Middle School Phenomenon Model Course 1 - Bundle 4
Energy, Force, and Motion: When Objects Collide

This is the fourth bundle of the Middle School Phenomenon Model Course 1. Each bundle has connections to the other bundles in the course, as shown in the [Course Flowchart].

Bundle 1 Question: This bundle is assembled to address the questions of "What happens when objects collide?"

Summary

The bundle organizes performance expectations around helping students understand how objects interact when in contact. Instruction developed from this bundle should always maintain the three-dimensional nature of the standards, but recognize that instruction is not limited to the practices and concepts directly linked with any of the bundle performance expectations.

Connections between bundle DCIs

Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed (PS3.A as in MS-PS3-1). This idea can be connected to the concept that when the motion energy of an object changes, there is inevitably some other change in energy at the same time (PS3.B as in MS-PS3-5). The concept of motion also connects to the idea that the motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change (PS2.A as in MS-PS2-2). The idea of forces connects to the concept that for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (PS2.A as in MS-PS2-1).

Concepts of force and motion also can connect to the ideas that a sound wave needs a medium through which it is transmitted (PS4.A as in MS-PS4-2), and the concept of sound waves connects to the idea that a simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude (PS4.Aas in MS-PS4-1). Finally, the concepts of waves connect to the idea of a wave model of light, and the idea that this wave model is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media (PS4.B as in MS-PS4-2).

Bundle Science and Engineering Practices

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the practices of planning and carrying out investigations (MS-PS2-2), developing and using models (MS-PS4-2), analyzing and interpreting data (MS-PS3-1), using mathematics and computational thinking (MS-PS4-1), constructing explanations and designing solutions (MS-PS2-1), and engaging in argument from evidence (MS-PS3-5 and MS-ETS1-2). Many other practice elements can be used in instruction.

Bundle Crosscutting Concepts

Instruction leading to this bundle of PEs will help students build toward proficiency in elements of the crosscutting concepts of Patterns (MS-PS4-1), Systems and System Models (MS-PS2-1), Stability and Change (MS-PS2-2), Scale, Proportion, and Quantity (MS-PS3-1), Energy and Matter (MS-PS3-5), and Structure and Function (MS-PS4-2). Many other crosscutting concepts elements can be used in instruction.

All instruction should be three-dimensional.

Performance Expectations	MS-PS2-1. **Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*** [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*] MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*] MS-PS3-1. **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.] MS-PS3-5. **Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.** [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary: Assessment does not include calculations of energy.*] MS-PS4-1. **Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.** [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*] MS-PS4-2. **Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.** [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]
Example Phenomena	When a car collides with a fire hydrant, the car stops suddenly. A train does not stop when it hits a car. A chair supports a person when she/he sits in it. A strong echo returns when you shout from the rim of the Grand Canyon. A pencil appears to bend when it is inserted into a cup of water.
Additional Practices Building to the PEs	**Asking Questions and Defining Problems** • Ask questions to determine relationships between dependent and independent variables, and relationships in models. Students could *ask questions to determine relationships between* t**he motion of an object** *(dependent variable)* **and the sum of the forces acting on it** *(independent variable)*. MS-PS2-2

Additional Practices Building to the PEs (Continued)	**Developing and Using Models** • Develop and/or use a model to predict and/or describe phenomena. Students could *develop a model to describe* [the] *phenomenon* [that] **for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction**. MS-PS2-1 Students could *use a model to predict* **the motion of an object** [based on] **the sum of the forces acting on it**. MS-PS2-2 **Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. Students could *plan an investigation* **about the path that light travels [including] at surfaces between different transparent materials**. [Then], *in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim*. MS-PS4-2 ● Evaluate the accuracy of various methods for collecting data. Students could *evaluate the accuracy of various methods for collecting data* [to determine the] **kinetic energy** [of an object]. MS-PS3-1 **Analyzing and Interpreting Data** • Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success. Students could *analyze data to define an optimal operational range for a proposed tool [related to]* **the force** [exerted on each of two] **interacting objects**. MS-PS2-1 **Using Mathematics and Computational Thinking** • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. Students could apply mathematical concepts and processes (e.g., rate, basic operations, simple algebra) to scientific questions related to the **kinetic energy** [of an object, which] **it is proportional to the mass of the moving object and grows with the square of its speed.** MS-PS3-1 **Constructing Explanations and Designing Solutions** • Construct an explanation using models or representations. Students could construct an explanation [related to the concept that] **when the motion energy of an object changes, there is inevitably some other change in energy at the same time**. MS-PS3-5

