



## Earth Impact! –

# Saving Earth with Newton's Law of Universal Gravitation

TEACHER NOTES



### Objectives

- Students will interpret graphs based on their interactions with a simulation that leads to a deeper understanding of the inverse square law.
- Students will be immersed in a hypothetical urgent issue and will be required to come up with possible solutions.
- Students will explore the different variables that make up Newton's law of universal gravitation.



### Vocabulary

- |                          |                       |
|--------------------------|-----------------------|
| • Collision              | • Tsunami             |
| • Asteroid               | • Impact              |
| • Torino Scale           | • Near Earth Objects  |
| • Trajectory             | • Velocity            |
| • Gravitational Constant | • Gravitational Force |
| • Density                | • Newton's Law of     |
| • Inverse-Square Law     | Universal Gravitation |

### About the Lesson

- This lesson introduces the concept of Newton's law of universal gravitation using a fictional rogue asteroid named 2013TX7, which is on a collision course with Earth.
- Teaching time: one to two 45-minute class period(s)
- As a result, students will:
  - Interpret graphs to make predictions.
  - Use simulations to understand the inverse-square law as it relates to Newton's law of universal gravitation.



### TI-Nspire™ Navigator™

- Send out the *Earth\_Impact.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

### Activity Materials

- Compatible TI Technologies: TI-Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software

### Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>.

### Lesson Files:

#### Student Activity

- Earth\_Impact\_Student.pdf
- TI-Nspire document
- Earth\_Impact.tns



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### Background

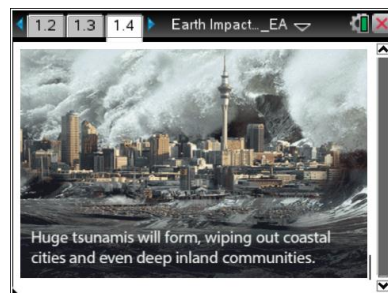
**STEM** - This activity portrays a scenario in which a team of scientists, engineers, mathematicians, programmers, and other experts have come together to determine solutions for how to deflect a rogue asteroid from colliding with Earth. The asteroid in question is, of course, fictional, but it is important for students to understand that Earth has had collisions in the past and will continue to have collisions with near Earth objects (NEOs) in the future. For dramatic effect, the asteroid portrayed in this activity is on the extreme side of both size and density.

**SIMULATION** - This particular activity starts by encouraging students (team members) to experiment with a simulation created by a fictitious teammate who is known to be a great computer programmer. The students should experiment with each of the variables in the simulation while monitoring the behavior of the asteroid. This will give them a visual sense of the scenario. Explain to them that there are problems with any simulation trying to represent reality, but simulations are intended to be used as tools for understanding, and are not exact replicas of nature. This provides an opportunity to generate a great discussion on the limitations of any model used to solve a problem.

**NEWTON'S LAW** - The activity progresses to focus on each component of Newton's law of universal gravitation and culminates with students performing some calculations embedded with inquiry-style questions. The aim is to have students understand that when distance is reduced by half, the gravitational force between Earth and the asteroid increases by 4 times. The square of the distance is inversely proportional to the gravitational force. Finally, students will reach a simulation in which the asteroid misses Earth, thus sparing our planet from destruction.

### Move to pages 1.2–1.6.

1. Students will read the scenario in which a rogue asteroid is on a collision course with Earth. They will examine the artist-rendered images on each page to get an idea of what kind of devastation would happen if the asteroid hits Earth.





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After students review the scenario and images, ask them:

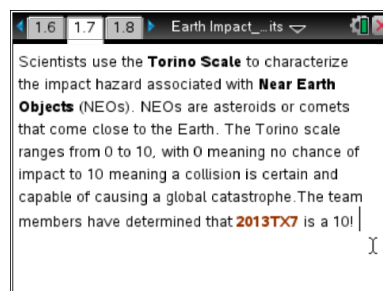
*Have you heard of any asteroids coming toward Earth?*

**Sample answers:** Small objects hit Earth's atmosphere all the time. Shooting stars are meteoroids that have entered Earth's atmosphere and generate light from the heat of friction between the meteor and the atmosphere. Larger objects, such as asteroids, hit with less frequency. Most recently, the Chelyabinsk meteor buzzed Earth over Russia on February 15, 2013. It was about 15 miles high when it exploded into smaller fragments. In some places, parts of buildings collapsed, windows were blown out and there were a large number of injuries from flying debris.



