

Correlation to Massachusetts Science and Technology Curriculum Framework
Foundations of Physics
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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
INQ.01 Earth and Space Science	High School	Inquiry	Pose questions and state hypotheses based on prior scientific experiences.	3 3	using life experiences and common sense inquiry starts with questions	89	what is it that moves in the case of a wave?
INQ.02 Earth and Space Science	High School	Inquiry	Distinguish between hypothesis and theory as scientific terms.	8 9 37 60 96 97	testing hypotheses with experiments physics vocabulary is very specific understanding the word "per" understanding the Greek letter delta terms of mass and weight understanding symbols		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
INQ.04 Inquiry and Experimentation	High School	Inquiry	Use mathematics to analyze and support findings and to model conclusions.	11	Ptolemy model vs. Copernicus model of the solar system	13	compare prediction to measurement
				40	making a good model	13	create a graph
				43	constructing a graph	16	create a graph
				43	graphs are a way of representing data	16	describe the graph
				44	graphical models	22	create graphs
				44	using a graphical model to make a prediction and checking the model's accuracy	22	compare calculation with graph estimate
				45	recognizing patterns using graphs	22	how do you measured positions compare to model?
				54	understanding patterns in relationships between variables	22	uniform acceleration model
				54	constructing a graph	24	create an algebraic model
				55	create a graph from a data table	25	find the average time
				56	indicate relationships between variables in graphs	28	solve second law equation for string tension
				60	creating the acceleration formula from experiments	29	does experiment agree with prediction?
				66	developing the formulas for a model of motion with constant acceleration	32	develop a model that predicts acceleration
				246	understanding graphs of harmonic motion	37	make a graph
						38	make a graph
		43	create algebraic model				
		43	sketch four graphs				

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				282	write a formula relating velocity of wave to period and wavelength	43	how does the measurement compare to your prediction?
				290	the process of digital sound reproduction	49	write a formula
				297	frequency spectrum	56	create a graph
				304	comparison of wave forms from guitar sounds	58	find average of three trials
				307	decibel level vs. frequency graph for human hearing	66	create a graph of speed vs. position
				312	light intensity follows an inverse square law	67	calculate average of three times
				411	the waveform of AC electricity	71	calculate average work and power
				412	average voltage and current of AC power	76	compare predicted mass to actual mass
				427	diagramming electric fields using field lines	82	make three different graphs
				443	diagramming magnetic fields using magnetic field lines	87	sketch a graph
				479	current vs.voltage graph for a transistor	94	give an equation that describes your observations
						114	are there differences between your prediction and measurement?
						135	graph voltage vs. current
						136	graph voltage vs. current
						151	make a graph of voltage vs. time
						160	create a graph

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
						167	make a graph of voltage vs. number of magnets
						169	make a current vs. voltage graph for the diode
						189	Bernoulli's equation
INQ.05 Inquiry and Experimentation	High School	Inquiry	Simulate physical processes or phenomena using different kinds of representations.	9	testing ideas against scientific evidence	21	conduct the experiment
				242	finding a basic cycle of harmonic motion	28	set up the ultimate pulley
				456	an experiment with a wire and compass	43	perform experiment
				463	building an electromagnet with wire and a nail	65	investigate motion on a roller coaster
				467	experiment demonstrating electromagnetic induction	67	set up the straight track
						67	investigate motion on a roller coaster
						82	plan three experiments to determine which variable affects the period of a pendulum
						85	select appropriate technology to make measurements
						85	design and test a way to increase natural frequency
						129	choose circuit parts to light a bulb
						202	conduct your experiment

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INQ.06 Inquiry and Experimentation	High School	Inquiry	Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.	11 25 40 42 44 297	Ptolemy model vs. Copernicus model of the solar system why accuracy and precision are important making a good model controlling variables in experiments using a graphical model to make a prediction and checking the model's accuracy frequency spectrum	13 22 22 29 43 43 45 76 114 202	compare prediction to measurement how do you measured positions compare to model? compare calculation with graph estimate does experiment agree with prediction? discuss sources of error how does the measurement compare to your prediction? discuss sources of errors compare predicted mass to actual mass are there differences between your prediction and measurement? identify two sources of experimental error
INQ.07 Inquiry and Experimentation	High School	Inquiry	Revise scientific models.	7 8	revising explanations through observation refining theories based on observations		

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INQ.08 Inquiry and Experimentation	High School	Inquiry	Communicate and defend a scientific argument.	42	writing procedures in a lab notebook helps make sure your results are repeatable	16	what do the results tell you?
				306	explain why hearing can be damaged by loud sounds	18	are the accelerations different?
						19	does the ball accelerate?
						43	what would happen if...?
						58	explain why the angular acceleration is different
						80	explain your observations
						87	explain how force applied causes the response
						90	explain why higher tension makes waves move faster
						92	explain how wind might cause big waves in water
						109	explain how the colored filters work
						122	communicate your findings
						132	what conclusions can you draw?
						133	analyze data and explain a rule
						175	display information you found for your element
						202	keep detailed notes as you work

