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

**Introduction**

In the last task, students explored different contact forces that have an effect on how objects move and collide. However, there is another less tangible force that also affects how objects move and collide—gravity. In this task, students use a model to begin thinking about their own prior knowledge and experience with gravity, mostly their understanding that gravity pulls objects down towards Earth. In order for students to be able to thwart an asteroid collision, they will have to delve deeper than this basic understanding. As students collect information from three different resources, they will find that gravity does not just attract objects towards Earth, but also towards other bodies, and that this attraction has everything to do with an object’s mass. By the end of this task, students will be able to dispel some common misconceptions about gravity and use their new understanding to brainstorm more ways to prevent the collision of *Etiam* with Earth.

**Alignment Table**

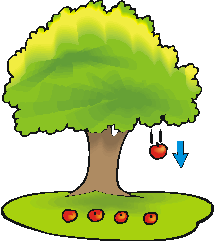
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| **Performance Expectations** | **Scientific and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-PS2-4**.**Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.** [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton’s Law of Gravitation or Kepler’s Laws. | **Engaging in Argument From Evidence**   * Construct 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 or a solution to a problem. | **PS2.B: Types of Interactions**   * Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. | **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. |
| **Equity and Groupwork**   * Work in specific group roles to analyze resources. * Discuss and record ideas from other group members. | | | |
| **Language**   * Gather information from video and textual resources and record written notes. * Record observations in words and pictures. * Orally share conclusions about gravity. * Construct a written argument supported by evidence. | | | |

**Learning Goals**

This learning task asks students to gather evidence of how gravitational interactions are attractive and depend on the masses of interacting objects. More specifically, the purpose is to:

* Use a model to engage prior knowledge and experiences of gravity.
* Analyze evidence about gravity, specifically its relationship with mass.
* Explain what gravity is and how mass affects gravitational force, using examples.
* Construct an argument that uses evidence to dispel a misconception about gravity.
* Apply knowledge of gravity to brainstorm solutions to thwart an asteroid collision.

**Content Background for Teachers**

 By this grade level, most students understand that gravity is a force of attraction—the force that keeps them on the ground and causes objects to fall. However, most students’ understanding of gravity is set within the context of Earth, rather than the solar system as a whole, which is what they will need to understand if they are to thwart the collision of *Etiam* with Earth in their Culminating Project.

We can define gravity as a force that pulls objects towards each other. Centuries ago, Sir Isaac Newton was sitting under a tree when an apple fell and hit him on the head. This led him to ask the following questions: Why should an apple always fall perpendicularly to the ground? Why should it not go sideways or upwards? He soon hypothesized that there was some invisible force that was pulling all objects towards the center of the Earth. Students often conceptualize this as “what comes up must come down”, which is technically true. However, what they really mean by “down” is that there is a gravitational pull attracting objects “towards” the center of the Earth.

http://idahoptv.org/sciencetrek/topics/gravity/facts.cfm

This idea of objects being attracted towards Earth only applies when the objects are on or near Earth’s surface and have a smaller mass than Earth. What may be new to students in this task is that Earth is not the only body that has gravity. Each body with a large mass also has its own gravitational field. For example, when an object gets far enough away from Earth’s gravity and close to the moon’s gravity, that object will be attracted towards the center of the moon. This is a concept that students will be able to apply when they think about the trajectory of *Etiam*.

Another gravity-related concept that may be newer for students is that the greater an object’s mass is, the greater the effect of its gravity. In this task, students will look at data that shows them how the masses of different planets affects the gravitational force on those planets. This will also affect how they think about interfering with *Etiam*’s collision with Earth.

