AP Physics 1

Curriculum Guide

Dunmore School District

Dunmore, PA



AP Physics 1

Prerequisite:

From The College Board[®] AP[®] Physics 1: Algebra-Based Course and Exam Description,

"Students should have completed geometry and be concurrently taking Algebra II or an equivalent course. Although the Physics 1 course includes basic use of trigonometric functions, this understanding can be gained either in the concurrent math course or in the AP Physics 1 course itself."

Note: Materials that are "Teacher Prepared" are reflected in The College Board[®] approved AP[®] Course Audit.

AP Physics 1 is an algebra-based college level course designed to either prepare students to succeed in their introductory college physics courses or to possibly test out of their introductory college physics courses based on performance on the AP[®] Physics 1 exam by The College Board[®]. Course content is aligned to course framework described in *AP[®] Physics 1: Algebra-Based Course and Exam Description*.

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Year-at-a-glance

Subject: AP Physics 1	Grade Level: 12	Date Completed: 1/23/2018
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1st Quarter

Торіс	Resources	Standards
Content Area 1: Kinematics	Teacher Prepared	3.A, 4.A
Content Area 2: Dynamics	Teacher Prepared	1.A, 1.C, 2.B, 3.A, 3.B, 4.A
Content Area 3: Circular Motion and Gravitation	Teacher Prepared	1.C, 2.A, 2.B, 3.A,

2nd Quarter

Торіс	Resources	Standards
Content Area 4: Energy	Teacher Prepared	3.E, 4.C, 5.A, 5.B, 5.D
Content Area 5: Momentum	Teacher Prepared	3.D, 4.B, 5.A, 5.D
Content Area 6: Simple Harmonic Motion	Teacher Prepared	3.B, 5.B

3rd Quarter

Торіс	Resources	Standards
Content Area 7: Torque and Rotational Motion	Teacher Prepared	3.A, 3.F, 4.D, 5.E
Content Area 8: Electric Charge and Electric Force	Teacher Prepared	1.B, 3.C, 5.A

4th Quarter

Торіс	Resources	Standards
Content Area 9: DC Circuits	Teacher Prepared	1.B, 1.E, 5.B, 5.C
Content Area 10: Mechanical Waves and Sound	Teacher Prepared	6.A, 6.B, 6.D
Review and Final Exam		

General Topic	AP Standards	Learning Objective,	Resources &	Assessments	Suggested
Content Area 1:		Skills & Vocabulary	Activities		Time
Kinematics					(In Days)
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	3.A.1: An observer in a	3.A.1.1: The student is able	Lab Investigation 1:		
3.A: All forces	particular reference frame can	to express the motion of an	1D and 2D	Series available	
share certain	describe the motion of an object	object using narrative,	Kinematics	assessments online.	
common	using such quantities as	mathematical, and graphical		(Optional)	
characteristics	position, displacement,	representations. [SP 1.5, 2.1,	Projectile Motion		
when considered	distance, velocity, speed, and	2.2]	Activity (Optional)		
by observers in	acceleration.				
inertial reference		3.A.1.2: The student is able			
frames.	a. Displacement, velocity, and	to design an experimental			
	acceleration are all vector	investigation of the motion of			
4.A: The	quantities.	an object. [SP 4.2]			
acceleration of					
the center of mass	b. Displacement is change in	3.A.1.3: The student is able			
of a system is	position. Velocity is the rate of	to analyze experimental data			
related to the net	change of position with time.	describing the motion of an			
force exerted on	Acceleration is the rate of	object and is able to express			
the system, where	change of velocity with time.	the results of the analysis			
	Changes in each property are	using narrative,			
$\vec{a} = rac{\sum \vec{F}}{m}.$	expressed by subtracting initial	mathematical, and graphical			
$a = -\frac{1}{m}$.	values from final values.	representations.			
	Relevant Equations:	4.A.1.1 The student is able to			
	$\overrightarrow{\Delta x}$	use representations of the			
	$\overrightarrow{v_{avg}} = \frac{\overrightarrow{\Delta x}}{\Delta t}$	center of mass of an isolated			
		two-object system to analyze			
	$\overrightarrow{\Delta v}$	the motion of the system			
	$\overrightarrow{a_{avg}} = \frac{\Delta v}{\Delta t}$	qualitatively and semi-			

	quantitatively. [SP 1.2, 1.4,		
c. A choice of reference frame	2.3, 6.4]		
determines the direction and	2.3, 0.4]		
the magnitude of each of these	4.A.2.1 The student is able to		
-	make predictions about the		
quantities.			
d. These are three for demonstrat	motion of a system based on		
d. There are three fundamental	the fact that acceleration is		
interactions or forces in nature:	equal to the change in		
the gravitational force, the	velocity is equal to the		
electroweak force, and the	change in position per unit		
strong force. The fundamental	time. [SP 6.4]		
forces determine both the			
structure of objects and the	4.A.2.3: The student is able		
motion of objects.	to create mathematical		
	models and analyze graphical		
e. In inertial reference frames,	relationships for		
forces are detected by their	acceleration, velocity, and		
influence on the motion	position of the center of		
(specifically the velocity) of an	mass of a system and use		
object. So force, like velocity, is	them to calculate properties		
a vector quantity. A force vector	of the motion of the center		
has magnitude and direction.	of mass of a system. [SP 1.4,		
When multiple forces are	2.2]		
exerted on an object, the vector			
sum of these forces, referred to			
as the net force, causes a	Vocabulary:		
change in the motion of the	position		
object. The acceleration of the	displacement		
object is proportional to the net	velocity		
force.	acceleration		
	angular position		
f. The kinematic equations only	angular displacement		
apply to constant acceleration	angular velocity		
situations. Circular motion and	angular acceleration		
 situations. circular motion and			

projectile metion are both			[]
projectile motion are both	uniform motion		
included. Circular motion is			
further covered in Content Area			
3. The three kinematic			
equations describing linear			
motion with constant			
acceleration in one and two			
dimensions are:			
$12 - 12_{0} + at$			
$v = v_0 + at$			
$v = v_0 + at$ $x = x_0 = v_0 t + \frac{1}{2}at^2$			
$v^2 = v_0^2 + 2a\Delta x$			
$v = v_0 + 2u \Delta x$			
g. For rotational motion there			
are analogous quantities such as			
angular position, angular			
velocity, and angular			
acceleration. The kinematic			
equations describing angular			
motion with constant angular			
acceleration are:			
$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$			
$\omega = \omega_0 + \alpha t$ $\omega^2 = \omega_0^2 + 2\alpha \Delta \theta$			
$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$			
Circular motion and projectile			
motion are both included.			
Circular motion will be discussed			
later in this document.			
4.A.1: The linear motion of a			
system can be described by the			
system can be described by the			

displacement, velocity, and		
acceleration of its center of		
mass.		
a. The variables <i>x, v,</i> and <i>a</i> all		
refer to the center-of-mass		
quantities.		
Relevant Equations:		
$v = v_0 + at$ $x = x_0 = v_0 t + \frac{1}{2}at^2$		
$x = x = n t + \frac{1}{at^2}$		
$x = x_0 = v_0 t + \frac{1}{2} u t$		
$v^2 = v_0^2 + 2a\Delta x$		
4.A.2: The acceleration is equal		
to the rate of change of velocity		
with time, and velocity is equal to the rate of change of position		
with time.		
with time.		
a. The acceleration of the center		
of mass of a system is directly		
proportional to the net force		
exerted on it by all objects		
interacting with the system and		
inversely proportional to the		
mass of the system.		
b. Force and acceleration are		
both vectors, with acceleration		
in the same direction as the net		
force.		
The second sector fields		
c. The acceleration of the center		

	of mass of a system is equal to		
	the rate of change of the center		
	of mass velocity with time, and		
	the center of mass velocity is		
	equal to the rate of change of		
	the position of the center of		
	mass with time.		
	d. The variables <i>x, v,</i> and <i>a</i> all		
	refer to the center-of-mass		
	quantities.		
	Relevant Equations:		
	N E		
	$\vec{a} = \frac{\sum \vec{F}}{m}$		
	m _{system}		
	$\overline{v_{ana}} = \frac{\Delta x}{\Delta x}$		
	$\overrightarrow{v_{avg}} = \frac{\overrightarrow{\Delta x}}{\Delta t}$		
	Ā		
	$\overrightarrow{a_{avg}} = \frac{\overrightarrow{\Delta v}}{\Delta t}$		
	Δt		
L			

General Topic Content Area 2: Dynamics	AP Standards	Learning Objective, Skills & Vocabulary	Resources & Activities	Assessments	Suggested Time (In Days)
Enduring Understanding:	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared tests, quizzes, etc.	17
	1.A.1: A system is an object or a	1.A.5.1: The student is	Lab Investigation 2:		
1.A: The internal	collection of objects. Objects are	able to model verbally or	Newton's Second Law	Series available	
structure of a	treated as having no internal	visually the properties		assessments	
system	structure.	of a system based on its		online. (Optional)	
determines many		substructure and to relate			
properties of the	a. A collection of particles in	this to changes in the			
system.	which internal interactions	system properties over			
	change little or not at all, or in	time as external variables			
1.C: Objects and	which changes in these	are changed. [SP 1.1, 7.1]			
systems have	interactions are irrelevant to the				
properties of	question addressed, can be	1.C.1.1: The student			
inertial mass and	treated as an object.	is able to design an			
gravitational mass		experiment for collecting			
that are	b. Some elementary particles	data to determine the			
experimentally	are fundamental particles (e.g.,	relationship between the			
verified to be the	electrons). Protons and	net force exerted on an			
same and that	neutrons are composed of	object its inertial mass			
satisfy	fundamental particles (i.e.,	and its acceleration.			
conservation	quarks) and might be treated as	[SP 4.2]			
principles.	either systems or objects,				
	depending on the question	1.C.3.1: The student is			
2.B: A	being addressed.	able to design a plan for			
gravitational field		collecting data to measure			
is caused by an	c. The electric charges on	gravitational mass and to			
object with mass.	neutrons and protons result	measure inertial mass and			
	from their quark compositions.	to distinguish between the			
3.A: All forces		two experiments. [SP 4.2]			

share certain	1.A.5: Systems have properties			
common	determined by the properties	2.B.1.1: The student is		
characteristics	and interactions of their	able to apply to calculate the		
when considered	constituent atomic and	gravitational force on an		
by observers in	molecular substructures. In AP	object with mass m in a		
inertial reference	Physics, when the properties of	gravitational field of strength		
frames.	the constituent parts are not	g in the context of the effects		
	important in modeling the	of a net force on objects and		
3.B: Classically,	behavior of the macroscopic	systems. [SP 2.2, 7.2]		
the acceleration	system, the system itself may be			
of an object	referred to as an object.	3.A.2.1: The student		
interacting with		is able to represent		
other objects can	1.C.1: Inertial mass is the	forces in diagrams or		
be predicted by	property of an object or a	mathematically using		
using	system that determines how its	appropriately labeled		
$\vec{a} - \sum \vec{F}$	motion changes when it	vectors with magnitude,		
$\vec{a} = \frac{\sum \vec{F}}{m_{system}}.$	interacts with other objects or	direction, and units during		
	systems.	the analysis of a situation.		
	a.	[SP 1.1]		
3.C: At the	$\sum \vec{F}$			
macroscopic level,	$\vec{a} = rac{\sum \vec{F}}{m_{system}}$	3.A.3.1: The student		
forces can be	Illsystem	is able to analyze a		
categorized as		scenario and make claims		
either long-range	1.C.3: Objects and systems have	(develop arguments,		
(action-at-a-	properties of inertial mass and	justify assertions) about		
distance) forces or	gravitational mass that are	the forces exerted on an		
contact forces.	experimentally verified to be the	object by other objects for		
	same and that satisfy	different types of forces or		
4.A: The	conservation principles.	components of forces.		
acceleration of		[SP 6.4, 7.2]		
the center of mass	2.B.1: A gravitational field \vec{g} at			
of a system is	the location of an object with	3.A.3.2: The student is		
related to the net	-	able to challenge a claim		
force exerted on	mass <i>m</i> causes a gravitational	that an object can exert a		
the system, where	force <i>mg</i> to be exerted on the	-		