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PHY.01.01 Physical Sciences/ Physics	High School	Motion and Forces	Distinguish between vector quantities (velocity, acceleration, and force) and scalar quantities (speed and mass).	26	weight is a measure of the force of gravity pulling on mass	39	investigating vectors
				43	calculate the velocity vector		
				27	understanding and measuring mass	44	investigating force vectors
				38	compare and contrast speed and velocity	49	draw a free body diagram and label forces
				82	English unit of force is the pound	52	converting mass to weight
				92	measuring forces from a vertical jump		
				93	explain the difference between mass and weight		
				96	differences between mass and weight		
				98	weight and acceleration		
				99	weight is a force but mass is not		
				115	explain weight and mass		
				116	calculate mass from weight		
				118	vectors have magnitude and direction		
				119	displacement vectors		
				124	definition of the velocity vector		
				125	speed is the magnitude of the velocity vector		
125	the velocity vector						

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				126	components of the velocity vector		
				127	adding velocity vectors		
				132	the force vector describes the strength and direction of a force		
				136	calculate the acceleration of a skier on a slope		
				152	attractive force between mass of person and mass of object is weight		
				186	work done by a force at an angle to the distance		
PHY.01.02 Physical Sciences/ Physics	High School	Motion and Forces	Illustrate how to represent vectors graphically and be able to add them graphically.	119	adding vectors	41	calculate the resultant vector
				120	adding vectors		
				121	adding and subtracting vectors		
				127	adding velocity vectors		

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PHY.01.03 Physical Sciences/ Physics	High School	Motion and Forces	Distinguish between, and solve problems involving, velocity, speed, and constant acceleration.	36	the precise meaning of speed	9	calculate speed of rolling marble
				37	calculating speed	9	collect data and calculate speed of car
				37	how to calculate speed	10	make object move with speed of 1 m/sec
				38	compare and contrast speed and velocity	12	finding speed of ball with one photogate
				38	the speed formula and calculating speed	14	find the speed of the ball
				41	speed of a ball on a ramp	15	find speed of the ball
				46	speed is the rate of change of position	17	find the acceleration
				47	average and instantaneous speed	17	studying acceleration
				47	average and instantaneous speed	17	find two speeds
				48	determining speed from the slope of a position vs. time graph	17	learn techniques for finding acceleration
				55	calculate the average speed and distance traveled	20	understanding equation for uniform accelerated motion
				58	acceleration is the rate of change in the speed of an object	21	calculate speed of ball
				58	acceleration is the rate of change in the speed of an object	25	derive acceleration equation
				59	comparing speed and acceleration	26	make ball roll at constant speed
				60	formula for acceleration	29	calculate the acceleration
				60	calculating acceleration from experiments	33	calculate the predicted speed
				39	investigating vectors		

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				61	zero acceleration vs. constant acceleration vs. acceleration with zero speed	42	find initial speed of ball
				61	general definition of acceleration	43	calculate the velocity vector
				62	acceleration is total change of speed divided by total change in time	50	calculate the speed of the ball
				64	calculate speed in accelerated motion	66	find the speed of the ball
				64	calculating the speed of an object that is accelerating	68	what is speed of the ball?
				64	calculate speed in accelerated motion	76	calculate speeds of projectile and target balls
				67	calculate time and distance from acceleration	90	calculate the speed of the wave pulse
				70	calculating height and time of flight in free fall problems	191	calculate speed of air in homemade air-speed tester
				74	understanding average speed and instantaneous speed		
				75	calculations of speed		
				84	direction of net force and acceleration and speed		
				103	calculate the acceleration of a car including friction		

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				118	vectors have magnitude and direction		
				119	displacement vectors		
				124	definition of the velocity vector		
				125	the velocity vector		
				125	speed is the magnitude of the velocity vector		
				126	components of the velocity vector		
				127	adding velocity vectors		
				128	constant velocity of horizontal component of projectile motion		
				129	analyze a horizontally launched projectile		
				130	analyzing changing velocity in vertical component of projectile motion		
				142	calculating acceleration for sled on slope		
				146	calculating linear speed of a moving wheel		
				147	the linear speed of a rolling wheel		
				150	centripetal acceleration		

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				150	calculate the centripetal acceleration of a motorcycle		

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PHY.01.04 Physical Sciences/ Physics	High School	Motion and Forces	Create and interpret graphs of motion (position vs. time, speed vs. time, velocity vs. time, constant acceleration vs. time).	47	position vs. time graph	13	graph speed versus position
				48	determining speed from the slope of a position vs. time graph	16	create a speed vs. time graph
				48	graphs showing changes in speed	16	create a position vs. time graph
				49	speed vs. time graph for constant speed	19	make a speed vs. time graph
				50	graphs for motion of increasing speed and decreasing speed	20	speed vs. time graph for uniform acceleration
				50	speed vs. time graph for downhill motion	22	create a speed vs. time graph
				54	graphing speed vs. time	22	create a position vs. time graph
				55	analyzing distance vs. time graph		
				61	constant speed and constant acceleration		
				62	speed vs. time graph for accelerated motion		
				63	complex speed vs. time graphs		
				63	calculating acceleration from a speed vs. time graph		
				65	calculating distance from speed vs. time graph		
				74	sketching speed vs. time graphs for different changes of motion		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				74	describing motion with speed vs. time graph		
				76	analyzing graph for changes in motion		
				260	velocity vs. time graph of harmonic motion		
				260	position vs. time graph of harmonic motion		
PHY.01.05 Physical Sciences/ Physics	High School	Motion and Forces	Explain the relationship between mass and inertia.	26	inertia is an effect of mass	85	where is the mass that provides inertia?
				79	descriptions of inertia and Newton's first law		
				87	forces always come in pairs		
				94	inertia problem		
				151	centrifugal force is actually an example of inertia		
				249	inertia and restoring force cause harmonic motion		
				642	inertial mass		

