Forces and Motion

Overview

Unit abstract

Forces and Motion focuses on helping students understand ideas related to why some objects will keep moving and why objects fall to the ground. Students will be able to apply Newton's third law of motion to related forces to explain the motion of objects. Students are also able to apply an engineering practice and concept to solve a problem caused when objects collide. The crosscutting concepts of system and system models and stability and change serve as organizing concepts for these disciplinary core ideas. Students are expected to demonstrate proficiency in asking questions, planning and carrying out investigations, designing solutions, engaging in argument from evidence, developing and using models, and constructing explanations and designing solutions, and they are expected to use these practices to demonstrate understanding of the core ideas.

Essential questions

- How can one describe physical interactions between objects and within systems of objects?

- What is the effect of force on any pair of interacting objects?

- How is the motion of an object determined?

Written Curriculum

Next Generation Science Standards

MS. 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 expectations above were 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
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. (MS-PS2-1)	**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). (MS-PS2-1)	**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. (MS-PS2-1) -------------------------------------- ***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. (MS-PS2-1)

Connections to other DCIs in this grade-band: **MS.PS3.C** (MS-PS2-1)

Articulation across grade-bands: **3.PS2.A** (MS-PS2-1); **HS.PS2.A** (MS-PS2-1)

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions *(MS-PS2-1)*
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. *(MS-PS2-1)*
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. *(MS-PS2-1)*

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-PS2-1)
6.NS.C.5	Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. (MS-PS2-1)
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-1)*
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-PS2-1)*

7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-PS2-1)*

MS. 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 expectations above were 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
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 <u>multiple variables</u> 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. (MS-PS2-2) --------------------------------------- ***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. (MS-PS2-2)	**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. (MS-PS2-2) ▪ 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. (MS-PS2-2)	**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. (MS-PS2-2

Connections to other DCIs in this grade-band: **MS.PS3.A** (MS-PS2-2); **MS.PS3.B** (MS-PS2-2); **MS.ESS2.C** (MS-PS2-2)

Articulation across grade-bands: **3.PS2.A** (MS-PS2-2); **5HS.PS2.A** (MS-PS2-2); **HS.PS3.B** (MS-PS2-2); **HS.ESS1.B** (MS-PS2-2)

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (MS-PS2-2)
WHST.6-8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-PS2-2)

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-PS2-2)
6.EE.A.2	Write, read, and evaluate expressions in which letters stand for numbers. *(MS-PS2-2)*
7.EE.B.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-PS2-2)*
7.EE.B.4	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-PS2-2)*

MS. Engineering Design

Students who demonstrate understanding can:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

The performance expectations above were 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
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. ▪ Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)	**Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1) ▪ The uses of technologies and 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. (MS-ETS1-1)

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include: Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:
   Physical Science: MS-PS3-3
Connections to MS-ETS1.B: Developing Possible Solutions Problems include:
   Physical Science: MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5
Connections to MS-ETS1.C: Optimizing the Design Solution include:
   Physical Science: MS-PS1-6

Articulation of DCIs across grade-bands: **3-5.ETS1.A** (MS-ETS1-1); **3-5.ETS1.C** (MS-ETS1-1); **HS.ETS1.A** (MS-ETS1-1); **HS.ETS1.B** (MS-ETS1-1)

Common Core State Standards Connections:
ELA/Literacy –
RST.6-8.1   Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1)
WHST.6-8.8   Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources. (MS-ETS1-1)
Mathematics –
MP.2   Reason abstractly and quantitatively. *(MS-ETS1-1)*
7.EE.3   Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-ETS1-1)*

MS. Engineering Design

Students who demonstrate understanding can:

MS-ETS1-2.   Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

The performance expectations above were 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 world. ▪ Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)	**ETS1.B: Developing Possible Solutions** ▪ There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2)	N/A

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:
    Physical Science: MS-PS3-3
Connections to MS-ETS1.B: Developing Possible Solutions Problems include:
    Physical Science: MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5
Connections to MS-ETS1.C: Optimizing the Design Solution include:
    Physical Science: MS-PS1-6

Articulation of DCIs across grade-bands: **3-5.ETS1.A** (MS-ETS1-2); **3-5.ETS1.B** (MS-ETS1-2); **3-5.ETS1.C** (MS-ETS1-2); **HS.ETS1.A** (MS-ETS1-2); **HS.ETS1.B** (MS-ETS1-2)

Common Core State Standards Connections:
ELA/Literacy –
RST.6-8.1   Cite specific textual evidence to support analysis of science and technical texts. *(MS-ETS1-2)*
RST.6-8.9   Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2)
WHST.6-8.7   Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)
WHST.6-8.9   Draw evidence from informational texts to support analysis, reflection, and research. *(MS-ETS1-2)*
Mathematics –
MP.2   Reason abstractly and quantitatively. *(MS-ETS1-2)*
7.EE.3   Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-ETS1-2)*

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MS. Engineering Design

Students who demonstrate understanding can:

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

The performance expectations above were 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 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. ▪ Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3)	**ETS1.B: Developing Possible Solutions** ▪ There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-3) ▪ Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) **ETS1.C: Optimizing the Design Solution** ▪ Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3)	N/A

