**Unit Essential Question:** *What are the effects of an asteroid collision and how can we prevent a future one?*

**Introduction**

Now that students have the motivation to prevent another asteroid collision, it is time for them to learn more about the scientific concepts of forces and motion in order to do so. In this task, students will investigate what factors affect the motion of objects and use this knowledge to help prevent a collision. While students can’t experiment with a collision of the same scale as an asteroid collision, they can experiment with smaller models—in this case, rolling marbles and a stack of pennies. By planning and carrying out their own investigations with these everyday materials, students can leverage their experiential knowledge of objects in motion and begin to ascribe scientific concepts to these experiences. By the end of this task, students should be able to understand *Etiam’s* collision with Earth within the context of mass, forces, and motion, and then use this new knowledge to brainstorm ideas on deflecting *Etiam*.

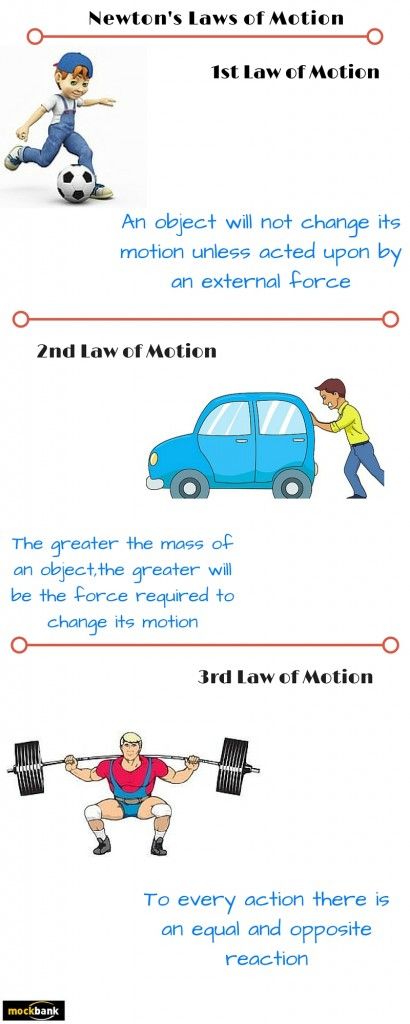
**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **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.] | **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. | **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. | **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-PS2-1**. **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.] | **Designing Solutions**   * Apply scientific ideas or principles to design an object, tool, process or system. | **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). | **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-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.] | **Analyzing and Interpreting Data**   * 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. |
| **Equity and Groupwork**   * Discuss and come to consensus to describe collision scenarios. * Work together to design defection strategies and plan and carry out a collision investigation. * Discuss analysis questions to learn from each others’ perspectives. | | | |
| **Language**   * Orally present descriptions of collision scenarios. * Interpret video resources and define main terms and laws. * Describe a multi-step procedure. * Write lab conclusions based on data. * Describe graphs and mathematical relationships in words. | | | |

**Learning Goals:**

This learning task asks students to investigate how different factors affect the motion of objects and use this knowledge to help prevent a collision. More specifically, students will:

* Use their experiential knowledge to describe the reasons behind different collision scenarios.
* Design different solutions to deflect an asteroid from Earth.
* Use scientific ideas, like Newton’s laws, to explain why things move.
* Plan and carry out an investigation to test different conditions of an asteroid hitting Earth.
* Apply knowledge of kinetic energy and Newton’s laws to come up with ideas on deflecting an asteroid.

**Content Background for Teachers**

https://www.pinterest.com/pin/52917364350091037/

In this task, students learn about all the forces acting on objects as they move, don’t move, and collide. Students experiment with these scientific concepts before learning about them explicitly, and then re-applying that new knowledge.

Specifically, students learn that a force is a push or pull upon an object resulting from the object’s interaction with another object. Forces can consist of contact forces and non-contact forces. In this task, students are dealing with contact forces, which are all those types of forces that result when the two interacting objects are physically contacting each other. Some examples of this are friction, normal forces, air resistance, and applied forces. For example, in this task, a moving ball hits a stack of pennies. The force of the ball hitting the stack of pennies would be an applied force.

In this same scenario of a ball hitting (or not hitting) a stack of pennies, students can also apply Newton’s three laws. Newton’s first law states that an object at rest stays at rest and an object in motion stays in motion with the same speed and direction unless acted upon by an unbalanced force. In other words, the pennies will stay stationary until the force of the ball sets them in motion. Newton’s second law states that the acceleration of an object is dependent on both the net force acting upon the object and the mass of the object. This is what students examine in the Elaborate portion of the task, and they find that a greater mass will increase the force of the rolling ball. Related to this experiment, students also learn that the kinetic energy of an object, or the energy due to its motion, is dependent on the mass of that object. By graphing data, they will see that the relationship is proportional. Students will also graph and see the relationship with speed in that the kinetic energy of an object grows with the square of its speed. Lastly, Newton’s third law states that for every action, there is an equal and opposite reaction. Students will see this firsthand, as the ball bounces backward once it collides with the pennies.