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PHY.01.06 Physical Sciences/ Physics	High School	Motion and Forces	Interpret and apply Newton's first law of motion.	61	any acceleration must come from a force	26	study Newton's first law
				78	changes in motion only occur through force	27	collect data on Newton's first law
				79	all objects tend to resist changes in motion	27	explain how Newton's first law applies
				85	if there is acceleration there must be force		
				94	seat belt problem		
				148	direction of force determines linear or rotational motion		
				168	Newton's first law and rotational inertia		
				222	Newton's first law and momentum		

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PHY.01.07 Physical Sciences/ Physics	High School	Motion and Forces	Interpret and apply Newton's second law of motion to show how an object's motion will change only when a net force is applied.	81	Newton's second law of motion	28	investigate Newton's second law
				83	calculation using Newton's second law	77	relationship between force and motion and the second law
				84	Newton's second law and dynamics problems		
				85	finding force from acceleration		
				85	force problems		
				93	problems using Newton's first law and second law		
				106	Newton's second law and net force		
				108	equilibrium and Newton's second law		
				108	use equilibrium to find an unknown force		
				116	calculate the acceleration of a toy		
				136	calculating acceleration on a ramp		
				137	calculating acceleration from 3-D forces		
				137	the vector form of Newton's second law		
				149	calculating centripetal force		
				150	formula for centripetal acceleration		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				169	Newton's second law applies to rotational motion		
				171	Newton's second law for rotational motion variables		
				228	Newton's second law relating force and momentum		
				229	momentum form of Newton's second law		
				252	Newton's second law and natural frequency		

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PHY.01.08 Physical Sciences/ Physics	High School	Motion and Forces	Use a free body force diagram with only co-linear forces to show forces acting on an object, and determine the net force on it.	83 84 86 89 103 106 107 107 112 135 141	finding the net force calculating net force zero acceleration means net zero force solving problems with action-reaction forces net force includes the force of friction net force must be zero in equilibrium net force of zero and free-body diagram forces on a free-body diagram analysis of forces on a bridge normal force of an inclined plane calculate the net force	30 31 45	Newton's third law and free body diagrams draw free body diagrams and identify action-reaction pairs balancing a specified force

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PHY.01.09 Physical Sciences/ Physics	High School	Motion and Forces	Qualitatively distinguish between static and kinetic friction, what they depend on and their effects on the motion of objects.	41	effect of friction on motion of a ball on a ramp	34	investigate static and sliding friction
				71	air resistance and terminal speed	61	what effect does friction have on mechanical advantage?
				72	friction and traction and antilock brakes		
				100	the force of friction and the different types of friction		
				101	a model for friction		
				102	calculating the force of friction		
				103	friction and motion		
				104	reducing friction force		
				105	friction applications		
				115	friction of a pulled sled		
				124	effects of friction on trajectories		
				135	frictional force on an inclined plane		
				136	calculating acceleration on a ramp accounting for friction		
				142	effects of friction on acceleration		
				183	friction and mechanical advantage of wheel and axle		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				184	friction and mechanical advantage of ramps and screws		
				245	friction causes damping in oscillators		
				256	friction and steady state		

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PHY.01.10 Physical Sciences/ Physics	High School	Motion and Forces	Interpret and apply Newton's third law of motion.	87	forces always occur in action-reaction pairs	30	Newton's third law and free body diagrams
				88	Newton's third law operates on pairs of objects	30	investigate Newton's third law
				89	solving problems with action-reaction forces	31	draw free body diagrams and identify action-reaction pairs
				89	identifying which force is acting on which object		
				102	the normal force as the reaction in an action-reaction pair		
				107	forces on a free-body diagram		
				111	understanding reaction forces in terms of springs and deformation		
				112	analysis of forces on a bridge		
				135	normal force of an inclined plane		
				224	momentum and Newton's third law		
				425	electric forces always occur in pairs according to Newton's third law		
				548	Newton's third law and pressure in a fluid		
				550	pressure and the third law		
				557	pressure of gases		

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PHY.01.11 Physical Sciences/ Physics	High School	Motion and Forces	Understand conceptually Newton's law of universal gravitation.	152	description of law of universal gravitation	51	calculate gravitational force of attraction
				153	formula and calculations for law of universal gravitation	51	investigate law of universal gravitation
				154	satellites and orbital motion		
				154	orbital motion		
				155	satellite motion application		
				156	HEO and geostationary orbit		
				158	calculate weight and acceleration due to gravity on Pluto		
				216	tides are due to force of gravity		
				243	orbit is a type of cycle		
642	Newton's laws and gravity						