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$\vec{a} = \frac{\sum \vec{F}}{m}$.	object in the direction of the	force on itself. [SP 6.1]	
m _{system}	field.		
		3.A.3.3: The student is	
	a. On Earth, this gravitational	able to describe a force	
	force is called weight.	as an interaction between	
		two objects and identify	
	b. The gravitational field at a	both objects for any force.	
	point in space is measured by	[SP 1.4]	
	dividing the gravitational force		
	exerted by the field on a test	3.A.4.1: The student	
	object at that point by the mass	is able to construct	
	of the test object and has the	explanations of physical	
	same direction as the force.	situations involving the	
		interaction of bodies	
	c. If the gravitational force is the	using Newton's third law	
	only force exerted on the object,	and the representation of	
	the observed free-fall	action-reaction pairs of	
	acceleration of the object (in	forces. [SP 1.4, 6.2]	
	meters per second per second)		
	is numerically equal to the	3.A.4.2: The student is	
	magnitude of the gravitational	able to use Newton's third	
	field (in Newtons per kilogram)	law to make claims and	
	at that location	predictions about the	
		action-reaction pairs of	
	Relevant Equation:	forces when two objects	
		interact.	
	$\vec{F} = m\vec{q}$	[SP 6.4, 7.2]	
	3.A.2: Forces are described by	3.A.4.3: The student is	
	vectors.	able to analyze situations	
		involving interactions	
	a. Forces are detected by their	among several objects	
	influence on the motion of an	by using free-body	
	object.	diagrams that include the	
	Relevant Equation: $\vec{F} = m\vec{g}$ 3.A.2: Forces are described by vectors. a. Forces are detected by their influence on the motion of an	action-reaction pairs of forces when two objects interact. [SP 6.4, 7.2] 3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body	

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	application of Newton's		
b. Forces have magnitude and	third law to identify		
direction.	forces. [SP 1.4]		
3.A.3: A force exerted on an	3.B.1.1: The student is		
object is always due to the	able to predict the motion		
interaction of that object with	of an object subject		
another object.	to forces exerted by		
	several objects using an		
a. An object cannot exert a force	application of Newton's		
on itself.	second law in a variety		
b. Even though an object is at	of physical situations		
rest, there may be forces exerted	with acceleration in one		
on that object by other objects.	dimension. [SP 6.4, 7.2]		
c. The acceleration of an object,	3.B.1.2: The student is		
but not necessarily its velocity, is	able to design a plan		
always in the direction of the net			
force exerted on the object by	data for motion (static,		
other objects.	constant, or accelerating)		
	from force measurements		
3.A.4: If one object exerts a force	and carry out an		
on a second object, the second	analysis to determine the		
object always exerts a force of	relationship between the		
equal magnitude on the first	net force and the vector		
object in the opposite direction.	sum of the individual		
3.B.1: If an object of interest	forces. [SP 4.2, 5.1]		
interacts with several other	2 D 4 2. The student		
objects, the net force is the vector	3.B.1.3: The student		
sum of the individual forces.	is able to re-express		
Projectile motion and circular	a free-body diagram		
motion are both included in AP	representation into		
Physics 1.	a mathematical		
	representation and		

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[SP 1.5, 2.2]			
3.B.2.1: The student is able			
to create and use free- body			
diagrams to analyze physical			
situations to solve problems			
with motion qualitatively and			
quantitatively. [SP 1.1, 1.4,			
2.2]			
3.C.4.1: The student is			
able to make claims about			
various contact forces			
between objects based on			
the microscopic cause of			
those forces. [SP 6.1]			
3.C.4.2: The student is			
able to explain contact			
forces (tension, friction,			
normal, buoyant,			
spring) as arising from			
interatomic electric forces			
and that they therefore			
have certain directions. [SP			
6.2]			
4.A.1.1 The student			
is able to use			
representations of the			
center of mass of an			
	to create and use free- body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [SP 1.1, 1.4, 2.2] 3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [SP 6.1] 3.C.4.2: The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.2] 4.A.1.1 The student is able to use representations of the	representation for the acceleration of the object. [SP 1.5, 2.2] 3.B.2.1: The student is able to create and use free- body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [SP 1.1, 1.4, 2.2] 3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [SP 6.1] 3.C.4.2: The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.2] 4.A.1.1 The student is able to use representations of the	representation for the acceleration of the object. [SP 1.5, 2.2] 3.8.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [SP 1.1, 1.4, 2.2] 3.C.4.1: The student is able to make claims about various contact forces between objects based on the microscopic cause of those forces. [SP 6.1] 3.C.4.2: The student is able to explain contact forces (tension, friction, normal, buoyant, spring) as arising from interatomic electric forces and that they therefore have certain directions. [SP 6.2] 4.A.1.1 The student is able to use representations of the

			1	1	
C	A coordinate system with one	isolated two-object system			
ax	is parallel to the direction of	to analyze the motion of			
the	e acceleration simplifies	the system qualitatively			
the	e translation from the free	and semiquantitatively.			
bo	ody diagram to the algebraic	[SP 1.2, 1.4, 2.3, 6.4]			
re	presentation.				
d.	Free-body diagrams are	4.A.2.2: The student is			
de	picted where the forces	able to evaluate using			
ex	erted on an object are	given data whether all			
re	presented as arrows pointing	the forces on a system			
ou	itward from a dot, and	or whether all the parts			
als	so diagrams that show at what	of a system have been			
ро	pint on the object each force is	identified. [SP 5.3]			
ex	erted.				
		4.A.3.1: The student is			
3.0	C.4: Contact forces result from	able to apply Newton's			
the	e interaction of one object	second law to systems			
to	uching another object and	to calculate the change			
the	ey arise from interatomic	in the center-of-mass			
ele	ectric forces. These forces	velocity when an external			
inc	clude tension, friction, normal,	force is exerted on the			
sp	ring (Physics 1), and buoyant	system. [SP 2.2]			
(PI	hysics 2).				
		4.A.3.2: The student			
Re	elevant Equations:	is able to use visual			
		or mathematical			
	$\left \overrightarrow{F_{f}} \right = \mu \left \overrightarrow{F_{N}} \right $	representations of the			
		forces between objects			
	$\left \overrightarrow{F_{sp}} \right = k \left \overrightarrow{x} \right $	in a system to predict			
		whether or not there will			
4.1	A.1: The linear motion of a	be a change in the center-			
	stem can be described by the	of-mass velocity of that			
	splacement, velocity, and	system. [SP 1.4]			
	celeration of its center of				
de			1	1	1

r	nass. The variables x, v, and a;			
a	all refer to the center-of-mass	Vocabulary:		
C	quantities.	Force		
		Newton's Laws of Motion		
F	Relevant Equations:	Object		
		System		
	$v = v_0 + at$	Particle		
	$v = v_0 + at$ $x = x_0 = v_0 t + \frac{1}{2}at^2$	Center of mass		
		Weight		
	$v^2 = v_0^2 + 2a\Delta x$	Gravitational field		
	I.A.2: The acceleration is equal	Electrostatic Force		
	to the rate of change of velocity	Normal Force		
	with time, and velocity is	Tension Force		
	equal to the rate of change of	Friction Force Static coefficient of friction		
	position with time.	Kinetic coefficient of friction		
-	a. The acceleration of the center	Spring Force		
	of mass of a system is directly	Spring constant		
	proportional to the net force	Equilibrium		
e	exerted on it by all objects	Free Body Diagram		
i	nteracting with the system and	Force Equation		
i	nversely proportional to the			
r	mass of the system.			
F	Relevant Equation:			
	-			
	$\vec{a} = \frac{\sum \vec{F}}{\sum \vec{F}}$			
	$\vec{a} = rac{\sum \vec{F}}{m_{system}}$			
	 Force and acceleration are 			
	both vectors, with acceleration			
	n the same direction as the			
r	net force.			

Relevant Equation	15:		
$\overrightarrow{v_{avg}} =$ $\overrightarrow{a_{avg}} =$	$\frac{\overrightarrow{\Delta x}}{\Delta t}$ $\frac{\overrightarrow{\Delta v}}{\Delta t}$		
c. The acceleration of mass of a syste the rate of change center of mass ve time, and the cent velocity is equal to change of the pos center of mass wit d. The variables x, refer to the cente quantities.	m is equal to e of the locity with ter of mass o the rate of ition of the th time. v, and a all		
Relevant Equation: $\vec{a} = \frac{\sum \vec{F}}{m}$ 4.A.3: Forces that on each other are	$=\frac{\overrightarrow{F_{net}}}{m}$ systems exert		
interactions between the systems. If the systems of the system system, there will in the center-of-methat system.	een objects the interacting of the same be no change		

Relevant Equation:		
$\vec{a} = rac{\sum \vec{F}}{m} = rac{\overline{F_{net}}}{m}$		

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 3:		Skills & Vocabulary			Time
Circular Motion					(In Days)
and Gravitation					
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	1.C.2: Gravitational mass is the	1.C.3.1: The student is	Lab Investigation 3:		
1.C: Objects and	property of	able to design a plan for	Circular Motion	Series available	
systems have	an object or a system that	collecting data to measure		assessments	
properties	determines the	gravitational mass and to		online. (Optional)	
of inertial mass	strength of the gravitational	measure inertial mass and			
and	interaction with	to distinguish between the			
gravitational mass	other objects, systems, or	two experiments. [SP 4.2]			
that are	gravitational fields.				
experimentally	a. The gravitational mass of an	2.B.1.1: The student is			
verified	object	able to apply			
to be the same	determines the amount of force	$ec{F}=mec{g}$			
and that	exerted on the	to			
satisfy	object by a gravitational field.	calculate the gravitational			
conservation	b. Near the Earth's surface, all	force on an object with			
principles.	objects fall	mass <i>m</i> in a gravitational			
	(in a vacuum) with the same	field of strength <i>g</i> in the			
2.A: A field	acceleration,	context of the effects of a			
associates a	regardless of their inertial mass.	net force on objects and			
value of some		systems. [SP 2.2, 7.2]			
physical	1.C.3: Objects and systems have				
quantity with	properties	2.B.2.1: The student is			
every point	of inertial mass and gravitational	able to apply			
in space. Field	mass that	$\vec{a} - GM$			
models	are experimentally verified to be	$\vec{g} = \frac{dM}{r^2}$			
are useful for	the same and	to			
describing	that satisfy conservation	calculate the gravitational			

interactions that	principles.	field due to an object with		
occur		mass <i>M</i> , where the field is		
at a distance	2.A.1: A vector field gives, as a	a vector directed toward		
(long-range	function of	the center of the object of		
forces) as well as	position (and perhaps time), the	mass <i>M</i> . [SP 2.2]		
a	value of a			
variety of other	physical quantity that is	2.B.2.2: The student is		
physical	described by a vector.	able to approximate a		
phenomena.	a. Vector fields are represented	numerical value of the		
	by field vectors	gravitational field (g) near		
2.B: A	indicating direction and	the surface of an object		
gravitational field	magnitude.	from its radius and mass		
is caused by an	b. When more than one source	relative to those of the		
, object	object with	Earth or other reference		
with mass.	mass or electric charge is	objects. [SP 2.2]		
	present, the field			
3.A: All forces	value can be determined by	3.A.1.1: The student		
share	vector addition.	is able to express the		
certain common	c. Conversely, a known vector	motion of an object using		
characteristics	field can be	narrative, mathematical,		
when	used to make inferences about	and graphical		
considered by	the number,	representations.		
observers	relative size, and location of	[SP 1.5, 2.1, 2.2]		
in inertial	sources.			
reference		3.A.1.2: The student		
frames.	Boundary Statement:	is able to design an		
	Physics 1 treats gravitational	experimental investigation		
3.B: Classically,	fields; Physics 2 treats electric	of the motion of an object.		
the	and magnetic fields.	[SP 4.2]		
acceleration of an				
object	2.B.1: A gravitational field <i>g</i> at	3.A.1.3: The student		
interacting with	the location of an object with	is able to analyze		
other	mass <i>m</i> causes a gravitational	experimental data		
objects can be	force of magnitude <i>mg</i> to be	describing the motion of		