By understanding these scientific concepts of forces and motion within the context of this small model—the ball and the pennies—students will be able to apply these scientific concepts to the bigger problem they are addressing—the asteroid collision. Not only does this task help them explain the scientific nature of the asteroid movement and collision, it will also help them start thinking about how they can use these scientific concepts to thwart the collision.

**Academic Vocabulary**

* Trajectory
* Trial
* Control
* Dependent Variable
* Independent Variable
* Procedure
* Mass
* Kinetic Energy
* Speed
* Force
* Newton’s First Law
* Newton’s Second Law
* Newton’s Third Law

**Time Needed (Based on 45-Minute Periods)**

5 Days

* Engage: 0.5 period
* Explore: 1 period
* Explain: 0.5 period
* Elaborate: 2 periods
* Evaluate and Reflection: 1 period

**Materials**

* Unit 1, Task 2 Student Version

Explore (per group)

* Stack of 40 pennies (Earth)
* Heavy ball or large marble (asteroid *Etiam*)
* A track for *Etiam’s* trajectory (pipe insulation tubing, cut in half lengthwise)
* Risers (4 textbooks)
* Ruler
* String
* Balls of varying mass (Recommended: <http://www.arborsci.com/physics-balls>, but if not, use marbles of different size and mass)
* Foam
* Rubberbands
* Popsicle sticks
* Plastic spoons
* Tape

Explain

* Projector and speakers
* Tablets/computers
* Headphones (optional)

Elaborate

* Stack of 40 pennies (Earth)
* A track for *Etiam’s* trajectory (pipe insulation tubing, cut in half lengthwise)
* Risers (4 textbooks)
* Ruler
* Marbles of varying mass (see recommendation above)
* Calculators (Optional)

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 2: In Task 1, you learned about a historical asteroid collision that had big consequences. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 2: Now that you know why it’s so important we protect against another asteroid collision, it’s time to figure out how we might do it. To do this, let’s look more closely at what might happen when other things collide.
   * Now pass out their Task 2 student guide.
3. Students are given a series of scenarios to examine (below). For each scenario, ask students to use their own knowledge to explain why they think these happen as best they can. This not only introduces content by activating experiential knowledge, it also introduces students to one of the crosscutting concepts focused on in this task.
   * Students engage with **Systems and System Models** as they draw diagram models of each scenario to represent the system at work.
   * This activity should be done in partners, but each student should be individually recording their descriptions in their own student guides.
   * The scenarios can either be read aloud or projected for students to see (or both). The scenarios are as follows:
     + A moving soccer ball gets kicked.
     + A rocket launches from earth, leaves the atmosphere, and goes into space.
     + You are standing in a bus that stops suddenly, and you keep moving/falling forward.
     + A comet in space continues to move without slowing down or speeding up.
     + A large asteroid crashes into the moon.
     + A small asteroid crashes into the moon.
4. Recommended: Ask students to be prepared to share their descriptions of the scenarios. When calling on pairs of students to share their description of a scenario, it is recommended that you call on pairs using equity sticks. This encourages more equitable participation in class-wide discussions (See “How to Use This Curriculum” for more details)

**Explore**

1. We recommend reading the introduction on their student guides aloud and projecting the set-up diagram and materials list to review as a class. This allows students to understand the context of the activity and what each part of the model represents. In this activity, students will be using a smaller model to help them design ways they might save the Earth from an impending collision with the asteroid *Etiam*.
   * This activity emphasizes the crosscutting concept of **Stability and Change** as students examine the forces involved in the prevention of a collision at a much smaller scale in order to inform their explanation of stability and change in a much larger system—an asteroid collision.
2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Reporter.
   * Ask Facilitator to read the directions and to make sure everyone understands the task.
   * Ask the Materials Manager to handle any resources needed to complete the task.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Reporter to make sure the group is recording their setup, observations, and reasoning in their student guides and reporting all the necessary information for the final poster.
3. The nature of this exploration is very open, allowing students the freedom to try all kinds of ideas as a part of the process of **Designing Solutions.** In alignment with this SEP, students should use any scientific ideas they already have about forces and motion as well as relevant experiences to inform the design of their collision prevention.

* In groups, students will try a number of different strategies in order to attempt to deflect “*Etiam*.” For each attempt, they should record both their observations and their reasoning of why they think objects moved the way they did.
  + Possible attempts might include blocking the asteroid, changing the asteroid’s course, slowing the asteroid down, changing the size of the asteroid, etc.