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PHY.01.12 Physical Sciences/ Physics	High School	Motion and Forces	Identify appropriate standard international units of measurement for force, mass, distance, speed, acceleration, and time, and explain how they are measured.	18	measurements of distance in units of length	2	practice length measurement
				19	description of length measured in English and metric systems	3	convert from inches to meters
				19	scientists use metric units	4	measuring time
				20	how to convert units of measurement	7	estimating mass
				21	conversions between area and volume units	9	make distance measurement
				22	time intervals	18	measure the length
				23	units for measuring time	23	measure the distance
				24	time intervals in physics	26	find length in centimeters
				27	measuring mass in kg and grams	29	measure the force
				33	commonly used units for measuring mass	34	measure the mass
				34	converting length units between systems	34	measure the force
				37	units for speed	36	measure the mass
				58	units of acceleration	36	measure the new position
				60	understanding units of acceleration	62	measure string length
				82	unit of force is derived	65	measure vertical distance
				82	units of force are pounds and newtons	68	convert grams to kilograms
						70	measure and mark height
		78	measure mass of ball				
		78	make the string 70 cm long				
		178	measure 100 grams of water				

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				83	understanding units for using Newton's second law	192	find the mass of the bottle
				110	units for spring constant	202	find the mass
				144	units of angular speed		
				186	units of work are joules		
				428	deriving units for measuring electric fields		

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PHY.02.01 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Interpret and provide examples that illustrate the law of conservation of energy.	194	the law of conservation of energy	66	law of conservation of energy
				194	conservation of energy explained	68	find the total energy at each position
				194	conservation of energy	74	investigating collisions and conservation of energy
				195	conservation of energy in a closed system		
				195	applying conservation of energy for a marble rolling on a hilly track		
				197	conservation of energy for Hoover Dam		
				203	efficiency and conservation of energy		
				206	connection between efficiency and time		
				215	energy flows in biological systems		
				227	kinetic energy conservation for elastic collisions		
				370	relationship and conservation of mass and energy		
				469	energy conservation and Faraday's law		
				515	thermodynamics and conservation of energy		
552	conservation of energy in fluids						

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				553	energy conservation and Bernoulli's equation		
				629	conservation of energy in nuclear reactions		
PHY.02.02 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Provide examples of how energy can be transformed from kinetic to potential and vice versa.	194	energy transformations	66	law of conservation of energy
				195	applying conservation of energy for a marble rolling on a hilly track	68	find the total energy at each position
				196	energy transformation hydroelectric plant	72	potential to kinetic energy conversion in a pendulum
				197	conservation of energy for Hoover Dam	74	investigating collisions and conservation of energy
				199	kinetic and potential energy conversions while bouncing in a trampoline	88	potential to kinetic energy conversions of a pendulum
				212	energy flow in a pendulum		
				245	kinetic to potential energy changes in motion of an oscillator		
				253	oscillators exchange energy back and forth between potential and kinetic		

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PHY.02.03 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Apply quantitatively the law of conservation of mechanical energy to simple systems.	195	applying conservation of energy for a marble rolling on a hilly track	66	law of conservation of energy
				197	conservation of energy for Hoover Dam	68	find the total energy at each position
						74	investigating collisions and conservation of energy

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PHY.02.04 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Describe the relationship among energy, work, and power both conceptually and quantitatively	185	how to calculate work	64	relationship between work and energy
				185	work and energy	70	calculate work
				187	calculating work done against gravity	70	calculate person's power
				189	relationship between work and energy	71	calculate work done
				191	the symmetry between work and energy	71	calculate power output for each climber
				191	calculate the potential energy of a cart		
				192	calculating kinetic energy depends on speed and mass		
				193	calculate the kinetic energy of a moving car		
				197	calculating energy supplied by Hoover Dam		
				207	calculate power in climbing stairs		
				207	power is the rate of doing work or using energy		
				208	power formulas		
				208	units of power		
				209	calculating power for common devices		
				210	estimating the power in wind		
				211	estimate average input power of a person		

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				211	power in biological systems		
				216	estimating the energy in tides		
				220	calculate energy and power for humans		
				220	calculate power rating		
				409	power and efficiency of electric cars		

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PHY.02.05 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Interpret the law of conservation of momentum and provide examples that illustrate it. Calculate the momentum of an object.	222	comparison of kinetic energy and momentum	73	momentum is a vector
				223	momentum is a vector	73	calculating momentum
				223	momentum formula and calculating momentum	75	investigate collisions and conservation of momentum
				224	law of conservation of momentum	77	the momentum form of Newton's second law
				225	conservation of momentum in collisions	78	which ball had a greater change in momentum?
				226	applying conservation of momentum	79	investigate angular momentum
				226	solving elastic and inelastic collision problems	80	explain life application of conservation of momentum
				227	momentum conservation for collisions in two and three dimensions	80	angular momentum behaves like a vector
				229	force on a rocket from change in momentum		
				230	calculate change in momentum for elastic vs. inelastic collisions		
				231	what is angular momentum		
				231	conservation of angular momentum examples		
				232	conservation of angular momentum		

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				232	angular momentum depends on speed and mass and shape		
				233	formula for angular momentum		
				235	jet engines work because of conservation of momentum		
				236	momentum conservation of turbofan engine		
				237	why is momentum a vector		
				238	momentum in billiards		
				239	calculate momentum		
				276	natural frequency and harmonics		
				370	Einstein's thinking about momentum of particles moving near the speed of light		
				629	conservation of momentum in nuclear reactions		