	Engaging in Argument From Evidence • Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. Students could r*espectfully receive critiques about* [their] *models* [of] **a simple wave** [that] **has a repeating pattern with a specific wavelength, frequency, and amplitude** *citing relevant evidence and responding to questions that elicit pertinent elaboration and detail*. MS-PS4-1 **Obtaining, Evaluating, and Communicating Information** • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). Students could *critically read scientific texts adapted for classroom use* [about] **sound waves** *to determine the central ideas*, [including that they] **need a medium through which [they are] transmitted.** MS-PS4-2
Additional Crosscutting Concepts Building to the PEs	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems. Students could describe how they can *use cause and effect relationships to predict* **the motion of an object** [based on] **the sum of the forces acting on it**. MS-PS2-2 **Scale, Proportion, and Quantity** • Scientific relationships can be represented through the use of algebraic expressions and equations. Students could describe how they are able to *represent scientific relationships* [related to] **simple waves,** [which have] **a repeating pattern with a specific wavelength, frequency, and amplitude**, *through the use of equations.* MS-PS4-1 **Systems and System Models** • Models are limited in that they only represent certain aspects of the system under study. Students could describe how *models* [of] **the motion of an object** [based on] **the sum of the forces acting on it** *are limited in that they only represent certain aspects of the system under study*. MS-PS2-2
Additional Connections to Nature of Science	**Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** • Laws are regularities or mathematical descriptions of natural phenomena. Students could identify that *laws*— [such as] **for any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction**—*are regularities or mathematical descriptions of natural phenomena*. MS-PS2-1 **Science is a Human Endeavor** • Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas. Students could read about how the *scientist* [Sir Isaac Newton] *was guided by habits of mind* [that supported him in discovering that] **the motion of an object is determined by the sum of the forces acting on it.** MS-PS2-2

MS-PS2-1 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*[Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [*Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design an object, tool, process or system.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

Crosscutting Concepts

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

- -

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Observable features of the student performance by the end of the course:			
1	Using scientific knowledge to generate design solutions		
	a	Given a problem to solve involving a collision of two objects, students design a solution (e.g., an object, tool, process, or system). In their designs, students identify and describe*:	
		i.	The components within the system that are involved in the collision.
		ii.	The force that will be exerted by the first object on the second object.
		iii.	How Newton's third law will be applied to design the solution to the problem.
		iv.	The technologies (i.e., any human-made material or device) that will be used in the solution.
2	Describing* criteria and constraints, including quantification when appropriate		
	a	Students describe* the given criteria and constraints, including how they will be taken into account when designing the solution.	
		i.	Students describe* how the criteria are appropriate to solve the given problem.
		ii.	Students describe* the constraints, which may include:
			1. Cost.
			2. Mass and speed of objects.
			3. Time.
			4. Materials.
3	Evaluating potential solutions		
	a	Students use their knowledge of Newton's third law to systematically determine how well the design solution meets the criteria and constraints.	
	b	Students identify the value of the device for society.	
	c	Students determine how the choice of technologies that are used in the design is affected by the constraints of the problem and the limits of technological advances.	