[l .	[]	n	
predicted	exerted on the object in the	an object and is able to			
by using	direction of the field.	express the results of the			
$\vec{a} = \frac{\Sigma \vec{F}}{m}$.	a. On Earth, this gravitational	analysis using narrative,			
m m	force is called	mathematical and			
	weight.	graphical representatives.			
2 C. At the	b. The gravitational field at a	[SP 5.1]			
3.C: At the	point in space is				
macroscopic	measured by dividing the	3.A.2.1: The student is			
level, forces can	gravitational force	able to represent forces in			
be categorized as	exerted by the field on a test	diagrams or mathematically			
either long-range	object at that	using appropriately labeled			
(action-at-a-	point by the mass of the test	vectors with magnitude,			
distance) forces or	object and has	direction, and units during			
contact forces.	the same direction as the force.	the analysis of a situation.			
	c. If the gravitational force is the	[SP 1.1]			
3.G: Certain types	only force				
of forces are	exerted on the object, the	3.A.3.1: The student			
considered	observed free-fall	is able to analyze a			
fundamental.	acceleration of the object (in	scenario and make claims			
	meters per	(develop arguments,			
4.A: The	second squared) is numerically	justify assertions) about			
acceleration of	equal to	the forces exerted on an			
the center of mass	the magnitude of the	object by other objects for			
of a system is	gravitational field (in	different types of forces or			
related to the net	Newtons/kilogram) at that	components of forces.			
force exerted on	location.	[SP 6.4, 7.2]			
the system, where					
$\vec{a} = rac{\sum \vec{F}}{m_{system}}.$	Relevant Equation:	3.A.3.3: The student is			
m_{system}		able to describe a force as			
	$\overrightarrow{F_{\pi}}$	an interaction between two			
	$ec{g}=rac{ec{F_g}}{m}$	objects and identify both			
	m	objects for any force.			
	2.B.2: The gravitational field	[SP 1.4]			
	caused by a				
			1		

spherically symmetric object	3.A.4.1: The student is able		
with mass is	to construct explanations		
radial and, outside the object,	of physical situations		
varies as the	involving the interaction of		
inverse square of the radial	bodies using Newton's third		
distance from the	law and the representation		
center of that object.	of action-reaction pairs of		
a. The gravitational field caused	forces. [SP 1.4, 6.2]		
by a spherically symmetric			
object is a vector whose	3.A.4.2: The student is able		
magnitude outside the object is	to use Newton's third law to		
equal to $G \frac{M}{r^2}$.	make claims and predictions		
b. Only spherically symmetric	about the action-reaction		
objects will	pairs of forces when two		
be considered as sources of the	objects interact. [SP 6.4, 7.2]		
gravitational			
field.	3.A.4.3: The student is		
	able to analyze situations		
3.A.1: An observer in a	involving interactions		
particular reference	among several objects by		
frame can describe the motion	using free-body diagrams		
of an object	that include the application		
using such quantities as	of Newton's third law to		
position, displacement,	identify forces. [SP 1.4]		
distance, velocity, speed, and			
acceleration.	3.B.1.2: The student is		
a. Displacement, velocity, and	able to design a plan		
acceleration are	to collect and analyze		
all vector quantities.	data for motion (static,		
b. Displacement is change in	constant, or accelerating) from force measurements		
position.			
Velocity is the rate of change of	and carry out an analysis to determine the		
position with	relationship between the		
time. Acceleration is the rate of			

change of	net force and the vector		
velocity with time. Changes in	sum of the individual		
each property	forces. [SP 4.2, 5.1]		
are expressed by subtracting			
initial values	3.B.1.3: The student		
from final values.	is able to re-express		
c. A choice of reference frame	a free-body diagram		
determines the	representation into		
direction and the magnitude of	a mathematical		
each of these	representation and		
quantities.	solve the mathematical		
d. We know of three	representation for the		
fundamental interactions	acceleration of the object.		
or forces in nature: the	[SP 1.5, 2.2]		
gravitational force,			
the electroweak force, and the	3.B.2.1: The student is		
strong force.	able to create and use free-		
The fundamental forces	body diagrams to analyze		
determine both the	physical situations to		
structure of objects and the	solve problems with		
motion of objects.	motion qualitatively and		
e. In inertial reference frames,	quantitatively. [SP 1.1,		
forces are	1.4, 2.2]		
detected by their influence on			
the motion	3.C.1.1: The student is		
(specifically the velocity) of an	able to use Newton's law		
object. So	of gravitation to calculate		
force, like velocity, is a vector	the gravitational force the		
quantity. A force	two objects exert on each		
vector has magnitude and	other and use that force in		
direction. When	contexts other than orbital		
multiple forces are exerted on	motion. [SP 2.2]		
an object, the			
vector sum of these forces,	3.C.1.2: The student is		

referred to as the	able to use Newton's law		
net force, causes a change in the	of gravitation to calculate		
motion of	the gravitational force		
the object. The acceleration of	between two objects and		
the object is	use that force in contexts		
proportional to the net force.	involving orbital motion		
f. The three kinematic equations	(for circular orbital motion		
only apply	only in Physics 1). [SP		
to constant acceleration	2.2]		
situations. Circular			
motion and projectile motion	3.C.2.2: The student		
are both	is able to connect the		
included. Circular motion is	concepts of gravitational		
further covered in	force and electric force to		
Content Area 3.	compare similarities and		
g. The kinematic equations only	differences between the		
apply to	forces. [SP 7.2]		
constant acceleration situations			
Circular	3.G.1.1: The student is		
motion and projectile motion	able to articulate situations		
are both	when the gravitational		
included. Circular motion will be	force is the dominant		
discussed	force and when the		
later in this document.	electromagnetic, weak,		
h. For rotational motion, there	and strong forces can be		
are analogous	ignored. [SP 7.1]		
quantities such as angular			
position, angular	4.A.2.2: The student is		
velocity, and angular	able to evaluate using		
acceleration.	given data whether all		
i. This also includes situations	the forces on a system		
where there is	or whether all the parts		
both a radial and tangential	of a system have been		
acceleration for	identified. [SP 5.3]		

an object moving in a		
path.	Vocabulary:	
	Gravitational Field	
Relevant Equation:	Gravitational Mass	
	Gravitational Force	
v^2	Coulomb's Law	
$a_c = \frac{v^2}{r}$	Weight	
	Centripetal Force	
3.A.2: Forces are desc		
vectors.	Angular Velocity	
a. Forces are detected		
influence on the	Uniform Circular Motion	
motion of an object.		
b. Forces have magnit	ude and	
direction.		
3.A.3: A force exerted	on an	
object is always		
due to the interaction	of that	
object with another		
object.		
a. An object cannot ex	ert a force	
on itself.		
b. Even though an obj	ect is at	
rest, there may be		
forces exerted on that	object by	
other objects.		
c. The acceleration of	an object	
but not		
necessarily its velocity	, is always	
in the direction	, 15 01000 495	
of the net force exerte	ad on the	
object by other		
object by other		
objects.		

3.A.4: If one object exerts a force on a second object, the second object always exerts a force of equal magnitude on the first object in the opposite direction.		
3.B.1: If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.		
3.B.2: Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation. a. An object can be drawn as if it was extracted from its environment and the interactions with the environment identified. b. A force exerted on an object		
can be represented as an arrow whose length represents the magnitude of the		

force and		
whose direction shows the		
direction of the		
force.		
c. A coordinate system with one		
axis parallel		
to the direction of the		
acceleration simplifies		
the translation from the free		
body diagram to		
the algebraic representation.		
3.C.1: Gravitational force		
describes the interaction of one		
object with mass with		
another object with mass.		
a. The gravitational force is		
always attractive.		
b. The magnitude of force		
between two		
spherically symmetric objects of		
mass m_1 and m_2 is $\frac{Gm_1m_2}{r^2}$ where		
r is the center-to-center		
distance between the objects.		
c. In a narrow range of heights		
above the		
Earth's surface, the local		
gravitational field, g,		
is approximately constant.		
3.C.2: Electric force results from		
the		
interaction of one object that		
has an electric		

charge with another object that		
has an electric		
charge.		
a. Electric forces dominate the		
properties		
of the objects in our everyday		
experiences.		
However, the large number of		
particle		
interactions that occur make it		
more		
convenient to treat everyday		
forces in terms of		
nonfundamental forces called		
contact forces,		
such as normal force, friction,		
and tension.		
b. Electric forces may be		
attractive or		
repulsive, depending upon the		
charges on the		
objects involved.		
Relevant Equations:		
$F_g = \frac{Gm_1m_2}{r^2}$ $F_e = \frac{kq_1q_2}{r^2}$		
$r_g = \frac{r^2}{r^2}$		
$F_{-} = \frac{kq_1q_2}{kq_1q_2}$		
r^{e} r^{2}		
2 C 1. Crowitational forces are		
3.G.1: Gravitational forces are		
exerted at all		
scales and dominate at the		
largest distance		
and mass scales.		

4.A.2: The acceleration is equal		
to the rate of		
change of velocity with time,		
and velocity is		
equal to the rate of change of		
position with		
time.		
a. The acceleration of the center		
of mass of a		
system is directly proportional		
to the net force		
exerted on it by all objects		
interacting with the		
system and inversely		
proportional to the mass		
of the system.		
b. Force and acceleration are		
both vectors,		
with acceleration in the same		
direction as the		
net force.		