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PHY.02.06 Physical Sciences/ Physics	High School	Conservation of Energy and Momentum	Identify appropriate standard international units of measurement for energy, work, power, and momentum.	185	work and energy	63	studying the concept of work
				185	how to calculate work	64	relationship between work and energy
				185	physics definition of work	70	calculate work
				186	the work done by a force	70	calculate person's power
				187	work done against gravity	71	calculate work done
				187	calculating work done against gravity	71	calculate power output for each climber
				189	relationship between work and energy		
				191	the symmetry between work and energy		
				193	deriving the formula for kinetic energy		
				199	concept of work		
				200	calculate work done		
				207	calculate power in climbing stairs		
				208	power formulas		
				210	estimating the power in wind		
				211	power in biological systems		
				220	calculate power rating		
				408	measuring power in watts		
				409	power and efficiency of electric cars		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				409	units of watts and horsepower used in electrical circuits		
				410	electric companies charge for kilowatt-hours used		
				513	joules and calories and Btus		
PHY.03.01 Physical Sciences/ Physics	High School	Heat and Heat Transfer	Relate thermal energy to molecular motion.	506	temperature and addition of heat energy		
				506	temperature measures average kinetic energy		
				520	relationship between temp and average kinetic energy		
PHY.03.02 Physical Sciences/ Physics	High School	Heat and Heat Transfer	Differentiate between specific heat and heat capacity.	514	specific heat and the heat equation	179	specific heat

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.03.03 Physical Sciences/ Physics	High School	Heat and Heat Transfer	Explain the relationship among temperature change in a substance for a given amount of heat transferred, the amount (mass) of the substance, and the specific heat of the substance.	509	temperature change and thermal energy	179	specific heat
				513	transfer of thermal energy		
				513	balance of thermal energy		
				513	joules and calories and Btus		
				514	specific heat and the heat equation		
				522	thermal equilibrium		
				523	thermal conductors and insulators		
				534	R-value		
				537	heat flow between objects of different temperature		
				538	using heat conduction equation to calculate R-value		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.03.04 Physical Sciences/ Physics	High School	Heat and Heat Transfer	Recognize that matter exists in four phases, and explain what happens during a phase change.	30	physical differences between solids and liquids and gases	177	observe a common phase change
				30	relationship between states of matter and arrangement and motion of atoms and molecules		
				33	describe movement of atoms in solids and gases		
				508	phases of matter and arrangement of molecules		
				508	characteristics of matter related to its phase		
				509	temp vs. time graph for phase change of ice to water		
				509	temp vs. time graph for phase change of ice to water		
				509	heat of fusion		
				509	melting		
				509	changing from solid to liquid		
				510	changing from liquid to gas		
				510	heat of vaporization		
				510	boiling		
				511	evaporation and condensation		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				519	temp vs. time graphs for various materials		
				519	phases of matter		
				520	temp vs. time curve question		
				595	chemical bonds determine properties of materials		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.01 Physical Sciences/ Physics	High School	Waves	Differentiate between wave motion (simple harmonic nonlinear motion) and the motion of objects (nonharmonic).	242	definition of an oscillator	84	examples of harmonic motion systems
				243	examples of oscillators		
				246	understanding graphs of harmonic motion		
				247	graphs of in-phase and out-of-phase harmonic motion		
				248	equilibrium and oscillators		
				252	mass on a spring acts as an oscillator		
				258	name common oscillators		
				258	label graph of harmonic motion		
				262	waves transmit energy		
				263	waves are a form of traveling energy		
				265	wave pulse		
				267	water waves are transverse and Slinky is longitudinal		
				268	one- and two- and three-dimensional waves		
				272	waves transfer energy through absorption		
				275	standing waves on a string		
				277	standing waves on a string		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				277	energy of a wave		
				530	energy and radiation relationships		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.02 Physical Sciences/ Physics	High School	Waves	Recognize the measurable properties of waves (e.g., velocity, frequency, wavelength) and explain the relationships among them.	242	what is a cycle?	81	investigate the motion of a pendulum
				244	concepts of period and frequency explained	88	if frequency is increased what happens to total energy?
				245	concept of amplitude explained	89	study characteristics of a wave pulse on a string
				249	analyze the motion of the cycle of a pendulum	90	measure speed of a wave pulse
				251	systems tends to have a preferred frequency	90	study the speed of the wave pulse
				258	identify period and frequency and cycle and amplitude	93	investigate frequency and wavelength
				260	calculate speed of an oscillator	94	investigate the wavelength of standing waves
				264	basic properties of frequency and wavelength and amplitude	94	investigate the frequency of standing waves
				264	frequency and amplitude and wavelength in waves	125	study the polarization of a transverse spring wave
				265	concept of speed of a wave		
				266	formula for speed of a wave		
				266	speed of a wave is the speed at which a cycle moves		
				268	creating plane waves and circular waves		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				277	energy of a wave is proportional to frequency and amplitude		
				278	wavelength of a standing wave		
				282	describe relationship between wave characteristics		
				286	properties of sound waves		
				287	frequency and pitch of sound		
				288	relationship of loudness and amplitude and pressure in sound wave		
				291	pressure and amplitude of sound waves		
				292	importance of wavelength of sound waves		
				292	frequency and wavelengths of sound		
				300	pitch and frequency in music		
				303	design of a guitar		
				308	wave amplitude and harmonics of tuning fork and musical instrument		
				452	MRI--each nucleus is a resonant oscillator		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail	
PHY.04.03 Physical Sciences/ Physics	High School	Waves	Distinguish between transverse and longitudinal waves	265	wave pulse	89	making wave pulses on a string	
				267	water waves are transverse and Slinky is longitudinal		89	study wave pulses on elastic cord
				267	transverse and longitudinal waves		91	making circular waves in a ripple tank
				268	one- and two- and three-dimensional waves		91	make different types of waves in a ripple tank
				275	standing waves on a string		91	making plane waves in a ripple tank
				277	standing waves on a string		91	is your water wave transverse or longitudinal?
				278	modes of a wave			
				279	modes of vibration			
				283	type of wave represented by a spring			
				292	sound is a longitudinal wave			
PHY.04.04 Physical Sciences/ Physics	High School	Waves	Distinguish between mechanical and electromagnetic waves.	286	sound waves require matter to traverse			
				530	electromagnetic radiation			