MS-PS2-2 Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.** [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [*Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS2.A: Forces and Motion

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Crosscutting Concepts

Stability and Change

- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Observable features of the student performance by the end of the course:			
1	Identifying the phenomenon to be investigated		
	a	Students identify the phenomenon under investigation, which includes the change in motion of an object.	
	b	Students identify the purpose of the investigation, which includes providing evidence that the change in an object's motion is due to the following factors:	
		i.	Balanced or unbalanced forces acting on the object.
		ii.	The mass of the object.
2	Identifying the evidence to address the purpose of the investigation		
	a	Students develop a plan for the investigation individually or collaboratively. In the plan, students describe*:	
		i.	That the following data will be collected:
			1. Data on the motion of the object.
			2. Data on the total forces acting on the object.
			3. Data on the mass of the object.
		ii.	Which data are needed to provide evidence for each of the following:
			1. An object subjected to balanced forces does not change its motion (sum of F=0).
			2. An object subjected to unbalanced forces changes its motion over time (sum of F≠0).

		3. The change in the motion of an object subjected to unbalanced forces depends on the mass of the object.
3	Planning the investigation	
	a	In the investigation plan, students describe*:
		i. How the following factors will be determined and measured:
		1. The motion of the object, including a specified reference frame and appropriate units for distance and time.
		2. The mass of the object, including appropriate units.
		3. The forces acting on the object, including balanced and unbalanced forces.
		ii. Which factors will serve as independent and dependent variables in the investigation (e.g., mass is an independent variable, forces and motion can be independent or dependent).
		iii. The controls for each experimental condition.
		iv. The number of trials for each experimental condition.

MS-PS3-1 Energy

Students who demonstrate understanding can:

MS-PS3-1. **Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.** [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Observable features of the student performance by the end of the course:			
1	Organizing data		
	a	Students use graphical displays to organize the following given data:	
		i.	Mass of the object.
		ii.	Speed of the object.
		iii.	Kinetic energy of the object.
	b	Students organize the data in a way that facilitates analysis and interpretation.	
2	Identifying relationships		
	a	Using the graphical display, students identify that kinetic energy:	
		i.	Increases if either the mass or the speed of the object increases or if both increase.
		ii.	Decreases if either the mass or the speed of the object decreases or if both decrease.
3	Interpreting data		
	a	Using the analyzed data, students describe*:	
		i.	The relationship between kinetic energy and mass as a linear proportional relationship ($KE \propto m$) in which:
			1. The kinetic energy doubles as the mass of the object doubles.
			2. The kinetic energy halves as the mass of the object halves.
		ii.	The relationship between kinetic energy and speed as a nonlinear (square) proportional relationship ($KE \propto v2$) in which:
			1. The kinetic energy quadruples as the speed of the object doubles.
			2. The kinetic energy decreases by a factor of four as the speed of the object is cut in half.

MS-PS3-5 Energy

Students who demonstrate understanding can:

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [*Assessment Boundary: Assessment does not include calculations of energy.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education:*

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed worlds. • Construct, use, and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon. - ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations	**PS3.B: Conservation of Energy and Energy Transfer** • When the motion energy of an object changes, there is inevitably some other change in energy at the same time.	**Energy and Matter** • Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).

Observable features of the student performance by the end of the course:			
1	Supported claims		
	a	Students make a claim about a given explanation or model for a phenomenon. In their claim, students include idea that when the kinetic energy of an object changes, energy is transferred to or from that object.	
2	Identifying scientific evidence		
	a	Students identify and describe* the given evidence that supports the claim, including the following when appropriate:	
		i.	The change in observable features (e.g., motion, temperature, sound) of an object before and after the interaction that changes the kinetic energy of the object.
		ii.	The change in observable features of other objects or the surroundings in the defined system.
3	Evaluating and critiquing the evidence		
	a	Students evaluate the evidence and identify its strengths and weaknesses, including:	
		i.	Types of sources.
		ii.	Sufficiency, including validity and reliability, of the evidence to make and defend the claim.
		iii.	Any alternative interpretations of the evidence and why the evidence supports the given claim as opposed to any other claims.
4	Reasoning and synthesis		
	a	Students use reasoning to connect the necessary and sufficient evidence and construct the argument. Students describe* a chain of reasoning that includes:	
		i.	Based on changes in the observable features of the object (e.g., motion, temperature), the kinetic energy of the object changed.
		ii.	When the kinetic energy of the object increases or decreases, the energy (e.g., kinetic, thermal, potential) of other objects or the surroundings within the system increases or decreases, indicating that energy was transferred to or from the object.
	b	Students present oral or written arguments to support or refute the given explanation or model for the phenomenon.	