General Topic Content Area 4: Energy	AP Standards	Learning Objective, Skills & Vocabulary	Resources & Activities	Assessments	Suggested Time (In Days)
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	3.E.1: The change in the kinetic	3.E.1.1: The student is	Lab Investigation 4:		
3.E: A force	energy of an	able to make predictions	Conservation of Energy	Series available	
exerted on	object depends on the force	about the changes in		assessments	
an object can	exerted on the	kinetic energy of an object		online. (Optional)	
change	object and on the displacement	based on considerations			
the kinetic energy	of the object	of the direction of the net			
of the	during the interval that the	force on the object as the			
object.	force is exerted.	object moves. [SP 6.4, 7.2]			
	a. Only the component of the				
4.C: Interactions	net force exerted	3.E.1.2: The student			
with	on an object parallel or	is able to use net force			
other objects or	antiparallel to the	and velocity vectors to			
systems	displacement of the object will	determine qualitatively			
can change the	increase	whether kinetic energy of			
total	(parallel) or decrease	an object would increase,			
energy of a	(antiparallel) the kinetic	decrease, or remain			
system.	energy of the object.	unchanged. [SP 1.4]			
	b. The magnitude of the change				
5.A: Certain	in the kinetic	3.E.1.3: The student			
quantities	energy is the product of the	is able to use force			
are conserved, in	magnitude of the	and velocity vectors to			
the	displacement and of the	determine qualitatively			
sense that the	magnitude of the	or quantitatively the net			
changes	component of force parallel or	force exerted on an object			
of those	antiparallel to the	and qualitatively whether			
quantities in a	displacement.	kinetic energy of that			
given system are		object would increase,			

always	Relevant Equation:	decrease, or remain		
equal to the	$\Delta E = W = F_{\parallel}d$	unchanged. [SP 1.4, 2.2]		
transfer of	$\Delta L = W = I \parallel u$			
that quantity to or	c. The component of the net	3.E.1.4: The student is		
from	force exerted on	able to apply mathematical		
the system by all	an object perpendicular to the	routines to determine the		
possible	direction of the	change in kinetic energy		
interactions with	displacement of the object can	of an object given the		
other	change the	forces on the object and the		
systems.	direction of the motion of the	displacement of the object.		
	object without	[SP 2.2]		
5.B: The energy of	changing the kinetic energy of			
а	the object. This	4.C.1.1: The student is		
system is	should include uniform circular	able to calculate the total		
conserved.	motion and	energy of a system and		
	projectile motion.	justify the mathematical		
5.D: The linear	d. The kinetic energy of a rigid	routines used in the		
momentum of a	system may	calculation of component		
system is	be translational, rotational, or a	types of energy within		
conserved.	combination	the system whose sum is		
	of both. The change in the	the total energy. [SP 1.4,		
	rotational kinetic	2.1, 2.2]		
	energy of a rigid system is the			
	product of the	4.C.1.2: The student is		
	angular displacement and the	able to predict changes		
	net torque.	in the total energy of a		
		system due to changes		
	Relevant Equations:	in position and speed		
	$\Delta E = W = F_{\parallel} d \cos\theta$	of objects or frictional		
	$K = \frac{1}{2}mv^2$	interactions within the		
	Z	system. [SP 6.4]		
	4.C.1: The energy of a system	4.C.2.1: The student is		
	includes	able to make predictions		

				· · · · · · · · · · · · · · · · · · ·
its kinetic energy,	potential about the changes	in the		
energy, and	mechanical energy	of a		
microscopic interr	nal energy. system when a con	nponent		
Examples include	of an external force	e acts		
gravitational pote	ntial energy, parallel or antipara	llel		
elastic potential	to the direction of	the		
energy, and kineti	ic energy. displacement of th	e center		
a. A rotating, rigid	body may be of mass. [SP 6.4]			
considered to				
be a system, and r	may have both 4.C.2.2: The studer	nt is		
translational	able to apply the co	oncepts		
and rotational kine	etic energy. of Conservation of	Energy		
b. Although therm				
not part of	theorem to determ	nine		
Physics 1, included	d is the idea qualitatively and/o	r		
that during an	quantitatively that	work		
inelastic collision,	some of the done on a two-obje	ect		
mechanical	system in linear mo	otion		
energy dissipates	as (converts will change the kin	etic		
to) thermal	energy of the center	er		
energy.	of mass of the syst	em,		
	the potential energ	gy of		
Relevant Equation		or the		
$K = \frac{1}{2}$	internal energy of t	the		
$K = \frac{1}{2}r$ $K = \frac{1}{2}$	system. [SP 1.4, 2.2	2, 7.2]		
$K = \frac{1}{2}$	$I\omega^2$			
2	5.A.2.1: The studer			
$\Delta U_g = n$	$\frac{ng}{2y}$ is able to define op	en		
$\Delta U_g = m$ $U_g = -\frac{G}{2}$ $U_s = \frac{1}{2}$	and closed systems			
1	r for everyday situat	ions		
$U_s = \frac{1}{2}$	kx^2 and apply conserva			
	concepts for energ	у,		
4.C.2: Mechanical	energy (the charge, and linear			
sum of kinetic	momentum to those	se		
			1	

and	potential energy) is	situations. [SP 6.4, 7.2]		
	sferred into or out	situations. [3P 0.4, 7.2]		
		5.B.1.1: The student is able		
	system when an external			
	e is exerted	to set up a representation		
	system such that a	or model showing that		
	ponent of the force	a single object can only		
	rallel to its displacement.	have kinetic energy and		
	process	use information about		
	ugh which the energy is	that object to calculate its		
	sferred is	kinetic energy. [SP 1.4, 2.2]		
	ed work.			
a. If t	the force is constant during	5.B.1.2: The student is		
a giv		able to translate between		
displ	lacement, then the work	a representation of a		
done	e is	single object, which		
the p	product of the displacement	can only have kinetic		
and	the	energy, and a system that		
com	ponent of the force parallel	includes the object, which		
or ar	ntiparallel	may have both kinetic		
to th	ne displacement.	and potential energies.		
b. W	/ork (change in energy) can	[SP 1.5]		
be fo	ound from			
the a	area under a graph of the	5.B.2.1: The student		
mag	nitude of the	is able to calculate the		
force	e component parallel to the	expected behavior of a		
displ	lacement	system using the object		
versi	us displacement.	model (i.e., by ignoring		
		changes in internal		
5.A.1	1: A system is an object or a	structure) to analyze a		
	ection of	situation. Then, when the		
obie	cts. The objects are treated	model fails, the student		
-	aving no	can justify the use of		
	rnal structure.	conservation of energy		
		principles to calculate		

		тт	
5.A.2: For all systems under all	_		
circumstances, energy, charge,			
linear	internal structure because		
momentum, and angular	the object is actually a		
momentum are	system. [SP 1.4, 2.1]		
conserved. For an isolated or a			
closed system,	5.B.3.1: The student		
conserved quantities are	is able to describe and		
constant. An open	make qualitative and/or		
system is one that exchanges	quantitative predictions		
any conserved	about everyday examples		
quantity with its surroundings.	of systems with internal		
	potential energy.		
5.A.3: An interaction can be	[SP 2.2, 6.4, 7.2]		
either a force			
exerted by objects outside the	5.B.3.2: The student is		
system or the	able to make quantitative		
transfer of some quantity with	calculations of the internal		
objects outside	potential energy of a		
the system.	system from a description		
	or diagram of that system.		
5.A.4: The placement of a	[SP 1.4, 2.2]		
boundary between			
a system and its environment i	s 5.B.3.3: The student		
a decision	is able to apply		
made by the person considering	g mathematical reasoning		
the situation	to create a description		
in order to simplify or otherwis	e of the internal potential		
assist in	energy of a system		
analysis.	from a description or		
	diagram of the objects		
5.B.1: Classically, an object car	and interactions in that		
only have	system. [SP 1.4, 2.2]		
kinetic energy since potential			

energy requires	5.B.4.1: The student		
an interaction between two or	is able to describe and		
more objects.	make predictions about		
	the internal energy of		
Boundary Statement:	systems. [SP 6.4, 7.2]		
Conservation principles apply in			
the context	5.B.4.2: The student is		
of the appropriate Physics 1 and	able to calculate changes		
Physics 2	in kinetic energy and		
courses. Work, potential energy,	potential energy of a		
and kinetic	system, using information		
energy concepts are related to	from representations of that		
mechanical	system. [SP 1.4, 2.1, 2.2]		
systems in Physics 1 and			
electric, magnetic,	5.B.5.1: The student		
thermal, and atomic and	is able to design an		
elementary particle	experiment and analyze		
systems in Physics 2.	data to examine how a		
	force exerted on an object		
5.B.2: A system with internal	or system does work on		
structure	the object or system as it		
can have internal energy, and	moves through a distance.		
changes in	[SP 4.2, 5.1]		
a system's internal structure can			
result in	5.B.5.2: The student		
changes in internal energy.	is able to design an		
[Physics 1:	experiment and analyze		
includes mass-spring oscillators	graphical data in which		
and simple	interpretations of the area		
pendulums. Physics 2: includes	under a force-distance		
charged	curve are needed to		
objects in electric fields and	determine the work done		
examining	on or by the object or		
changes in internal energy with	system. [SP 4.2, 5.1]		

i	1		
changes in			
configuration.]	5.B.5.3: The student		
	is able to predict and		
5.B.3: A system with internal	calculate from graphical		
structure can	data the energy transfer		
have potential energy. Potential	to or work done on an		
energy exists	object or system from		
within a system if the objects	information about a force		
within that	exerted on the object		
system interact with	or system through a		
conservative forces.	distance. [SP 1.4, 2.2, 6.4]		
a. The work done by a			
conservative force	5.B.5.4: The student		
is independent of the path	is able to make claims		
taken. The work	about the interaction		
description is used for forces	between a system and its		
external to the	environment in which the		
system. Potential energy is used	environment exerts a force		
when the	on the system, thus doing		
forces are internal interactions	work on the system and		
between parts	changing the energy of		
of the system.	the system (kinetic energy		
b. Changes in the internal	plus potential energy). [SP		
structure can result	6.4, 7.2]		
in changes in potential energy.			
Examples	5.B.5.5: The student is able		
include mass-spring oscillators,	to predict and calculate the		
objects falling	energy transfer to (i.e., the		
in a gravitational field.	work done on) an object or		
c. The change in electric	system from information		
potential in a circuit	about a force exerted on the		
is the change in potential energy	object or system through a		
per unit	distance. [SP 2.2, 6.4]		
charge. [Physics 1: only in the			

context of	5.D.1.1: The student is		
circuits.]	able to make qualitative		
	predictions about		
5.B.4: The internal energy of a	natural phenomena		
system	based on conservation		
includes the kinetic energy of	of linear momentum		
the objects that	and restoration of		
make up the system and the	kinetic energy in elastic		
potential energy	collisions. [SP 6.4, 7.2]		
of the configuration of the			
objects that make	5.D.1.2: The student		
up the system.	is able to apply the		
a. Since energy is constant in a	principles of conservation		
closed system,	of momentum and		
changes in a system's potential	restoration of kinetic		
energy can	energy to reconcile a		
result in changes to the system's	situation that appears to		
kinetic	be isolated and elastic,		
energy.	but in which data indicate		
b. The changes in potential and	that linear momentum		
kinetic	and kinetic energy are		
energies in a system may be	not the same after the		
further	interaction, by refining		
constrained by the construction	a scientific question to		
of the system.	identify interactions that		
	have not been considered.		
5.B.5: Energy can be transferred	Students will be expected		
by an	to solve qualitatively and/		
external force exerted on an	or quantitatively for one-		
object or system	dimensional situations and		
that moves the object or system	only qualitatively in two-		
through a	dimensional situations.		
distance; this energy transfer is	[SP 2.2, 3.2, 5.1, 5.3]		
called work.			