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.05 Physical Sciences/ Physics	High School	Waves	Interpret and be able to apply the laws of reflection and refraction (qualitatively) to all waves.	270	waves and refraction	92	observing reflection in water waves
				270	waves and reflection	92	investigate reflection in a ripple tank
				271	waves and reflection and boundaries	106	study refraction in a prism
				271	waves and refraction and boundaries	106	study reflection in a prism
				274	resonance and reflection	113	study how refraction works
				310	how we see		
				315	light bends as it moves into a material		
				315	light rays bounce off a surface		
				317	how the human eye sees color		
				318	how we perceive color		
				319	we see mostly reflected light		
				324	the process of how light is reflected		
				324	the process of how light is reflected		
				332	specular and diffuse reflection		
				333	finding the normal line for reflection		
				334	refraction is the bending of light rays		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				336	total internal reflection and the critical angle		
				339	the image formed in a mirror		
				340	design of a lens		
				356	electromagnetic waves are oscillations of an energy field		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.06 Physical Sciences/ Physics	High School	Waves	Recognize the effects of polarization, wave interaction, and the Doppler effect.	270	waves and reflection	92	observing reflection in water waves
				270	waves and diffraction	92	investigate reflection in a ripple tank
				270	waves and refraction	92	investigate diffraction in a ripple tank
				270	waves and absorption	101	investigate interference with sound waves
				270	concept of boundaries	123	study light interference
				271	waves and refraction and boundaries	125	polarization of water waves
				271	waves and reflection and boundaries	125	polarization of a spring wave
				271	curved boundaries	126	study the polarization of light
				272	waves and absorption and boundaries	126	polarization of light
				272	waves and diffraction and boundaries		
				273	constructive and destructive interference		
				273	sound and light waves and interference		
				274	resonance and reflection		
				278	nodes and antinodes		
				293	definition of the Doppler effect		
				294	Doppler effect and supersonic and subsonic motion		
				295	standing wave patterns of sound		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				296	interference of sound waves		
				301	consonance and dissonance and beats		
				306	beats in a musical sound		
				307	understanding of Doppler effect		
				356	electromagnetic waves are oscillations of an energy field		
				361	interference of light waves and Young's double-slit experiment		
				363	polarization		
				364	polarizers		
				365	applications of polarization		
				373	holograms and the interference of light		
				530	absorption of thermal radiation		
				638	Doppler effect and red shift		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.07 Physical Sciences/ Physics	High School	Waves	Explain, graph, and interpret graphs of constructive and destructive interference of waves.	246	understanding graphs of harmonic motion	83	investigate oscillators in-phase and out-of-phase
				247	the phase of an oscillator		
				258	label graph of harmonic motion		
				273	concept of the superposition principle		
				283	analyze superimposed waves		
				284	superimpose two waves		
				287	the superposition of sound waves		
				297	Fourier's theorem and superposition principle and frequency spectrum		
				307	applying superposition principle		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.08 Physical Sciences/ Physics	High School	Waves	Explain the relationship between the speed of a wave (e.g., sound) and the medium it travels through.	265	wave pulse	89	making wave pulses on a string
				265	speed of a wave vs. speed of its medium	89	study wave pulses on elastic cord
				267	water waves are transverse and Slinky is longitudinal	91	making circular waves in a ripple tank
				268	one- and two- and three-dimensional waves	91	make different types of waves in a ripple tank
				269	propagation of waves through continuous materials	91	making plane waves in a ripple tank
				275	standing waves on a string		
				277	standing waves on a string		
				284	which direction does a cork move on a water wave?		
294	speed of sound in different materials						

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.04.09 Physical Sciences/ Physics	High School	Waves	Recognize the characteristics of a standing wave and explain the conditions under which two waves on a string or in a pipe can interfere to produce a standing wave.	251	concept of natural frequency	85	investigate natural frequency
				252	changing natural frequency	86	investigate resonance and its importance
				254	concept of resonance	95	natural frequency and resonance of standing waves on a string
				254	periodic force and natural frequency		
				255	resonance occurs when periodic force matches natural frequency		
				255	resonance occurs when periodic force matches natural frequency		
				259	resonance and amplitude		
				270	concept of boundaries		
				271	curved boundaries		
				274	how resonance is created		
				274	natural frequency of waves		
				275	standing waves and natural frequency and resonance		
				275	boundaries and natural frequency		
				280	microwaves and resonance		
295	resonance of sound						