1. After students have implemented and recorded all their attempts, have them make a poster showing and explaining their best deflection strategy. This reinforces the crosscutting concept of **Systems and System Models**, as students use models to represent their deflection system. As students learn more about forces and motion, they will be able to identify explicit interactions and flows of energy. These can then be used for their culminating projects.
   * Groups should briefly present these posters, so the class gets an idea of the different solutions out there. You may also want to collect this as a formative assessment to identify trends in students’ ability to design solutions or use a model to represent a system. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.
   * *Optional*: students slow-motion record their best deflection strategy. We greatly encourage this, as many will choose to use this video in their news segment.

**Explain**

1. This section of the task takes what students experienced in the Explore lab and ascribes scientific concepts—specifically forces and Newton’s laws.
2. It is recommended that you begin this portion of the task with a class-wide **KWL** (what do you **K**now, what do you **W**onder, what did you **L**earn?) chart about force. Call on students to share ideas and questions for the **K** and the **W** portions and record on the class chart**.**
3. Project the video, “What is Force?”: <https://www.youtube.com/watch?v=GmlMV7bA0TM>
   * In the video, the host asks people on the street to define force. They seem to have trouble defining it, even though they appear to have an idea of what force does. *Stop the video here.* Have students share, first in pairs, then as a whole class, what their definition of force is. Again, use equity sticks to call on students.
   * After, resume the video for the reveal: A force is a *push or pull*. Have students record this in the chart on their student guides.
4. Distribute computers/ipads for students to watch the other videos on Newton’s laws. If these are not available, use the same video projection format as the previous video.
   * You may choose one or both of the following videos for students to watch
     + *Tiros Educational - Newton’s Laws of Motion and Forces*
       - * <https://www.youtube.com/watch?v=NYVMlmL0BPQ>
     + *Makemegenius. Newton’s 3 (three) Laws of Motion* 
       - * <https://www.youtube.com/watch?v=mn34mnnDnKU>
     + For students who are particularly interested in football, the National Science Foundation also has videos about the science of NFL football as it relates to Newton’s laws. These can be accessed on YouTube.
   * Students should fill out the graphic organizer in their student guides, making sure to not only record a definition, but also an example and diagram.
     + This will help them to describe the asteroid collision within the context of these laws.
     + As students fill out their charts, you may wish to formatively assess students with some of the following questions: What is the relationship between force and motion? What is the difference between equal and unequal forces? What is a scenario where forces are equal? How do unequal forces affect motion? What is a scenario where forces are unequal?
5. Debrief as a class, by adding to the **L** column in the class **KWL.** 
   * It is recommended that you facilitate connections of the newly learned vocabulary to the Explore Lab. Some options are:
     + Think-Pair-Share about how the videos help explain phenomena that occurred in the lab. Use equity sticks to equitably share out ideas.
     + Provide a diagram of the lab in action and have students write in labels of where Newton’s Laws occurred.
     + If students recorded slow-motion videos in the Explore, have them work on voiceovers using academic language of Newton’s Laws.
   * These can all be used as formative assessments to see trends in student understanding of the DCIs related to Newton’s Laws. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

**Elaborate**

1. This section of the task asks students to take all of their experiential and scientific knowledge around forces and motion and combine it within an investigation related to the relationship between mass and force.
   * This part of the task asks students to use the Science and Engineering Practice of **Planning and Carrying Out Investigations**. In the design, students identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, etc.
2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   * Ask Facilitator to read the directions and to make sure everyone understands the task.
   * Ask the Materials Manager to handle any resources needed to complete the task.
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Recorder to make sure the group is recording their experiment design, data, and analysis.
3. In this investigation, similar materials are provided as the Explore, but now the focus is not to attempt to deflect the asteroid, but rather just to determine how “asteroids” with different masses impact “Earth.” During their investigation, a stack of pennies will represent Earth and a set of rolling objects will represent *Etiam*.
   * As a class, review the experimental question as well as the list of possible materials.
4. In groups, students will use the planning questions to help them plan their investigation.
   * Students must get their experimental design cleared before they may continue with the experiment. When checking experimental designs, ensure that students have created an experiment that tests how marbles of different types affects the number of pennies knocked down. Everything else should be controlled.
5. Once students have run their experiments, they should record their data in the data table provided and answer the analysis questions in their student guides.
   * Based on student need, you may choose to help students fill in the blanks on their data table (pictured below):