**Move to pages 1.7–1.10.**

2. Page 1.7 explains a tool that astronomers use called the Torino Scale. They use the scale to categorize the impact hazard and amount of damage for a given NEO.



**Tech Tip:** To adjust the Zoom setting on page 1.10, the top part of the page must first be active (bold outline around it). Students should then use the **+/-** keys on the keyboard to Zoom In/Out. To reset the Zoom or Pan, have students select **Menu or Tools > Parameters > Reset Zoom/Pan**.



**Tech Tip:** To adjust the Zoom setting, have students select **Parameters > Zoom In/Out**. They can also reset the Zoom and Pan here.



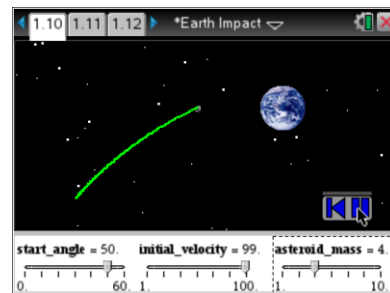
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- On page 1.10, students will use the sliders to experiment with the starting angle (measured in degrees), the initial velocity (measured in km/second), and the asteroid mass (measured in kg). For mass, the slider number is multiplied by  $10^8$ . Students should explore the variables and observe what happens with each change. As they explore the simulation, the data will be captured and displayed on graph pages for further analysis.



Ultimately, the goal is to enable students to see that by changing the trajectory of the asteroid they will save Earth. They should also notice that changing the mass doesn't significantly affect the outcome.

After students explore the simulation, ask:


*After experimenting with the simulation, what ideas do you have for saving Earth?*

**Sample answers: Changing the angle of the asteroid will change its course. Changing the speed of the asteroid could also change its course. Changing the mass didn't seem to have much of an effect, because the mass of Earth is so much greater than the mass of the asteroid.**



**Tech Tip:** Students may need to move the “space” background to adjust the visible area. To do this, they should press and hold the center click key on the keypad until the cursor turns to the “grab hand.” They can then drag the background around. Students may also need to adjust the Zoom with the **+/-** keys.



**Tech Tip:** Students should select the  button to reset the simulation and run it again with different parameters. The reset button will remove all data from the graphs. Note: This will not reset any Zoom applied.

**Move to pages 1.11–1.18.** Answer questions here or in the .tns file.

- Adjust the variables to have the asteroid collide with Earth and run the simulation again. Now, explore the graphs on the next pages. What do you notice about the velocity of 2013TX7 vs. its distance from Earth?

**Answer: Velocity increases as distance decreases.**



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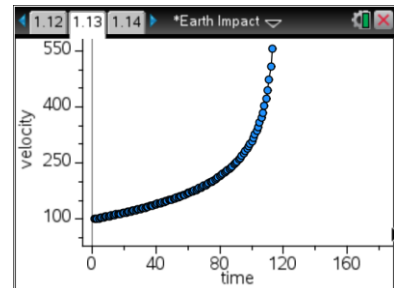
- Q2. Look at the data on the velocity vs. time graph on the next page (if there is no data, run the simulation again, but do not reset it). What point on the graph represents the point at which the asteroid is farthest from Earth? Which point represents the point at which the asteroid is closest to Earth?