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.05.01 Physical Sciences/ Physics	High School	Electromagnetism	Recognize the characteristics of static charge, and explain how a static charge is generated.	418	electric charge is a fundamental property of matter	146	build a simple electroscope
				419	observing forces between charges using an electroscope	147	investigate and understand how an electroscope works
				419	electric forces are created between electric charges	147	investigate the concept of electric charge
				420	explanation of coulomb	149	investigate charged balloons
				421	current is the flow of charge		
				422	negative charge of electrons and current flow		
				423	charging an electroscope by induction		
				423	static electricity and charge polarization and induction		
				424	relationship of electric force and charge		
				425	the force between charges		
				426	charge creates an electric field		
				428	source charges and test charges		
				430	a capacitor stores charge		
				433	ability of a capacitor to store charge is capacitance		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.05.02 Physical Sciences/ Physics	High School	Electromagnetism	Interpret and apply Coulomb's law.	424 425 437 438	Coulomb's law calculate force using Coulomb's law Coulomb's law is an inverse square law calculating charge using Coulomb's law	148	investigate Coulomb's law
PHY.05.03 Physical Sciences/ Physics	High School	Electromagnetism	Explain the difference in concept between electric forces and electric fields.	426 427 437 441 442 443 453 649	fields and forces an electric field exists around a charge strength of an electric field comparing magnetic and electric forces force between two magnetics is not an inverse square law magnets create a magnetic field around them magnetic poles and electric charge every field has an associated particle	154	how are magnetic field lines similar to electric field lines?