MS-PS4-1 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [*Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

- -

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Disciplinary Core Ideas

PS4.A: Wave Properties

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Crosscutting Concepts

Patterns

- Graphs and charts can be used to identify patterns in data.

Observable features of the student performance by the end of the course:

1	Representation		
	a	Students identify the characteristics of a simple mathematical wave model of a phenomenon, including:	
		i.	Waves represent repeating quantities.
		ii.	Frequency, as the number of times the pattern repeats in a given amount of time (e.g., beats per second).
		iii.	Amplitude, as the maximum extent of the repeating quantity from equilibrium (e.g., height or depth of a water wave from average sea level).
		iv.	Wavelength, as a certain distance in which the quantity repeats its value (e.g., the distance between the tops of a series of water waves).
2	Mathematical modeling		
	a	Students apply the simple mathematical wave model to a physical system or phenomenon to identify how the wave model characteristics correspond with physical observations (e.g., frequency corresponds to sound pitch, amplitude corresponds to sound volume).	
3	Analysis		
	a	Given data about a repeating physical phenomenon that can be represented as a wave, and amounts of energy present or transmitted, students use their simple mathematical wave models to identify patterns, including:	
		i.	That the energy of the wave is proportional to the square of the amplitude (e.g., if the height of a water wave is doubled, each wave will have four times the energy).
		ii.	That the amount of energy transferred by waves in a given time is proportional to frequency (e.g., if twice as many water waves hit the shore each minute, then twice as much energy will be transferred to the shore).
	b	Students predict the change in the energy of the wave if any one of the parameters of the wave is changed.	

MS-PS4-2 Waves and Their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [*Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

- Develop and use a model to describe phenomena.

Disciplinary Core Ideas

PS4.A: Wave Properties

- A sound wave needs a medium through which it is transmitted.

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Crosscutting Concepts

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Observable features of the student performance by the end of the course:			
1	Components of the model		
	a	Students develop a model to make sense of a given phenomenon. In the model, students identify the relevant components, including:	
		i.	Type of wave.
			1. Matter waves (e.g., sound or water waves) and their amplitudes and frequencies.
			2. Light, including brightness (amplitude) and color (frequency).
		ii.	Various materials through which the waves are reflected, absorbed, or transmitted.
		iii.	Relevant characteristics of the wave after it has interacted with a material (e.g., frequency, amplitude, wavelength).
		iv.	Position of the source of the wave.
2	Relationships		
	a	In the model, students identify and describe* the relationships between components, including:	
		i.	Waves interact with materials by being:
			1. Reflected.
			2. Absorbed.
			3. Transmitted.
		ii.	Light travels in straight lines, but the path of light is bent at the interface between materials when it travels from one material to another.
		iii.	Light does not require a material for propagation (e.g., space), but matter waves do require a material for propagation.
3	Connections		
	a	Students use their model to make sense of given phenomena involving reflection, absorption, or transmission properties of different materials for light and matter waves.	

	b	Students use their model about phenomena involving light and/or matter waves to describe* the differences between how light and matter waves interact with different materials.
	c	Students use the model to describe* why materials with certain properties are well-suited for particular functions (e.g., lenses and mirrors, sound absorbers in concert halls, colored light filters, sound barriers next to highways).