**Academic Vocabulary**

* Gravity
* Attraction
* Mass
* Gravitational pull
* Orbit

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

4 - 5 Days

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

**Materials**

* Unit 1, Task 3 Student Version

Engage

* 2 shallow pans or trays with edges
* Sand (to fill pans with)
* Two balls of different mass, but same size (we recommend a Styrofoam or wood ball and a steel ball – see the following website for examples: http://www.arborsci.com/physics-balls)

Explore

* Resource Cards 1-3 (1 copy of each per group)
* Computers or tablets (1 per group)

Explain

* Projector and Speakers

Evaluate

* Project Organizer Handout

**Instructions**

**Engage**

1. Introduce Task 3: In Task 2, you explored the obvious forces acting on objects as they move, don’t move, and collide. 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 3: Today, you will look at a less tangible force that also affects the collision course of the asteroid, *Etiam*.
   * Now pass out their Task 3 student guide.
3. Introduce the Crater demo to students by reading the second paragraph on their student guide aloud. In this model, the sand will represent Earth and the ball will represent *Etiam*. Conduct the demo using the materials outlined in the Materials section.
   * Fill two pans with sand and place on the ground. Hold the light ball and heavy ball above each of the trays from the same height (waist to chest height is sufficient). Drop the balls at the same time.
   * Have students discuss their observations and analyses in pairs and answer questions #1-4 on their student guide. Then use equity sticks to share out responses to the questions (See “How to Use This Curriculum” for more information)
   * The purpose of this activity is to expose students to gravity within the context of a model of their culminating project—an asteroid collision. Students should observe that when the same-size balls were dropped, they fell at the same time, but different-sized craters were created in the sand. This is because all objects free fall with the same acceleration, due to gravity. In accordance with Newton’s second law, the crater is larger for the ball with larger mass because the greater mass caused it to fall with greater force. While students may not explicitly articulate these scientific concepts at this point, they should be able to make experiential observations and connections to motion and gravity.
4. Question 5 asks students to think about other examples of gravity from their daily life.
   * They can discuss these with their group members and record in their student guide.
     + Optional: pose some of your own scenarios that elucidate some of the misconceptions around gravity. For example: a water bottle sitting on a table. Is this an example of gravity? Standing on Earth: is this an example of gravity?

**Explore**

1. In this section of the task, students utilize three different resources to collect more information about gravity.
2. Pass out the three resource cards to each group, as well as a computer or tablet. Then 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 findings in their student guides.
3. Students analyze the resource cards at their own pace, drawing pictures to show what they learn about gravity and answering the discussion questions provided. The purpose of these discussion questions is to guide students towards an understanding of gravity as an attractive force that is dependent on the mass of an object. The goal of drawing pictures is so students can represent the systems they are observing as models, showing how changing inputs affects outputs. This emphasizes the crosscutting concept of **Systems and System Models.**
   * The first and third resources provide students with models they can replicate and analyze.
   * The second and third resources ask students to explore components of these systems, specifically how mass affects the gravitational pull between parts of the system.
     + Optional: For Resource Card 2, have students time their own rock drop from a height of 10 meters to get a feel for how scientists collected that data.
   * Optional: You may want to show students how to draw larger force arrows to depict larger forces in a diagram, as shown in the computer simulation model (Resource 3).

Sample information Collection Chart

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| --- | --- | --- |
|  | **Draw pictures to show what the resource tells/shows you about gravity** | **Discussion Questions** |
| **Resource 1: Video Model** | *Students should draw a diagram that shows the following: There is a gravitational pull that holds the alien to the planet. When he jumps far enough away from the planet and gets closer to the other planet, he enters that planet’s gravitational field. Thus, he is attracted to the other planet.* | 1. What force keeps the pink and blue alien attracted to the planet he is first sitting on?   *Gravity*   1. When he first tries to jump to the other planet, what happens? Why do you think this happens?   *He gets pulled back toward the first planet because the gravitational pull towards his planet is strongest as he is nearest to it.*   1. Why do you think he is finally able to move to the other planet? What keeps him on the other planet?   *He is able to get closer to the other planet and thus that planet’s gravitational pull is stronger.* |
| **Resource 2: Data Set** | *Students should draw a diagram that shows the following: The greater the mass of the body, the quicker a 1 pound rock is able to fall to its surface. This means that the greater the mass of the body, the stronger the gravitational pull.* | 1. Which body has the largest mass?   *The sun*   * 1. How does the time it takes for a rock to reach that body’s surface compare to others?   *It is the shortest amount of time.*   1. Take a look at the right-hand column. If the time is shorter, does that mean the gravitational pull is stronger or weaker?   *The shorter the time, the stronger the gravitational pull.*   1. Now compare the two right-hand columns. Write a rule that compares mass of the body and gravitational pull. Optional sentence stem: The \_\_\_\_\_ the mass of the body, the \_\_\_\_ the gravitational pull.   *The greater the mass of the body, the stronger the gravitational pull.* |
| **Resource 3:**  **Computer Simulation Model** | *Students should draw a diagram that shows the following: When the mass of the Earth or Sun increases, the gravitational force increases. And vice versa.* | Part 1:   1. How does the mass of the Sun impact the orbit of Earth?   *It determines how close the Earth orbits the sun.*   1. What would happen if the mass of the Sun increased?   *It would attract Earth closer to the Sun.*   1. What would happen if the mass of the Sun decreased?   *Earth would drift farther away from the Sun rather than staying attracted in an orbit.*  Part 2:   1. How would you describe the Moon’s movement?   *It orbits in a circle around the Earth.*   1. What would happen to the Moon if the Earth’s mass decreased?   *It is no longer attracted to the Earth and drifts away.*   1. What would happen to the Moon if the Earth’s mass increased?   *It is extremely attracted to Earth and collides with it.* |