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.05.04 Physical Sciences/ Physics	High School	Electromagnetism	Develop a qualitative and quantitative understanding of current, voltage, resistance, and the connection between them.	386	relationship between current and resistance	134	Ohm's law
				388	Ohm's law	135	derive Ohm's law from experiment
				396	calculation of voltage from resistance and current	136	use Ohm's law to calculate the resistance
				399	calculating current in a series circuit using Ohm's law	138	apply Ohm's law to series circuits
				400	Kirchoff's voltage law	171	use Ohm's law to calculate the resistance of the transistor
				401	Kirchhoff's current law		
				403	using Ohm's law in parallel circuits		
				404	using Ohm's law for circuit analysis		
				404	using Kirchhoff's voltage law for circuit analysis		
				404	using Kirchhoff's current law for circuit analysis		
				405	analyzing a voltage divider circuit		
				407	calculate currents and voltages in a network circuit		
				416	using Ohm's law to calculate current		
				419	differences between electric force and gravity		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				424	the strength of electric forces		
				426	gravity is far weaker than electric forces		
				428	comparison between electric fields and gravitational fields		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.05.05 Physical Sciences/ Physics	High School	Electromagnetism	Identify appropriate units of measurement for current, voltage, and resistance, and explain how they are measured.	378	concept of electric current	131	explore the concept of electric current
				382	voltage measures differences in energy	131	measure current in a circuit
				382	unit of electric current is the ampere or amp (A)	132	explore the concept of voltage
				382	current flows through wires and carries energy	132	measure voltage in a circuit
				383	voltage and potential energy	134	study the relationship between resistance and current
				383	voltage is measured in volts (V)	134	apply the concept of electrical resistance
				386	concept of electrical resistance	137	measure voltage and current in series circuits
				387	electrical resistance is measured in ohms	138	determining total resistance in a series circuit
				387	measuring resistance	163	measure direct current
				389	the resistance of electrical devices	164	measure voltage of battery pack
				390	resistance of conductors and insulators	165	measure voltage
				391	resistors	169	measure current and voltage
				395	knowing difference between types of resistors	171	measure current and voltage
				399	adding resistance in a series circuit		
				408	current definition		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				408	voltage definition		
				408	resistance definition		
				416	calculating resistance in a circuit		
				421	one ampere is the flow of one coulomb per second		
				421	current is the flow of charge		
				422	negative charge of electrons and current flow		
				431	current into and out of capacitors		
				431	voltage of a capacitor circuit		
				479	resistance of a transistor		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.05.06 Physical Sciences/ Physics	High School	Electromagnetism	Analyze circuits (find the current at any point and the potential difference between any two points in the circuit) using Kirchoff's and Ohm's laws.	379	concept of a circuit	129	construct simple electric circuits
				380	understanding simple circuit and its diagram	131	construct a simple circuit
				384	battery uses chemical energy to produce electrical charge	134	Ohm's law
				386	simple bulb and battery circuits to illustrate electrical resistance	135	derive Ohm's law from experiment
				386	relationship between current and resistance	136	use Ohm's law to calculate the resistance
				388	calculate the current flowing in a circuit	137	parallel circuit and Ohm's law
				388	Ohm's law	137	investigate series circuits
				396	calculation of voltage from resistance and current	138	build a parallel circuit
				398	parallel circuit defined	138	apply Ohm's law to series circuits
				398	series circuit defined	139	compare series and parallel circuits
				399	current and resistance in a series circuit	139	analyze parallel circuits
				399	calculating current in a series circuit using Ohm's law	140	build and analyze network circuits
				400	Kirchoff's voltage law	171	use Ohm's law to calculate the resistance of the transistor
				400	voltage in a series circuit		
				401	parallel circuits		
				401	Kirchhoff's current law		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				402	voltage and current in a parallel circuit		
				402	advantages of parallel circuits over series circuits		
				403	using Ohm's law in parallel circuits		
				403	resistance in parallel circuits		
				404	using Ohm's law for circuit analysis		
				404	using Kirchhoff's voltage law for circuit analysis		
				404	using Kirchhoff's current law for circuit analysis		
				405	analyzing a voltage divider circuit		
				405	voltage dividers		
				406	comparing series and parallel circuits		
				407	solving network circuits		
				407	solving network circuits		
				407	calculate currents and voltages in a network circuit		
				414	why series circuits are not used in homes and buildings		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				414	why parallel circuits are used in homes and buildings		
				415	compare current in a series and parallel circuit		
				416	using Ohm's law to calculate current		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.06.01 Physical Sciences/ Physics	High School	Electromagnetic Radiation	Describe the electromagnetic spectrum in terms of wavelength and energy, and be able to identify specific regions such as visible light.	281	microwaves	122	study properties of the electromagnetic spectrum
				310	light is a form of energy	124	use a spectrometer to measure wavelength of different colors of light
				311	fluorescent bulbs create UV light		
				312	the intensity of light		
				313	light carries information		
				314	the speed of light		
				320	the energy of IR and UV light		
				320	visible light has just the right energy for life		
				328	how is light used for communication?		
				356	light can be described in terms of waves		
				357	relationship between frequency and energy and color of light		
				357	frequency and wavelength of light		
				358	speed of light is frequency multiplied by length		
				359	description and examples of infrared waves		
				359	waves of the electromagnetic spectrum		
				360	visible light waves		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				360	description and examples of ultraviolet waves		
				373	wave fronts of light		
				375	relate color to frequency for visible light		
				531	thermal radiation and infrared light		
				624	UV light is ionizing radiation		
PHY.06.02 Physical Sciences/ Physics	High School	Electromagnetic Radiation	Explain how the various wavelengths in the electromagnetic spectrum have many useful applications such as radio, television, microwave appliances, and cellular telephones.	262	waves are all around us		
				277	standing waves are used to store energy		
				281	use of microwaves in microwave ovens		
				359	descriptions of radio waves and microwaves and infrared rays		
				360	x-rays and gamma rays		
				452	MRI uses radio waves		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.06.03 Physical Sciences/ Physics	High School	Electromagnetic Radiation	Calculate the frequency and energy of an electromagnetic wave from the wavelength.	262	waves transmit energy	95	waves carry energy from one place to another
				263	waves are a form of traveling energy	124	use a spectrometer to measure wavelength of different colors of light
				272	waves transfer energy through absorption		
				277	energy of a wave		
				357	relationship between frequency and energy and color of light		
				375	relate color to frequency for visible light		
				530	energy and radiation relationships		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
PHY.06.04 Physical Sciences/ Physics	High School	Electromagnetic Radiation	Recognize and explain the ways in which the direction of visible light can be changed.	310	how we see	106	study refraction in a prism
				315	mirrors	106	use a mirror to study how light behaves
				315	light bends as it moves into a material	106	study reflection in a prism
				315	light rays bounce off a surface	109	examining the spectrum of a light source
				316	white light is the combination of all the colors	112	investigate law of reflection
				317	how the human eye sees color	113	study how refraction works
				318	how we perceive color	113	investigate Snell's law of refraction
				319	we see mostly reflected light	114	study the critical angle of refraction in a prism
				324	the process of how light is reflected	114	study index of refraction
				324	the process of how light is reflected	114	apply Snell's law of refraction
				331	mirrors reflect light	116	investigate how a converging lens bends light
				331	lenses bend light	121	study the thin lens formula
				331	prisms separate white light into its colors	123	study light interference
				332	specular and diffuse reflection	123	study light diffraction patterns
				332	the image in a mirror		
				333	finding the normal line for reflection		
				333	the laws of reflection		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				334	refraction is the bending of light rays		
				334	the index of refraction		
				335	Snell's law of refraction		
				335	refraction depends on index of refraction in both materials		
				336	total internal reflection and the critical angle		
				336	how fiber optics work		
				337	prisms and dispersion and rainbows		
				339	the image formed in a mirror		
				340	converging and diverging lenses		
				340	lenses follow Snell's law of refraction		
				340	design of a lens		
				345	diffraction spot size image defect		
				346	thin lens formula		
				352	law of reflection		
				353	explain fiber optic cables		
				353	explain index of refraction		
				354	using Snell's law		

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Standard #: Strand	Grade	Topic	Learning Standard	student text pg	detail	investigation pg	detail
				358	index of refraction is ratio of speed of light in material to speed of light in vacuum		
				361	interference of light waves and Young's double-slit experiment		
				362	diffraction grating		
				364	transmission of light through two polarizers		
				373	holograms and the interference of light		
				376	fiber optic cable calculation		
				530	absorption of thermal radiation		
				531	blackbody and perfect absorption of light		
				574	absorption of light		
				586	emission and absorption of photons in laser light		