En anna tura afra ta analar	incluse F. D. 1 . 2: The student		
Energy transfer in mechan			
electrical	is able to apply		
systems may occur at diffe			
rates. Power	appropriately to		
is defined as the rate of er	•.		
transfer into,	elastic collisions in one		
out of, or within a system.			
piston filled with	the selection of those		
gas getting compressed or			
expanded is treated	based on conservation		
in Physics 2 as part of	of momentum and		
thermodynamics.]	restoration of kinetic		
	energy. [SP 2.1, 2.2]		
Relevant Equation:			
$D = \frac{\Delta E}{\Delta E}$	5.D.1.4: The student		
P =	is able to design an		
	experimental test		
5.D.1: In a collision betwee	en of an application of		
objects, linear	the principle of the		
momentum is conserved.	In an conservation of linear		
elastic	momentum, predict an		
collision, kinetic energy is	the outcome of the experiment		
same before	using the principle,		
and after.	analyze data generated		
a. In a closed system, the l			
momentum is	whose uncertainties are		
constant throughout the	expressed numerically,		
collision.	and evaluate the match		
b. In a closed system, the l			
energy after	and the outcome. [SP 4.2,		
an elastic collision is the sa			
the kinetic			
energy before the collisior	5.D.1.5: The student is		
	able to classify a given		
	able to slassify a Biteli	1	

	· ·	-	
5.D.2: In a collision between	collision situation as		
objects, linear	elastic or inelastic,		
momentum is conserved. In an	justify the selection of		
inelastic	conservation of linear		
collision, kinetic energy is not	momentum and restoration		
the same before	of kinetic energy as the		
and after the collision.	appropriate principles		
a. In a closed system, the linear	for analyzing an elastic		
momentum is	collision, solve for missing		
constant throughout the	variables, and calculate		
collision.	their values. [SP 2.1, 2.2]		
b. In a closed system, the kinetic			
energy after	5.D.2.1: The student		
an inelastic collision is different	is able to qualitatively		
from the	predict, in terms of linear		
kinetic energy before the	momentum and kinetic		
collision.	energy, how the outcome		
	of a collision between		
	two objects changes		
	depending on whether		
	the collision is elastic or		
	inelastic. [SP 6.4, 7.2]		
	5.D.2.3: The student		
	is able to apply the		
	conservation of linear		
	momentum to a closed		
	system of objects involved		
	in an inelastic collision		
	to predict the change in		
	kinetic energy. [SP 6.4,		
	7.2]		
	Vocabulary:		

Mechanical Energy Work Translational Kinetic Energy Rotational Kinetic Energy Gravitational Potential Energy Elastic Potential Energy Power Elastic Collision Conservation of Energy	
Conservation of Energy	

General Topic Content Area 5: Momentum	AP Standards	Learning Objective, Skills & Vocabulary	Resources & Activities	Assessments	Suggested Time (In Days)
Enduring Understanding:	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared tests, quizzes, etc.	17
_	3.D.1: The change in	3.D.1.1: The student is able	Lab Investigation 5:		
3.D: A force	momentum of an object	to justify the selection of	Impulse and	Series available	
exerted on	is a vector in the direction of the	data needed to determine	Momentum	assessments	
an object can	net force exerted on the object.	the relationship between the		online. (Optional)	
change the	Relevant Equation:	direction of the force acting			
momentum of the	$\overrightarrow{\Delta p} = \vec{F} \Delta t$	on an object and the change			
object.	•	in momentum caused by			
	3.D.2: The change in	that force. [SP 4.1]			
4.B: Interactions	momentum of an object				
with	occurs over a time interval.	3.D.2.1: The student is able			
other objects or	a. The force that one object	to justify the selection of			
systems	exerts on a	routines for the calculation			
can change the	second object changes the	of the relationships			
total linear	momentum of the	between changes in			
momentum of a	second object (in the absence of	momentum of an object,			
system.	other forces	average force, impulse, and			
	on the second object).	time of interaction. [SP 2.1]			
5.A: Certain	b. The change in momentum of				
quantities	that	3.D.2.2: The student is			
are conserved, in	object depends on the impulse,	able to predict the change			
the	which is	in momentum of an object			
sense that the	the product of the average force	from the average force			
changes	and the	exerted on the object and			
of those	time interval during which the	the interval of time during			
quantities in a	interaction	which the force is exerted.			
given system are always	occurred.	[SP 6.4]			
equal to the	4.B.1: The change in linear	3.D.2.3: The student is			
transfer of	momentum for	able to analyze data to			

			1		
that quantity to or	a constant-mass system is the	characterize the change			
from	product of	in momentum of an object			
the system by all	the mass of the system and the	from the average force			
possible	change in	exerted on the object and			
interactions with	velocity of the center of mass.	the interval of time during			
other	Relevant Equation:	which the force is exerted.			
systems.	$ec{p}=mec{v}$	[SP 5.1]			
5.D: The linear	4.B.2: The change in linear	3.D.2.4: The student is			
momentum of a	momentum of	able to design a plan for			
system is	the system is given by the	collecting data to investigate			
, conserved.	product of the	the relationship between			
	average force on that system	changes in momentum and			
	and the time	the average force exerted on			
	interval during which the force	an object over time. [SP 4.2]			
	is exerted.				
	a. The units for momentum are	4.B.1.1: The student is able			
	the same as	to calculate the change in			
	the units of the area under the	linear momentum of a two-			
	curve of a	object system with constant			
	force versus time graph.	mass in linear motion from			
	b. The change in linear	a representation of the			
	momentum and force	system (data, graphs, etc.).			
	are both vectors in the same	[SP 1.4, 2.2]			
	direction.				
		4.B.1.2: The student is			
	5.A.2: For all systems under all	able to analyze data to			
	circumstances, energy, charge,	find the change in linear			
	linear	momentum for a constant-			
	momentum, and angular	mass system using the			
	momentum are	product of the mass and the			
	conserved. For an isolated or a	change in velocity of the			
	closed	center of mass. [SP 5.1]			
	system, conserved quantities				
	system, conserved quantities		<u> </u>	1	1

		1	
are constant.	4.B.2.1: The student is		
An open system is one that	able to apply mathematical		
exchanges any	routines to calculate the		
conserved quantity with its	change in momentum of		
surroundings.	a system by analyzing the		
	average force exerted over a		
5.D.1: In a collision between	certain time on the system.		
objects, linear	[SP 2.2]		
momentum is conserved. In an			
elastic	4.B.2.2: The student is		
collision, kinetic energy is the	able to perform analysis on		
same before	data presented as a force-		
and after.	time graph and predict the		
a. In a closed system, the linear	change in momentum of a		
momentum	system. [SP 5.1]		
is constant throughout the			
collision.	5.A.2.1: The student is		
b. In a closed system, the kinetic	able to define open and		
energy after	closed systems for everyday		
an elastic collision is the same as	situations and apply		
the kinetic	conservation concepts		
energy before the collision.	for energy, charge, and		
	linear momentum to those		
Boundary Statement:	situations. [SP 6.4, 7.2]		
Physics 1 includes a quantitative			
and	5.D.1.1: The student is		
qualitative treatment of	able to make qualitative		
conservation	predictions about natural		
of momentum in one dimension	phenomena based on		
and a	conservation of linear		
semiquantitative treatment of	momentum and restoration		
conservation	of kinetic energy in elastic		
of momentum in two	collisions. [SP 6.4, 7.2]		
dimensions. Test items			
conservation of momentum in two	of kinetic energy in elastic		

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involving solution of	5.D.1.2: The student is able		
simultaneous equations	to apply the principles of		
are not included in Physics 1,	conservation of momentum		
but items	and restoration of kinetic		
testing whether students can set	energy to reconcile a		
up the	situation that appears to		
equations properly and can	be isolated and elastic,		
reason about how	but in which data indicate		
changing a given mass, speed, or	that linear momentum		
angle would	and kinetic energy are		
affect other quantities are	not the same after the		
included.	interaction, by refining		
Physics 1 includes only	a scientific question to		
conceptual	identify interactions that		
understanding of center of mass	have not been considered.		
motion of	Students will be expected		
a system without the need for	to solve qualitatively and/		
calculation of	or quantitatively for one-		
center of mass.	dimensional situations and		
The Physics 1 course includes	only qualitatively in two-		
topics from	dimensional situations. [SP		
Enduring Understanding 5.D in	2.2, 3.2, 5.1, 5.3]		
the context of			
mechanical systems.	5.D.1.3: The student is		
	able to apply mathematical		
5.D.2: In a collision between	routines appropriately to		
objects, linear	problems involving elastic		
momentum is conserved. In an	collisions in one dimension		
inelastic	and justify the selection		
collision, kinetic energy is not	of those mathematical		
the same	routines based on		
before and after the collision.	conservation of momentum		
a. In a closed system, the linear	and restoration of kinetic		
momentum	energy. [SP 2.1, 2.2]		

nstant throughout the				
-	E D 1 4. The student			
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sion.	•			
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	•			
•	•			
nged by an	numerically, and evaluate			
raction within the system.	the match between the			
sics 1:	prediction and the outcome.			
ides no calculations of	[SP 4.2, 5.1, 5.3, 6.4]			
ers of mass;				
equation is not provided	5.D.1.5: The student is			
Physics	able to classify a given			
owever, without doing	collision situation as elastic			
ulations,	or inelastic, justify the			
sics 1 students are expected	selection of conservation			
2	of linear momentum and			
to locate the center of mass	restoration of kinetic energy			
ghly				
	for analyzing an elastic			
as a				
orm rod or cube of uniform				
-				
	5.D.2.1: The student is able			
•				
-				
	action within the system. sics 1: des no calculations of ers of mass; equation is not provided Physics owever, without doing ilations, ics 1 students are expected to locate the center of mass ghly metric mass distributions, as a	sion.5.D.1.4: The studenta closed system, the kineticis able to design angyan inelastic collision isan inelastic collision isexperimental test of anapplication of the principleof the conservation of linearsinetic energy before theof the conservation of linearsion.outcome of the experimentassusing the principle,ast The velocity of the centeranalyze data generated byassuncertainties are expressede system cannot beuncertainties are expressedged by annumerically, and evaluateaction within the system.the match between theprediction and the outcome.[SP 4.2, 5.1, 5.3, 6.4]PhysicsS.D.1.5: The student isowever, without doingable to classify a givencollision, situation as elasticor inelastic, justify theselection of conservationof linear momentum andrestoration of kinetic energyas the appropriate principlesfor analyzing an elasticcollision, solve for missingvariables, and calculatetheir values. [SP 2.1, 2.2]spheres of equal mass.]S.D.2.1: The student is ableto qualitatively predict, interms of linear momentum	sion.5.D.1.4: The studenta closed system, the kineticis able to design angyexperimental test of anan inelastic collision isapplication of the principleof the conservation of linearof the conservation of lineardinetic energy before theoutcome of the experimentsion.using the principle,at The velocity of the centeranalyze data generated byassthat experiment whoseuccrtainties are expressednumerically, and evaluateaction within the system.the match between thesics 1:prediction and the outcome.des no calculations of[SP 4.2, S.1, S.3, 6.4]Physicsable to classify a givencollision stuation as elasticor inelastic, justify thesics 1 students are expectedselection of kinetic energyas acollision, solve for missingyrur od or cube of uniformfor analyzing an elasticorm rod or cube of uniformcollision, solve for missingvariables, and calculatetheir values. [SP 2.1, 2.2]spheres of equal mass.] 5.D.2.1 : The student is ableto masses and positionsterms of linear momentum	sion.S.D.1.4: The studenta closed system, the kineticis able to design angyexperimental test of anan inelastic collision isapplication of the principleof the conservation of linearmomentum, predict andinetic energy before theoutcome of the experimentison.using the principle,as The velocity of the centeranalyze data generated bythat experiment whoseuncertainties are expressedged by annumerically, and evaluateaction within the system.the match between thesiss 1:prediction and the outcome.des no calculations of[SP 4.2, 5.1, 5.3, 6.4]evaluation is not providedSol.1.5: The student isphysicsable to classify a givencollision situation as elasticor inelastic, justify thesics 1:selection of conservationof linear momentum andrestoration of kinetic energyadations,or inelastic, justify thesequation is not providedfor analyzing an elasticor inelastic, justify theselection of kinetic energyghlyas the appropriate principlesfor analyzing an elasticcollision, solve for missingyraibles, and calculatetheir values. [SP 2.1, 2.2]spheres of equal mass.]ee center of mass of ato qualitatively predict, inity, orther masses and positionsther masses and positionsto rune of linear momentum

in the system. In an is			
system (a	between two objects		
system with no exter	nal forces) changes depending on		
the velocity	whether the collision is		
of the center of mass	does not elastic or inelastic.		
change.	[SP 6.4, 7.2]		
b. When objects in a	system		
collide, the	5.D.2.2: The student is		
velocity of the center	of mass of able to plan data collection		
the system	strategies to test the law o	f	
will not change unles	s an conservation of momentur	n	
external force is	in a two-object collision th	at	
exerted on the system	m. is elastic or inelastic and		
c. Included in Physics	1 is the analyze the resulting data		
idea that	graphically. [SP 4.1, 4.2, 5.	L]	
where there is both a	heavier		
and lighter	5.D.2.3: The student is able		
mass, the center of m	nass is to apply the conservation		
closer to	of linear momentum to a		
the heavier mass. On	ly a closed system of objects		
qualitative	involved in an inelastic		
understanding of this	s concept is collision to predict the		
required.	change in kinetic energy.		
	[SP 6.4, 7.2]		
	5.D.2.4: The student is able		
	to analyze data that verify		
	conservation of momentur	n	
	in collisions with and		
	without an external friction	n	
	force. [SP 4.1, 4.2, 4.4, 5.1		
	5.3]		
	5.D.2.5: The student is		

	able to 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. [SP
	2.1, 2.2]
	5.D.3.1: The student is able
	to predict the velocity of the
	center of mass of a system
	when there is no interaction
	outside of the system but
	there is an interaction
	within the system (i.e., the
	student simply recognizes
	that interactions within a
	system do not affect the
	center of mass motion of
	the system and is able to
	determine that there is no
	external force). [SP 6.4]
	Vocabulary:
	Impulse
	Momentum
<u> </u>	