**Explain**

1. Now that students have used models and data to gather more information on gravity, it is time for them to put it all together.
2. First, students summarize what they learned from the Explore in the first two columns of a KWL chart (Know and Want to Know).

* This may be done individually, in pairs, or in groups. However, we recommend it be done individually since student knowledge may vary.
* It is recommended you ask students to share out a few of their “Knows” and “Want to Knows” with the class, using equity sticks for more equitable participation.

1. Project the following video on gravity that will help to summarize some of the concepts students learned through the resources: <https://www.youtube.com/watch?v=EwY6p-r_hyU> ?. Stop the video at 10:25.

* Students fill in the “Learned” section of their KWL chart individually, before discussing their understandings with group members.
* After students discuss with their group members, have them add new understandings to the “Learned” section of their KWL chart.
* It is recommended you also summarize these points in a class-wide discussion.

1. Lastly, students will draw two conclusions about gravity: how they would define it and how mass affects gravitational force. In both cases, students are asked to use examples from the information they have collected to back up their descriptions. This can be done in their groups as well.

**Elaborate**

1. Now that students have explored and explained gravity, they should be ready to tackle a common misconception. The Elaborate outlines a scenario in which two friends are arguing about how astronauts on the moon avoid floating away into space.

* Friend 1 says the astronauts must have a cord tied to them at all times in order to avoid floating away into space. Friend 2 says the astronauts must always wear heavy boots to avoid floating away into space.
* Because students have now learned about the gravitational pull of other bodies like the moon, through many different resources, they should be able to explain to their friends that the moon’s gravity is what keeps the astronauts from floating away.
* Here students are using the Science and Engineering Practice of **Engaging in Argument From Evidence**, as they construct an accurate argument that refutes both of their friends’ arguments, using evidence and scientific reasoning from the rest of the task.

1. We encourage students to do this independently, since this is a good opportunity for formative assessment. Collect student work and identify trends in students’ ability to construct an accurate argument using evidence and reasoning. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.
2. 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: gravity and mass.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concept 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:
  + **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.
* 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 3 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. Their prompt is as follows: In this task, you learned about another, less tangible force that also affects the motion of *Etiam*. Look back at the trajectory of *Etiam* from your Culminating Project handout and brainstorm where this force may help you prevent *Etiam’s* collision with Earth.

* Draw a diagram showing how gravity is currently influencing *Etiam.*
* What other objects in our solar system might influence *Etiam’s* movements as it travels through space? Why?
* Illustrate moments in *Etiam’s* trajectory where the asteroid might be impacted by other gravitational forces in a way that changes its trajectory.
  + Explain how this works.

**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 predicted why objects fall down towards Earth. Look back at your initial response: after learning everything you have about gravity, how can you make your response more specific? What other details have you learned about gravity?
* In this task, we focused on the crosscutting concept of **Systems and System Models:** Models can be used to represent systems and their interactions. Where did you see examples of **Systems and System Models** in this task?
* Now that you have learned more about how gravity may be 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.