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:
    Physical Science: MS-PS3-3
Connections to MS-ETS1.B: Developing Possible Solutions Problems include:
    Physical Science: MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5
Connections to MS-ETS1.C: Optimizing the Design Solution include:
    Physical Science: MS-PS1-6

Articulation of DCIs across grade-bands: **3-5.ETS1.A** (MS-ETS1-3); **3-5.ETS1.B** (MS-ETS1-3); **3-5.ETS1.C** (MS-ETS1-3); **HS.ETS1.B** (MS-ETS1-3); **HS.ETS1.C** (MS-ETS1-3)

Common Core State Standards Connections:
ELA/Literacy –

RST.6-8.1	Cite specific textual evidence to support analysis of science and technical texts. *(MS-ETS1-3)*
RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)
RST.6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-3)

Mathematics –

MP.2	Reason abstractly and quantitatively. *(MS-ETS1-3)*
7.EE.3	Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-ETS1-3)*

MS. Engineering Design
Students who demonstrate understanding can:
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The performance expectations above were 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
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)	**ETS1.B: Developing Possible Solutions** - A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) - Models of all kinds are important for testing solutions. (MS-ETS1-4) **ETS1.C: Optimizing the Design Solution** - The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)	N/A

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include: **Physical Science:** MS-PS3-3 *Connections to MS-ETS1.B: Developing Possible Solutions Problems include:* **Physical Science:** MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5 *Connections to MS-ETS1.C: Optimizing the Design Solution include:* **Physical Science**: MS-PS1-6
Articulation of DCIs across grade-bands: **3-5.ETS1.B** (MS-ETS1-4); **3-5.ETS1.C** (MS-ETS1-4); **HS.ETS1.B** (MS-ETS1-4); **HS.ETS1.C** (MS-ETS1-4)

Common Core State Standards Connections: *ELA/Literacy –*	
SL.8.5	Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. *(MS-ETS1-4)*
Mathematics –	
MP.2	Reason abstractly and quantitatively. *(MS-ETS1-4)*
7.SP	Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. *(MS-ETS1-4)*

Clarifying the standards

Prior learning

The following disciplinary core ideas are prior learning for the concepts in this unit of study. By the end of Grade 5, students know that:

- Each force acts on one particular object and has both strength and a direction.

- An object at rest typically has multiple forces acting on it, but these forces add to give zero net force on the object.

- Forces that do not sum to zero can cause changes in the object's speed or direction of motion.

- The patterns of an object's motion in various situations can be observed and measured; when the past motion exhibits a regular pattern, future motion can be predicted from it.

- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Progression of current learning

Driving question 1
What is the effect of force on any pair of interacting objects?

Concepts	Practices
- 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). - Models can be used to represent the motion of objects in colliding systems and their interactions, such as inputs, processes, and outputs, as well as energy and matter flows within systems. - 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. - The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. - Specification of constraints includes consideration of scientific principles and other relevant knowledge, which are likely to limit possible solutions.	- Apply Newton's third law to design a solution to a problem involving the motion of two colliding objects. - Define a design problem involving the motion of two colliding objects that can be solved through the development of an object, tool, process, or system and that includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. - Evaluate competing design solutions involving the motion of two colliding objects based on jointly developed and agreed-upon design criteria. - Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. - Analyze and interpret data to determine similarities and differences in findings.

- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design

- A solution needs to be tested and then modified on the basis of the test results in order to improve it.

- Models of all kinds are important for testing solutions.

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Driving question 2
How is the motion of an object determined?

Concepts	Practices
- The change in an object's motion depends on balanced (Newton's first law) and unbalanced forces in a system - 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 includes qualitative comparisons of forces, mass, and changes in motion (Newton's second law); frame of reference; and specification of units - 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.	- Plan an investigation individually and collaboratively 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. - Design an investigation and 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. - Make logical and conceptual connections between evidence and explanations. - Examine the changes over time and forces at different scales to explain the stability and change in designed systems.

- For any given object, a larger force causes a larger change in motion.

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

Integration of content, practices, and crosscutting concepts

Throughout this unit of study, students will be examining and interacting with objects in motion. They will begin this unit by investigating Newton's third law of motion by observing the action/reaction forces involved during a collision. Students will expand their idea of collisions beyond the narrow view of collisions as being an accident in which two or more objects crash into each other. They will learn that scientists' use of the word *collision* does not refer to the size of the force; instead it describes any interaction between two objects. We want students to understand that a collision can be as small as an ant walking on a blade of grass—that is, that a collision is any touch between two objects, no matter how small or how large the force.

Some possible observations may include the action/reaction forces involved in roller skating, skateboarding, moving boxes of different masses, etc. Students will then apply Newton's third law to possible problems and solutions. Some possible investigations could include designing and launching rockets or protecting eggs in a collision.

Students then investigate Newton's first and second laws of motion through hands-on activities in which they observe the result of balanced and unbalanced forces on an object's motion. Some examples may include using a seesaw or kicking a ball. In addition, students will observe how an object's motion will change depending upon the mass of the object and the amount of force applied. Activities could include pushing objects of different masses and comparing the forces needed to accelerate the objects.