	Impulse-Momentum		
	Theorem		
	Conservation of Momentum		
	Elastic Collision		
	Perfectly Inelastic Collision		

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 6:		Skills & Vocabulary			Time
Simple Harmonic					(In Days)
Motion					
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	3.B.3: Restoring forces can	3.B.3.1: The student is	Lab Investigation 6:		
3.B: Classically,	result in	able to predict which	Harmonic Motion	Series available	
the acceleration	oscillatory motion. When a	properties determine		assessments	
of an object	linear restoring	the motion of a simple		online. (Optional)	
interacting with	force is exerted on an object	harmonic oscillator and			
other objects can	displaced from an	what the dependence of			
be predicted by	equilibrium position, the object	the motion is on those			
using	will undergo a	properties. [SP 6.4, 7.2]			
$\vec{a} = \frac{\sum \vec{F}}{m_{system}}.$	special type of motion called				
$u = m_{system}$	simple harmonic	3.B.3.2: The student			
	motion. Examples include	is able to design a			
5.B: The energy of	gravitational force	plan and collect data			
а	exerted by the Earth on a simple	in order to ascertain			
system is	pendulum	the characteristics of			
conserved.	and mass-spring oscillator.	the motion of a system			
	a. For a spring that exerts a	undergoing oscillatory			
	linear restoring	motion caused by a			
	force, the period of a mass-	restoring force. [SP 4.2]			
	spring oscillator				
	increases with mass and	3.B.3.3: The student can			
	decreases with	analyze data to identify			
	spring stiffness.	qualitative or quantitative			
	b. For a simple pendulum, the	relationships between			
	period	given values and variables			
	increases with the length of the	(i.e., force, displacement,			
	pendulum	acceleration, velocity,			

and decreases with the	period of motion,	
magnitude of the	frequency, spring	
gravitational field.	constant, string length,	
c. Minima, maxima, and zeros of	mass) associated with	
position,	objects in oscillatory	
velocity, and acceleration are	motion to use that data to	
features of	determine the value of an	
harmonic motion. Students	unknown. [SP 2.2, 5.1]	
should be able to		
calculate force and acceleration	3.B.3.4: The student	
for any given	is able to construct a	
displacement for an object	qualitative and/or a	
oscillating on a	quantitative explanation	
spring.	of oscillatory behavior	
Relevant Equations:	given evidence of a	
$T = 2 - \sqrt{m}$	restoring force.	
$I_s = 2\hbar \sqrt{\frac{k}{k}}$	[SP 2.2, 6.2]	
$T_{s} = 2\pi \sqrt{\frac{m}{k}}$ $T_{p} = 2\pi \sqrt{\frac{l}{g}}$	5.B.2.1: The student	
\sqrt{y}	is able to calculate the	
	expected behavior of a	
5.B.2: A system with internal	system using the object	
structure	model (i.e., by ignoring	
can have internal energy, and	changes in internal	
changes in	structure) to analyze a	
a system's internal structure can	situation. Then, when the	
result	model fails, the student	
in changes in internal energy.	can justify the use of	
[Physics 1:	conservation of energy	
includes mass-spring oscillators	principles to calculate	
and simple	the change in internal	
pendulums. Physics 2: includes	energy due to changes in	
charged	internal structure because	
object in electric fields and	the object is actually a	

examining	system. [SP 1.4, 2.1]		
changes in internal energy with			
changes in	5.B.3.1: The student		
configuration.]	is able to describe and		
	make qualitative and/or		
5.B.3: A system with internal	quantitative predictions		
structure can	about everyday examples		
have potential energy. Potential	of systems with internal		
energy exists	potential energy. [SP 2.2,		
within a system if the objects	6.4, 7.2]		
within that			
system interact with	5.B.3.2: The student is		
conservative forces.	able to make quantitative		
a. The work done by a	calculations of the internal		
conservative force	potential energy of a		
is independent of the path	system from a description		
taken. The work	or diagram of that system.		
description is used for forces	[SP 1.4, 2.2]		
external to the			
system. Potential energy is used	5.B.3.3: The student		
when the	is able to apply		
forces are internal interactions	mathematical reasoning		
between parts	to create a description		
of the system.	of the internal potential		
b. Changes in the internal	energy of a system		
structure can result	from a description or		
in changes in potential energy.	diagram of the objects		
Examples	and interactions in that		
include mass-spring oscillators	system.		
and objects	[SP 1.4, 2.2]		
falling in a gravitational field.			
c. The change in electric	5.B.4.1: The student		
potential in a circuit	is able to describe and		
is the change in potential energy	make predictions about		

per unit	the internal energy of		
charge. [Physics 1: only in the	systems. [SP 6.4, 7.2]		
context of	, , , , ,		
circuits.]	5.B.4.2: The student is		
-	able to calculate changes		
5.B.4: The internal energy of a	in kinetic energy and		
system	potential energy of a		
includes the kinetic energy of	system, using information		
the objects that	from representations of		
make up the system and the	that system. [SP 1.4, 2.1,		
potential energy	2.2]		
of the configuration of the			
objects that make	Vocabulary:		
up the system.	Period		
a. Since energy is constant in a	Frequency		
closed system,	Restoring Force		
changes in a system's potential	Equilibrium		
energy can	Simple Harmonic Motion		
result in changes to the system's			
kinetic			
energy.			
b. The changes in potential and			
kinetic			
energies in a system may be			
further			
constrained by the construction			
of the system.			

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 7:		Skills & Vocabulary			Time
Torque and					(In Days)
Rotational Motion					
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	3.A.1: An observer in a	3.A.1.1: The student	Lab Investigation 7:		
3.A: All forces	particular reference	is able to express the	Rotational Motion	Series available	
share	frame can describe the motion	motion of an object using		assessments	
certain common	of an	narrative, mathematical,		online. (Optional)	
characteristics	object using such quantities as	and graphical			
when	position,	representations. [SP 1.5,			
considered by	displacement, distance, velocity,	2.1, 2.2]			
observers	speed, and				
in inertial	acceleration.	3.F.1.1: The student			
reference	a. For rotational motion, there	is able to use			
frames.	are analogous	representations of the			
	quantities such as angular	relationship between force			
3.F: A force	position, angular	and torque. [SP 1.4]			
exerted on an	velocity, and angular				
object can cause a	acceleration.	3.F.1.2: The student			
torque	Relevant Equations:	is able to compare the			
on that object.	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$	torques on an object caused by various forces.			
4.D: A net torque exerted	$\omega = \omega_0 + \alpha t$ $\omega^2 = \omega_0^2 + 2\alpha \Delta \theta$	[SP 1.4]			
on a system by	b. For uniform circular motion of	3.F.1.3: The student			
other	radius r, v	is able to estimate the			
objects or systems	is proportional to omega (for a	torque on an object			
will	given r), and	caused by various forces			
change the	proportional to r (for a given	in comparison to other			
angular	omega). Given a	situations. [SP 2.3]			
-	radius r and a period of rotation				

momentum of the	T, students			
system.	derive and apply $v = (2\pi r)/T$.	3.F.1.4: The student		
		is able to design an		
5.E: The angular	3.F.1: Only the force component	experiment and analyze		
momentum of a	perpendicular	data testing a question		
system is	to the line connecting the axis of	about torques in a		
conserved.	rotation and	balanced rigid system.		
	the point of application of the	[SP 4.1, 4.2, 5.1]		
	force results in			
	a torque about that axis.	3.F.1.5: The student is		
	a. The lever arm is the	able to calculate torques		
	perpendicular distance	on a two-dimensional		
	from the axis of rotation or	system in static		
	revolution to the	equilibrium, by examining		
	line of application of the force.	a representation or model		
	b. The magnitude of the torque	(such as a diagram or		
	is the product	physical construction).		
	of the magnitude of the lever	[SP 1.4, 2.2]		
	arm and the			
	magnitude of the force.	3.F.2.1: The student is		
	c. The net torque on a balanced	able to make predictions		
	system is	about the change in the		
	zero.	angular velocity about		
	Relevant Equation:	an axis for an object		
	$ au = r_{\perp}F = rF\sin\theta$	when forces exerted on		
		the object cause a torque		
	Boundary Statement:	about that axis. [SP 6.4]		
	Quantities such as angular			
	acceleration,	3.F.2.2: The student		
	velocity, and momentum are	is able to plan data		
	defined as vector	collection and analysis		
	quantities, but in Physics 1 the	strategies designed to test		
	determination	the relationship between		
	of "direction" is limited to	a torque exerted on an		