**Answer: Farthest: Velocity will typically be lowest the farther away the asteroid is from Earth.**

**Closest: Velocity will be highest when the asteroid is closest to Earth. On the graph these points are represented by the least amount of time for lowest velocity and most amount of time for highest velocity (just before impact).**

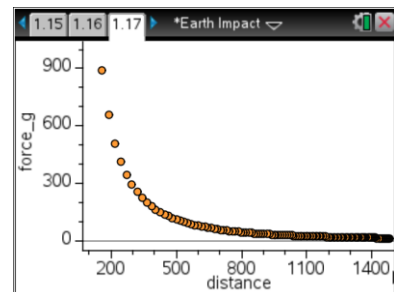
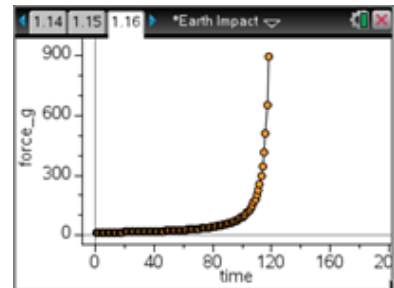
- Q3. From the graph, how can we tell the asteroid is getting faster as it approaches Earth?

**Answer: The graph is increasing in a nonlinear way. The velocity increases over time because the gravitational force produced by Earth is stronger as the asteroid gets closer, causing the asteroid to accelerate.**



- Q4. On the following two graphs, “force\_g” represents the gravitational force between 2013TX7 and Earth. What can you say about the gravitational force as the asteroid gets closer to Earth?

**Answer: The graph is increasing in a nonlinear way. The force increases as the asteroid approaches Earth. This is reflected over time and over distance in each of the two graphs.**



- Q5. Based on the data in the force\_g graphs, how are distance and gravitational force related?

**Answer: B. Inversely. As the square of the distance decreases, gravitational force increases.**



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Move to pages 2.1–2.4.

4. At this point, students will explore some physical characteristics of the asteroid, such as its volume and density. They will also calculate the mass. Students will answer the following questions.



- Q6. If 2013TX7 has a density of  $8 \text{ g/cm}^3$  ( $8,000 \text{ kg/m}^3$ ) and a volume of  $6 \text{ km}^3$  or  $6 \times 10^9 \text{ m}^3$ , calculate the mass of the asteroid.

**Answer:**

**Students should use the equation: Density = mass/volume and solve for mass.**

**Mass = Density  $\times$  volume**

$$\text{Mass} = (8,000 \text{ kg/m}^3) \times (6 \times 10^9 \text{ m}^3)$$

$$= 4.8 \times 10^{13} \text{ kg}$$

- Q7. The asteroid is traveling at an average speed of 25 km/sec. Based on a distance of 3.5 billion km from Earth, when will the asteroid hit Earth? Express your answer in days.

**Answer: Students will need to use the equation speed = distance/time and solve for time.**

$$\text{time} = \text{distance/speed: } (3,500 \text{ million km}) / (25 \text{ Km/sec}) = 1.4 \times 10^8 \text{ seconds.}$$

$$\text{In days, this would be: } (1.4 \times 10^8 \text{ sec}) \times (1 \text{ hour}/3,600 \text{ sec}) \times (1 \text{ day}/24 \text{ hours}).$$

$$= 1,620.37 \text{ days (4.44 years)}$$

- Q8. Based on your answer to the previous question, it may seem odd to worry about something that is years away. In your opinion, why is the team so worried about this situation?

**Answer: Answers will vary. The point of this question is to have students realize that even though an event is several years away, to solve a monumental problem like this, it takes time, coordination, and urgency. In fact, NASA, today, would not be able to deal with such a threat if we weren't able to detect it years away from impact. It would take a few years to figure out what to do about it, which is why there is such urgency to solve the problem. We also want to deflect or destroy the asteroid as far away from Earth as possible, because the closer it gets to Earth, the faster it will be moving, which would make it tougher to deflect.**



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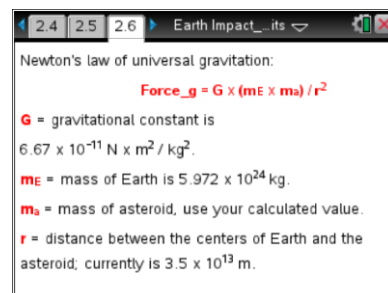
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Move to pages 2.5–2.12.