Students will continue their investigation of Newton's third law by participating in an engineering and design problem that will require them to design a solution to a problem involving the motion of two colliding objects. Students could begin by observing collisions. An example of a collision could be an egg in a cart rolling down an incline and colliding with a barrier. Based on their observations of collisions, students will jointly develop and agree upon the design problem that they will focus on. Students will begin by making a clear statement of the problem they are going to attempt to solve. Once students have a clearly stated problem, the teacher will need to provide them with time and opportunity to participate in a short research project where they will gather background information that will help them come up with possible design solutions. Students will need to document their findings, making sure that they cite the resources they use.

After students have collected evidence, they can then begin to brainstorm possible solutions. To begin this process, students will need to identify the constraints and criteria for a successful design solution. This would involve them identifying the limits of the design. For example, time, materials, and resources could be some constraints. Students will next identify the criteria for a successful design. For example, one criterion could be that the egg in the collision does not break at all, or that it may crack as long as the contents do not spill out. After the constraints and criteria have been identified, students can them generate possible solutions. Multiple solutions could be generated. Using the evidence collected during their research, as well as information they have learned as a part of their classroom experience, students can eliminate the solutions that seem least likely to be successful and focus on those that are more likely to be successful.

After students have identified the solutions that are most likely to be successful, they will evaluate their competing design solutions using a rubric, checklist, or decision tree to assist them in selecting the design solution they will take into the next phase of the process.

Students have reached the stage where they will need to create a model that can be tested. The model could be physical, graphical, mathematical, or it could be a scale model. Students will use the model to collect evidence that will help them determine which of the possible design solutions will be taken into the prototype phase.

During the prototype phase, students will create their actual model. Once students have constructed their devices, they should gather necessary data from tests performed on their design solutions. They will analyze and interpret these data to determine which design best minimizes the force acting upon the egg. For example, the materials of a particular design may be superior and/or the structure of another design may be more successful. Once students have evaluated competing solutions and analyzed and interpreted data, they may then begin to modify their original designs. It is important that students consider the benefits of each design solution. This is when they are deciding whether different parts of their solutions can be combined to maximize efficiency. The final goal is for students to identify the parts of each design solution that best fit their criteria and combine these parts into a design solution that is better than any of its predecessors. Students will then translate this activity to a real world-example in which they see the influence of science, engineering, and technology on society and the natural world.

Integration of engineering

This unit of study provides students with opportunities to participate in the complete engineering design process. ETS1-1 and ETS1-2 are required for these performance expectations; ETS1-3 and ETS1-4 are included as a way to provide students with an opportunity to experience the entire process at this grade level.

Integration of DCI from prior units within this grade level

In Unit 3, Study of the Ecosystem Dynamics, Functioning, and Resilience, students are introduced to engineering, technology, and science (ETS) in standard MSLS2-5.

Integration of mathematics and/or English language arts/literacy

Mathematics

- Reason abstractly and quantitatively when collecting and analyzing data about the application of Newton's third law in the course of designing a solution to a problem involving the motion of two colliding objects.

- Analyze data in the form of numbers and symbols to draw conclusions about how the sum of the forces on an object and the mass of an object change the object's motion.

- Understand that positive and negative numbers are used together to describe quantities having opposite directions or values; use positive and negative numbers to represent quantities in a design that applies Newton's third law to a problem involving the motion of two colliding objects.

- When collecting and analyzing data from investigations about how the sum of the forces on an object and the mass of the object changes the object's motion, write, read, and evaluate expressions in which letters stand for numbers.

English language arts/literacy

- Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions of the application of Newton's third law involving the motion of two colliding objects.

- Follow precisely a multistep procedure when carrying out experiments to apply Newton's third law when designing a solution to a problem involving the motion of two colliding objects, taking measurements, or performing technical tasks.

- Follow precisely a multistep procedure when performing an investigation that provides 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, taking measurements or performing technical tasks.

- Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading texts about the application of Newton's third law to the motion of two colliding objects

- Conduct a short research project to answer a question about the application of Newton's third law when designing a solution to a problem involving the motion of two colliding objects, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

- Conduct a short research project to answer a question about how the sum of the forces on the object and the mass of the object change an object's motion, drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

- Gather relevant information from multiple print and digital sources that provide information about the application of Newton's third law when designing a solution to a problem involving the motion of two colliding objects; assess the credibility of each source and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.

- Draw evidence from informational texts to support analysis, reflection, and research about the application of Newton's third law when designing a solution to a problem involving the motion of two colliding objects.

Future learning

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object.

- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.

- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic

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energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.

- The availability of energy limits what can occur in any system.

- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

- Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.

Number of Instructional Days

Recommended number of instructional days: 19 (1 day = approximately 50 minutes)

Note—The recommended number of days is an estimate based on the information available at this time. Teachers are strongly encouraged to review the entire unit of study carefully and collaboratively to determine whether adjustments to this estimate need to be made.