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	clockwise and	object and the change in		
	counterclockwise with respect	angular velocity of that		
	to a given axis	object about an axis. [SP		
	of rotation.	4.1, 4.2, 5.1]		
	3.F.2: The presence of a net	3.F.3.1: The student		
	torque along any	is able to predict the		
	axis will cause a rigid system to	behavior of rotational		
	change its	collision situations by		
	rotational motion or an object	the same processes that		
	to change its	are used to analyze linear		
	rotational motion about that	collision situations using		
	axis.	an analogy between		
	a. Rotational motion can be	impulse and change		
	described in terms	of linear momentum		
	of angular displacement, angular	and angular impulse		
	velocity, and	and change of angular		
	angular acceleration about a	momentum. [SP 6.4, 7.2]		
	fixed axis.			
	b. Rotational motion of a point	3.F.3.2: In an unfamiliar		
	can be related	context or using		
	to linear motion of the point	representations beyond		
	using the	equations, the student is		
	distance of the point from the	able to justify the selection		
	axis of rotation.	of a mathematical routine		
	c. The angular acceleration of an	to solve for the change in		
	object or	angular momentum of an		
	rigid system can be calculated	object caused by torques		
	from the net	exerted on the object.		
	torque and the rotational inertia	[SP 2.1]		
	of the object			
	or rigid system.	3.F.3.3: The student		
	Relevant Equation:	is able to plan data		
	$\alpha = \frac{\Sigma \tau}{\Delta T}$	collection and analysis		
	$u - \frac{1}{I}$			

	strategies designed to test		
3.F.3: A torque exerted on an	the relationship between		
object can	torques exerted on an		
change the angular momentum	object and the change in		
of an object.	angular momentum of		
a. Angular momentum is a	that object. [SP 4.1, 4.2,		
vector quantity,	5.1, 5.3]		
with its direction determined by			
a right-hand	4.D.1.1: The student		
rule.	is able to describe a		
b. The magnitude of angular	representation and use		
momentum of a	it to analyze a situation		
point object about an axis can	in which several forces		
be calculated	exerted on a rotating		
by multiplying the perpendicular	system of rigidly		
distance	connected objects change		
from the axis of rotation to the	the angular velocity and		
line of motion	angular momentum of the		
by the magnitude of linear	system. [SP 1.2, 1.4]		
momentum.			
c. The magnitude of angular	4.D.1.2: The student		
momentum	is able to plan data		
of an extended object can also	collection strategies		
be found	designed to establish that		
by multiplying the rotational	torque, angular velocity,		
inertia by the	angular acceleration, and		
angular velocity. Students do	angular momentum can		
not need to	be predicted accurately		
know the equation for an	when the variables are		
object's rotational	treated as being clockwise		
inertia, as it will be provided at	or counterclockwise with		
the exam.	respect to a well-defined		
They should have a qualitative	axis of rotation, and refine		
sense of what	the research question		

factors affect rotational inertia,	based on the examination		
for example	of data. [SP 3.2, 4.1, 4.2,		
why a hoop has more rotational	5.1, 5.3]		
inertia than a	5.1, 5.5]		
puck of the same mass and	4.D.2.1: The student is		
radius.	able to describe a model		
d. The change in angular	of a rotational system		
momentum of an	and use that model to		
object is given by the product of	analyze a situation in		
the average	which angular momentum		
torque and the time the torque	changes due to interaction		
is exerted.	with other objects or		
Relevant Equations:	systems. [SP 1.2, 1.4]		
$L = I\omega$, , , ,		
$\Delta L = \tau \Delta t$	4.D.2.2: The student		
L = mvr	is able to plan a data		
	collection and analysis		
4.D.1: Torque, angular velocity,	strategy to determine		
angular	the change in angular		
acceleration, and angular	momentum of a system		
momentum are	and relate it to interactions		
vectors and can be	with other objects and		
characterized as positive	systems. [SP 4.2]		
or negative depending upon			
whether they give	4.D.3.1: The student is		
rise to or correspond to	able to use appropriate		
counterclockwise or	mathematical routines to		
clockwise rotation with respect	calculate values for initial or		
to an axis.	final angular momentum,		
	or change in angular		
Boundary Statement:	momentum of a system,		
Students do not need to know	or average torque or time		
the right hand	during which the torque		
rule. A full dynamic treatment of	is exerted in analyzing a		

		1	
rolling without	situation involving torque		
slipping—for instance, using	and angular momentum.		
forces and torques	[SP 2.2]		
to find the linear and angular			
acceleration of a	4.D.3.2: The student is able		
cylinder rolling down a ramp—is	to plan a data collection		
not included	strategy designed to test		
in Physics 1.	the relationship between		
	the change in angular		
4.D.2: The angular momentum	momentum of a system and		
of a system may	the product of the average		
change due to interactions with	torque applied to the system		
other objects	and the time interval during		
or systems.	which the torque is exerted.		
a. The angular momentum of a	[SP 4.1, 4.2]		
system with			
respect to an axis of rotation is	5.E.1.1: The student is		
the sum of the	able to make qualitative		
angular momenta, with respect	predictions about the		
to that axis, of	angular momentum of		
the objects that make up the	a system for a situation		
system.	in which there is no net		
b. The angular momentum of an	external torque. [SP 6.4,		
object about	7.2]		
a fixed axis can be found by			
multiplying	5.E.1.2: The student is		
the momentum of the particle	able to make calculations		
by the	of quantities related to		
perpendicular distance from the	the angular momentum		
axis to the	of a system when the net		
line of motion of the object.	external torque on the		
c. Alternatively, the angular	system is zero. [SP 2.1,		
momentum of a	2.2]		
system can be found from the			

product of the	5.E.2.1: The student		
system's rotational inertia and	is able to describe or		
its angular	calculate the angular		
velocity. Students do not need	momentum and rotational		
to know the	inertia of a system in		
equation for an object's	terms of the locations		
rotational inertia, as	and velocities of objects		
it will be provided at the exam.	that make up the system.		
They should	Students are expected to		
have a qualitative sense that	do qualitative reasoning		
rotational inertia	with compound objects.		
is larger when the mass is	Students are expected		
farther from the	to do calculations with		
axis of rotation.	a fixed set of extended		
	objects and point masses.		
4.D.3: The change in angular	[SP 2.2]		
momentum is			
given by the product of the	Vocabulary:		
average torque and	Torque		
the time interval during which	Rotational Inertia (Moment		
the torque is	of Inertia)		
exerted.	Angular Acceleration		
	Angular Velocity		
5.E.1: If the net external torque	Angular Momentum		
exerted on the	Conservation of Angular		
system is zero, the angular	Momentum		
momentum of the	Unstable Equilibrium		
system does not change.	Stable Equilibrium		
5.E.2: The angular momentum			
of a system			
is determined by the locations			
and velocities			
of the objects that make up the			

system. The		
rotational inertia of an object or		
system		
depends upon the distribution		
of mass within		
the object or system. Changes in		
the radius of		
a system or in the distribution of		
mass within		
the system result in changes in		
the system's		
rotational inertia, and hence in		
its angular		
velocity and linear speed for a		
given angular		
momentum. Examples include		
elliptical orbits		
in an Earth-satellite system.		
Mathematical		
expressions for the moments of		
inertia will be		
provided where needed.		
Students will not be		
expected to know the parallel		
axis theorem.		
Students do not need to know		
the equation		
for an object's rotational inertia,		
as it will		
be provided at the exam. They		
should have		
a qualitative sense that		
rotational inertia is		
larger when the mass is farther		

from the axis of rotation.		

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 8:		Skills & Vocabulary			Time
Electric Charge					(In Days)
and Electric Force					
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	1.B.3: The smallest observed	1.B.1.1: The student is	Coulomb's Law Lab		
1.B: Electric	unit of charge	able to make claims about	Activity	Series available	
charge is	that can be isolated is the	natural phenomena based		assessments	
a property of an	electron charge,	on conservation of electric	Circuit Measuring	online. (Optional)	
object	also known as the elementary	charge. [SP 6.4]	Activity		
or system that	charge.				
affects	a. The magnitude of the	1.B.1.2: The student is			
its interactions	elementary charge is	able to make predictions,			
with	equal to 1.6×10^{-19} coulombs.	using the conservation of			
other objects or	b. Electrons have a negative	electric charge, about the			
systems	elementary	sign and relative quantity			
containing charge.	charge; protons have a positive	of net charge of objects			
	elementary	or systems after various			
3.C: At the	charge of equal magnitude,	charging processes,			
macroscopic	although the mass	including conservation of			
level, forces can	of a proton is much larger than	charge in simple circuits.			
be	the mass of an	[SP 6.4, 7.2]			
categorized as	electron.				
either		1.B.2.1: The student			
long-range	3.C.2: Electric force results from	is able to construct an			
(action-at-a-	the	explanation of the two-			
distance) forces or	interaction of one object that	charge model of electric			
contact	has an electric	charge based on evidence			
forces.	charge with another object that	produced through			
	has an electric	scientific practices. [SP			
5.A: Certain	charge.	6.2]			
quantities	a. Electric forces dominate the				
are conserved, in	properties	1.B.3.1: The student is			

the	of the objects in our everyday	able to challenge the		
sense that the	experiences.	claim that an electric		
changes	However, the large number of	charge smaller than the		
of those	particle	elementary charge has		
quantities in a	interactions that occur make it	been isolated. [SP 1.5,		
given system are	more	6.1, 7.2]		
always	convenient to treat everyday			
equal to the	forces in terms of	3.C.2.1: The student is		
transfer of	nonfundamental forces called	able to use Coulomb's		
that quantity to or	contact forces,	law qualitatively and		
from	such as normal force, friction,	quantitatively to make		
the system by all	and tension.	predictions about the		
possible	b. Electric forces may be	interaction between two		
interactions with	attractive or	electric point charges		
other	repulsive, depending upon the	(interactions between		
systems.	charges on the	collections of electric		
	objects involved.	point charges are not		
	Relevant Equations:	covered in Physics 1 and		
	$F_e = \frac{kq_1q_2}{r^2}$	instead are restricted to		
		Physics 2).		
	$I = \frac{\Delta q}{\Delta t}$	[SP 2.2, 6.4]		
	Δt			
		3.C.2.2: The student		
	5.A.2: For all systems under all	is able to connect the		
	circumstances, energy, charge,	concepts of gravitational		
	linear	force and electric force to		
	momentum, and angular	compare similarities and		
	momentum are	differences between the		
	conserved. For an isolated or a	forces. [See SP 7.2]		
	closed system,			
	conserved quantities are	5.A.2.1: The student		
	constant. An open	is able to define open		
	system is one that exchanges	and closed systems		
	any conserved	for everyday situations		
	quantity with its surroundings.			

and apply conservation concepts for energy, charge and linear momentum to those situations. [SP 6.4, 7.2]		
Vocabulary: Electrostatic Force Coulomb's Law Charge Current		

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 9:		Skills & Vocabulary			Time
DC Circuits					(In Days)
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	1.B.1: Electric charge is	1.B.1.1: The student is	Lab Investigation 9:		
1.B: Electric	conserved. The net	able to make claims about	Resistor Circuits	Series available	
charge is	charge of a system is equal to the	natural phenomena based		assessments	
a property of an	sum of the	on conservation of electric		online. (Optional)	
object	charges of all the objects in the	charge. [SP 6.4]			
or system that	system.				
affects	a. An electrical current is a	1.B.1.2: The student is			
its interactions	movement of	able to make predictions,			
with	charge through a conductor.	using the conservation of			
other objects or	b. A circuit is a closed loop of	electric charge, about the			
systems	electrical	sign and relative quantity			
containing charge.	current.	of net charge of objects			
		or systems after various			
1.E: Materials	1.E.2 : Matter has a property	charging processes,			
have	called resistivity.	including conservation of			
many macroscopic	a. The resistivity of a material	charge in simple circuits.			
properties that	depends on its molecular and atomic structure.	[SP 6.4, 7.2]			
result		[5] 0.4, 7.2]			
from the	b. The resistivity depends on the temperature	1.E.2.1: The student			
arrangement and	of the material. Resistivity	is able to choose and			
interactions of the	changes with	justify the selection of			
atoms	temperature.	data needed to determine			
and molecules					
	5.B.9 : Kirchhoff's loop rule	resistivity for a given			
that make	describes	material. [SP 4.1]			
up the material.	conservation of energy in	5 B O 4. The student			
	electrical circuits.	5.B.9.1: The student			
5.B: The energy of	[The application of Kirchhoff's	is able to construct or			
а	laws to	interpret a graph of the			
system is	circuits is introduced in Physics 1	energy changes within			

	and further			<u> </u>
conserved.	and further	an electrical circuit with		
, _,	developed in Physics 2 in the	only a single battery and		
5.C: The electric	context of	resistors in series and/or		
charge of	more complex circuits, including	in, at most, one parallel		
a system is	those with	branch as an application		
conserved.	capacitors.]	of the conservation of		
	The potential difference across an	energy (Kirchhoff's loop		
	ideal	rule). [SP 1.1, 1.4]		
	battery is also referred to as the			
	emf of the	5.B.9.2: The student is		
	battery, represented as ε. [Non-	able to apply conservation		
	ideal batteries	of energy concepts to the		
	are not covered in Physics 1.]	design of an experiment		
	a. Energy changes in simple	that will demonstrate the		
	electrical circuits	validity of Kirchhoff's loop		
	are conveniently represented in	rule ($\Sigma \Delta V=0$) in a circuit		
	terms of	with only a battery and		
	energy change per charge moving	resistors either in series		
	through a	or in, at most, one pair of		
	battery and a resistor.	parallel branches. [SP 4.2,		
	b. Since electric potential difference times			
		6.4, 7.2]		
	charge is energy, and energy is			
	conserved,	5.B.9.3: The student is		
	the sum of the potential	able to apply conservation		
	differences about any	of energy (Kirchhoff's		
	closed loop must add to zero.	loop rule) in calculations		
	c. The electric potential difference	involving the total electric		
	across a	potential difference for		
	resistor is given by the product of	complete circuit loops		
	the current	with only a single battery		
	and the resistance.	and resistors in series		
	d. The rate at which energy is transferred from	and/or in, at most, one		
		parallel branch. [SP 2.2,		
	a resistor is equal to the product	6.4, 7.2]		
	of the electric			

