave and/or apply this concept to a real-world example.
- Use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.
- Use a visual representation of a periodic mechanical wave to determine the wavelength of the wave.
- Design an experiment to determine the relationship between periodic wave speed wavelength, and frequency and relate these concepts to everyday examples.
- Create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent on relative motions of source and observer.
- Use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.
- Design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).
- Design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.
- Analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.
- Refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.

- Predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.
- Plan data-collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared with the prediction, explain any discrepancy, and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.
- Describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.
- Challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source, regardless of the size of the region.
- Calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined and calculate numerical values of wavelengths and frequencies.
- Use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

# **Evidence of Learning**

Summative Assessment: Labs, Unit Tests, Benchmarks

### **Formative Assessments:**

- Quizzes
- Section Tests
- Take home assignments

### **Lesson Plans**

Activities/Interdisciplinary Connections	Timeframe
• Have students use long springs to create a standing wave. The students make measurements necessary to find the wave speed (wavelength and period data) and the maximum speed attained at an antinode point (amplitude and period data). Students then calculate the wave speed and maximum "particle speed" and see that they are different.	4 weeks
• Student A chooses one quantity (frequency, wavelength, wave speed) that stays constant, and a second that either increases or decreases. Student B must state what the third quantity does (increase or decrease) and then describe a situation where a wave undergoes the changes	

### that A prescribed.

• Students are given several glass bottles. The students choose a song, research its sheet music, fill the bottles with amounts of water calculated to cause the bottles to resonate at the different tones of the song, and then play the song with the bottles.	
• Have students blow perpendicularly across a straw while a tone-detecting app on a smartphone is listening. The app registers the fundamental frequency of the standing wave in the straw; students use this and the straw length to calculate the speed of sound. Cut off lengths of straw and repeat, linearizing frequency and wavelength to get the speed of sound.	
• A pipe 2 m long is in a room where the speed of sound in the air is 343 m/s. Square 1: Students draw the first three harmonics if the pipe is open and calculate the harmonic frequencies. Square 2: Students draw the first three harmonics if the pipe is closed and calculate the frequencies. Square 3: Students plot on a number line the first three open frequencies and the first three closed frequencies with different symbols. Square 4: Students describe the pattern on the number line.	
Teacher Resources	Teacher Note
<ul> <li>Lab equipment, computers, analysis programs, projectors</li> </ul>	

# Differentiating Instruction: Students with Disabilities, English Language Learners, and Gifted & Talented Students

Examples of Strategies and Practices that Support Students with Disabilities:

- Use of visual and multisensory formats
- Use of assisted technology
- Use of prompts

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• Modification of content and student products

• Testing accommodations

• Authentic assessments

Examples of Strategies and Practices that Support Gifted & Talented Students:

- Adjusting the pace of lessons
- Curriculum compacting
- Inquiry-based instruction
- Independent study
- Higher-order thinking skills
- Interest-based content
- Student-driven instruction
- Real-world problems and scenarios

Examples of Strategies and Practices that Support English Language Learners:

- Pre-teaching of vocabulary and concepts
- Visual learning, including graphic organizers
- Use of cognates to increase comprehension
- Teacher modeling

• Pairing students with beginning English language skills with students who have more advanced English language skills

- Scaffolding
- •Word walls
- •Sentence frames
- •Think-pair-share
- •Cooperative learning groups