**Data Table 1: Change in ball type**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **# pennies knocked over in each trial** | | | | |  |
| **Type of rolling object** | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** | **Average # of pennies knocked from stack** |
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1. To help students better process all the concepts they have been exploring, conduct a facilitated discussion with a class-wide demo of the above experiment. We recommend the use of Think-Pair-Shares and equity sticks to create a richer discussion and more equitable participation (See “How to Use This Curriculum” for more details).
   * Set up the experiment and run it with one type of ball first. Some facilitating questions to ask may be:
     + What kind of energy does the ball have while in motion?
     + What are all the different forces acting on the pennies?
     + Where do we see Newton’s first law happening?
     + Where do we see Newton’s third law happening?
   * Run the experiment again with a ball of different mass. You may ask the same facilitating questions above for reinforcement, but we also recommend asking the following facilitating questions:
     + How are the balls different?
     + What differences did you notice when you changed the type of ball?
     + Why do you think this happened?
     + How does this show Newton’s second law?
2. Analysis questions specifically connect the experiment results to the scientific concepts learned in the Explain. Because of the class-wide discussion above, students may be prepared to answer the questions individually, if you wish to use them as a form of formative assessment. However, because there are many concepts in this task, we recommend having students complete these questions in pairs or small groups.
   * 1: The pennies are at rest until a force acts on the object, in this case the ball hitting the pennies. This represents Newton’s first law.
     + This question emphasizes the crosscutting concept of **Stability and Change** by asking students to examine how forces in the experiment affect the stability and change of objects.
   * 2: After a ball hit the pennies, it would bounce back. This matches Newton’s third law, which says that for every action, there is an equal and opposite reaction. The action of the ball transferring motion to the pennies corresponds with the reaction of the ball bouncing back.
   * 3: When the ball had more mass, more pennies were knocked over.
   * 4a: Students should draw two line graphs of the data and describe the relationship between mass and kinetic energy and the relationship between speed and kinetic energy. Students should notice that kinetic energy is proportional to the mass of the object (a ratio of 200/1) and kinetic energy grows with the square of its speed.
     + This question asks students to use the Science and Engineering Practice of **Analyzing and Interpreting Data** as they construct and interpret graphical displays to identify linear and nonlinear relationships.
   * 4b: Balls with more mass knock over more pennies because they have more kinetic energy to be passed to the pennies they hit. Thus, if *Etiam* has a lot of mass, it has a lot more kinetic energy that it will pass on to Earth, thus doing a lot more damage.
     + This question emphasizes the crosscutting concept of **Scale, Proportion and Quantity** as students use the proportional relationship between different types of quantities (mass and energy) to provide information they can use for the larger-scale event of an asteroid collision.
3. Return to the whole-class concept map from the Lift-Off Task.

* In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
  + Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  + Draw circles around each question and boxes around each concept.
  + Write connector words to describe connections between the concept boxes.
  + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: contact forces, Newton’s laws, mass, speed, and kinetic energy.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concepts as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  + **Scale, Proportion, and Quantity**: These could be phrases such as, “is proportional to”, “compared to”, “has a ratio of”, “is bigger/smaller than”, “is longer/shorter than”, etc.
  + **Systems and Systems Models**: These could be phrases such as, “is a part of,” “is related to,” “consists of,” “interacts with,” “works together with,” etc.
  + **Stability and Change**: These could be phrases such as, “remains the same”, “is changed by”, “is disrupted by”, “changes”, “disrupts”, etc.
* Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 2 section of the Unit 1 Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
2. Students have been tasked with designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. The student prompt is as follows: In this task, you explored and studied how different contact forces and factors like mass help predict the motion of objects. Now, let’s use these ideas to start deciding how to deflect *Etiam* from its path towards Earth.

* How will Etiam’s large mass affect Earth? Use experimental evidence from the task as well as scientific ideas of mass, kinetic energy, and speed to back up your response.
* How can Newton’s three laws help us predict and explain what will happen when *Etiam* hits Earth?
* Record ideas you have on deflecting *Etiam*, using the following questions to help you:
  + In the experiments, which solutions worked best?
  + Based on the data, can you combine characteristics from the best solutions to create an even better one?
  + How does each solution use contact forces and your understanding of mass and motion?

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you attempted to explain why different scenarios happen the way they do. Look back at your responses: after learning everything you have about contact forces, how can you add to or revise your explanations? Use information from the task to better explain these scenarios with the new scientific ideas we learned today.
* In this task, we focused on the crosscutting concepts of: **Scale, Proportion, and Quantity**: There are proportional relationships between different types of quantities; **Systems and System Models**: Models can be used to represent systems and their interactions; and **Stability and Change:** We can examine forces at different scales to explain stability and change. Where did you see examples of **Scale, Proportion, and Quantity, Systems and System Models**, and **Stability and Change** in this task?
* Now that you have learned more about the contact forces that are involved in an asteroid collision and preventing an asteroid collision, what questions do you still have?

1. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. You may collect students’ Project Organizer and assess using:
   * *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   * This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.
2. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.