		ГГ	
potential difference across the			
resistor and the	5.C.3.1: The student is		
current through the resistor.	able to apply conservation		
	of electric charge		
5.C.3: Kirchhoff's junction rule	(Kirchhoff's junction rule)		
describes the	to the comparison of		
conservation of electric charge in	electric current in various		
electrical	segments of an electrical		
circuits. Since charge is	circuit with a single		
conserved, current	battery and resistors in		
must be conserved at each	series and in, at most,		
junction in	one parallel branch		
the circuit. Examples include	and predict how those		
circuits that	values would change		
combine resistors in series and	if configurations of the		
parallel.	circuit are changed. [SP		
[Physics 1: covers circuits with			
resistors in	6.4, 7.2]		
series, with at most one parallel			
branch, one	5.C.3.2: The student		
battery only. Physics 2: includes	is able to design an		
capacitors	investigation of an		
in steady-state situations. For	electrical circuit with one		
circuits with	or more resistors in which		
capacitors, situations should be	evidence of conservation		
limited to	of electric charge can be		
open circuit, just after circuit is	collected and analyzed.		
closed, and a	[SP 4.1, 4.2, 5.1]		
long time after the circuit is			
closed.]	5.C.3.3: The student is		
	able to use a description		
	or schematic diagram		
	of an electrical circuit to		
	calculate unknown values		
	of current in various		

segments or branches of the circuit. [SP 1.4, 2.2]	
Vocabulary: Charge Electromotive force Resistance Resistivity Kirchoff's Node Rule Kirchoff's Loop Rule Capacitance	

General Topic	AP Standards	Learning Objective,	Resources & Activities	Assessments	Suggested
Content Area 10:		Skills & Vocabulary			Time
Mechanical					(In Days)
Waves and Sound					
Enduring	Essential Knowledge:	Learning Objective:	Approved textbook	Teacher prepared	17
Understanding:				tests, quizzes, etc.	
	6.A.1 : Waves can propagate via	6.A.1.1: The student	Lab Investigation 8:		
6.A: A wave is a	different	is able to use a visual	Mechanical Waves	Series available	
traveling	oscillation modes such as	representation to		assessments	
disturbance that	transverse and	construct an explanation		online. (Optional)	
transfers	longitudinal.	of the distinction			
energy and	a. Mechanical waves can be either	between transverse and			
momentum.	transverse	longitudinal waves by			
	or longitudinal. Examples include	focusing on the vibration			
6.B: A periodic	waves on a	that generates the wave.			
wave	stretched string and sound waves.	[SP 6.2]			
is one that	b. This includes, as part of the				
repeats as	mechanism	6.A.1.2: The student			
a function of both	of "propagation," the idea that	is able to describe			
time	the speed of	representations			
and position and	a wave depends only on	of transverse and			
can	properties of the	longitudinal waves. [SP			
be described by	medium.	1.2]			
its	c. The propagation of sound waves included	1.2]			
amplitude,	in this EK includes the idea that	6.A.2.1: The student is			
frequency,	the traveling	able to describe sound			
wavelength,	disturbance consists of pressure	in terms of transfer of			
speed, and	variations	energy and momentum			
•	coupled to displacement	in a medium and relate			
energy.	variations.				
6.D: Interference	d. This applies to both periodic	the concepts to everyday			
and	waves and to	examples. [SP 6.4, 7.2].			
	wave pulses.				
superposition lead		6.A.3.1: The student is			
to	6.A.2: For propagation,	able to use graphical			

standing waves	mechanical waves	representation of a		
and beats.	require a medium, while	periodic mechanical		
	electromagnetic	wave to determine the		
	waves do not require a physical	amplitude of the wave.		
	medium.	[SP 1.4]		
	Examples include light traveling			
	through a	6.A.4.1: The student is		
	vacuum and sound not traveling	able to explain and/or		
	through a	predict qualitatively how		
	vacuum.	the energy carried by a		
		sound wave relates to the		
	6.A.3 : The amplitude is the	amplitude of the wave,		
	maximum displacement of a wave from its	and/or apply this concept		
	equilibrium	to a real-world example.		
	value.	[SP 6.4]		
	a. The amplitude is the maximum			
	displacement from equilibrium of	6.B.1.1: The student is		
	the wave.	able to use a graphical		
	A sound wave may be	representation of a periodic		
	represented by either	mechanical wave (position		
	the pressure or the displacement	versus time) to determine		
	of atoms or	the period and frequency of		
	molecules. This covers both	the wave and describe how		
	periodic waves	a change in the frequency		
	and wave pulses.	would modify features of		
	b. The pressure amplitude of a	the representation. [SP		
	sound wave	1.4, 2.2]		
	is the maximum difference			
	between local	6.B.2.1: The student		
	pressure and atmospheric	is able to use a visual		
	pressure.	representation of a		
		periodic mechanical wave		
	6.A.4: Classically, the energy	to determine wavelength		
	carried by	_		
	a wave depends upon and	of the wave. [SP 1.4]		

increases with amplitude. Examples include sound waves. a. Higher amplitude refers to both	6.B.4.1: The student is able to design an experiment to determine
greater pressure variations and greater displacement variations. b. Examples include both periodic waves and wave pulses.	the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. [SP 4.2, 5.1, 7.2]
 6.B.1: For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time. a. In a periodic sound wave, pressure variations and displacement variations are both present and with the same frequency. 	 6.B.5.1: The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer. [SP 1.4] 6.D.1.1: The student is able to use
 6.B.2: For a periodic wave, the wavelength is the repeat distance of the wave. 6.B.4: For a periodic wave, wavelength is the ratio of speed over frequency. 	representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses. [SP 1.1, 1.4]
6.B.5 : The observed frequency of a wave	6.D.1.2: The student

depends on the relative motion of	is able to design a		
source and	suitable experiment and		
observer. This is a qualitative	analyze data illustrating		
treatment only.	the superposition of		
	mechanical waves		
6.D.1: Two or more wave pulses	(only for wave pulses or		
can interact	standing waves). [SP 4.2,		
in such a way as to produce	5.1]		
amplitude	5.1]		
variations in the resultant wave.	6.D.1.3: The student is		
When two			
pulses cross, they travel through	able to design a plan for		
each other;	collecting data to quantify		
they do not bounce off each	the amplitude variations		
other. Where the	when two or more traveling		
pulses overlap, the resulting	waves or wave pulses		
displacement can	interact in a given medium.		
be determined by adding the	[SP 4.2]		
displacements of			
the two pulses. This is called	6.D.2.1: The student is		
superposition.	able to analyze data or		
	observations or evaluate		
6.D.2: Two or more traveling	evidence of the interaction		
waves can	of two or more traveling		
interact in such a way as to	waves in one or two		
produce amplitude	dimensions (i.e., circular		
variations in the resultant wave.	wave fronts) to evaluate		
	the variations in resultant		
6.D.3: Standing waves are the	amplitudes. [SP 5.1]		
result of the			
addition of incident and reflected	6.D.3.1: The student is		
waves that	able to refine a scientific		
are confined to a region and have	question related to		
nodes and	standing waves and		
antinodes. Examples include	design a detailed plan for		
waves on a fixed			

	Y	 	
length of string and sound waves	the experiment that can be		
in both	conducted to examine the		
closed and open tubes.	phenomenon qualitatively		
a. Reflection of waves and wave	or quantitatively. [SP 2.1,		
pulses, even	3.2, 4.2]		
if a standing wave is not created,	· •		
is covered in	6.D.3.2: The student is		
Physics 1.	able to predict properties		
b. For standing sound waves,	of standing waves that		
pressure nodes	result from the addition		
correspond to displacement	of incident and reflected		
antinodes, and	waves that are confined to		
vice versa. For example, the open			
end of a	a region and have nodes		
tube is a pressure node because	and antinodes. [SP 6.4]		
the pressure			
equalizes with the surrounding air	6.D.3.3: The student is		
pressure	able to plan data collection		
and therefore does not oscillate.	strategies, predict the		
The closed	outcome based on the		
end of a tube is a displacement	relationship under test,		
node because	perform data analysis,		
the air adjacent to the closed end	evaluate evidence		
is blocked	compared to the prediction,		
from oscillating.	explain any discrepancy		
	and, if necessary, revise		
6.D.4: The possible wavelengths	the relationship among		
of a standing	variables responsible for		
wave are determined by the size	establishing standing		
of the region	waves on a string or in a		
to which it is confined.	column of air. [SP 3.2, 4.1,		
a. A standing wave with zero	_		
amplitude at	5.1, 5.2, 5.3]		
both ends can only have certain			
wavelengths.	6.D.3.4: The student is able		
Examples include fundamental	to describe representations		

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and models of situations			
in which standing waves			
result from the addition			
of incident and reflected			
waves confined to a region.			
-			
[]			
6 D 1 1. The student is			
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-			
-			
-			
0			
the region. [SP 1.5, 6.1]			
6.D.4.2: The student			
is able to calculate			
wavelengths and			
frequencies (if given			
wave speed) of standing			
-			
-			
-			
-			
_			
instruments. [SP 2.2]			
	 in which standing waves result from the addition of incident and reflected waves confined to a region. [SP 1.2] 6.D.4.1: The student is able to 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. [SP 1.5, 6.1] 6.D.4.2: The student is able to calculate wavelengths and 	 in which standing waves result from the addition of incident and reflected waves confined to a region. [SP 1.2] 6.D.4.1: The student is able to 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. [SP 1.5, 6.1] 6.D.4.2: The student is able to 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. Examples include musical instruments. [SP 2.2] 6.D.5.1: The student 	in which standing waves result from the addition of incident and reflected waves confined to a region. [SP 1.2] 6.D.4.1: The student is able to 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. [SP 1.5, 6.1] 6.D.4.2: The student is able to 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. Examples include musical instruments. [SP 2.2] 6.D.5.1: The student

changes are calledrepresentation to explainbeats. Examples include thehow waves of slightlytuning of andifferent frequency giveinstrument.rise to the phenomenonb. The beat frequency is theof beats.difference in[SP 1.2]frequency between the twowaves.c. In Physics 1, only qualitativeVocabulary:understandingFrequencyof EK 6.D.5 is necessary.WavelengthAmplitudePitchWave SpeedSuperpositionInterferenceConstructive InterferenceDestructie InterferenceStanding Wave	
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General Topic	AP Standards	Learning Objective, Skills & Vocabulary	Resources & Activities	Assessments	Suggested Time (In Days)
Review For Final					10
Exam					