5. Pages 2.5 and 2.6 introduce Newton's law of universal gravitation. Up to this point, students have experimented with different aspects of the equation in the simulation and calculations. Now, students will put that experience to work by using the actual equation. Ideally, they will see that the closer the asteroid is to Earth, the harder it will be to deflect.



- Q9. Use the calculator to calculate **Force\_g**. Record your answer below.

**Answer:**

$$\text{Force}_g = (6.67 \times 10^{-11} \text{ N} \times \text{m}^2/\text{kg}^2) \times (5.972 \times 10^{24} \text{ kg} \times 4.8 \times 10^{13} \text{ kg}) / (3.5 \times 10^{13} \text{ m})^2$$

$$= 1.56 \text{ newtons}$$

- Q10. Now, determine the force when you cut the distance in half. Enter your answer below.

**Answer:**

$$\text{Force}_g = (6.67 \times 10^{-11} \text{ N} \times \text{m}^2/\text{kg}^2) \times (5.972 \times 10^{24} \text{ kg} \times 4.8 \times 10^{13} \text{ kg}) / (((3.5 \times 10^{13})/2) \text{ m})^2$$

$$= 6.24 \text{ newtons}$$

- Q11. Divide the last force you calculated (when distance was cut in half) by the first force you calculated. Round to the nearest whole number. Why is this number significant?

**Answer:**

$$\text{Force}_g = (6.24 \text{ newtons} / 1.56 \text{ newtons}) = 4$$

The number is significant because it shows that when the asteroid is half the distance from Earth the gravitational force between them is four times as much! This means the energy upon impact will also increase proportionally.





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Q12. The forces you calculated in the previous problems were very small due to the great distances. See what happens when you use  $r = 3.5 \times 10^6$  m in the calculator below. (Hint: You can copy and paste calculations from previous problems.)

**Answer:**  $((6.67 \times 10^{-11} \text{ N} \times \text{m}^2/\text{kg}^2) \times (5.972 \times 10^{24} \text{ kg}) \times (4.8 \times 10^{13} \text{ kg})) / (3.5 \times 10^6 \text{ m})^2$   
**= 1.5608127  $\times 10^{15}$  newtons**

Q13. NASA's Jet Propulsion Laboratory (JPL) constantly monitors asteroids and other NEOs and their trajectories. They are working on a project that will enable us to learn how to deflect these objects if they threaten to strike Earth. What are some possible methods you think JPL should consider when thinking about deflecting a real asteroid from hitting Earth?

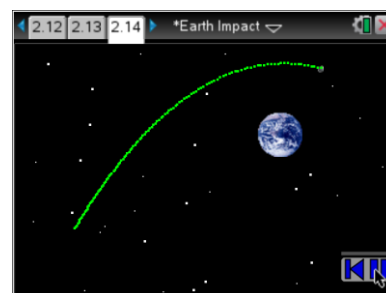
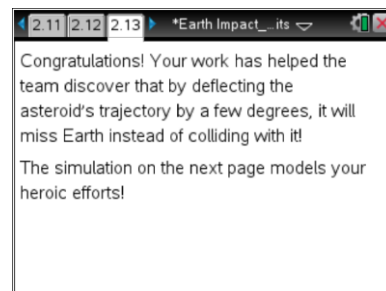
**Answer: Answers will vary. Some answers may be to use missiles, send a crew of astronauts to land on the asteroid and plant explosives, or use another asteroid to create a collision.**

Q14. When the distance between Earth and the asteroid is cut in half, its gravitational force increases by four times (based on the inverse-square law). Based on this, what would you say about the importance of *when* to deflect the asteroid?

**Answer: Knowing that as the asteroid gets closer the force increases at a higher rate than the distance decreases, students should realize the speed of the asteroid will increase at a rate that is proportional to the increase in force. As such, deflecting the asteroid sooner rather than later would make the most sense, because changing its trajectory will get harder and harder the faster the speed of the asteroid.**

**Move to pages 2.13–2.14.**

6. Thanks to the work done by the team, the asteroid was diverted.  
Page 2.13 gives a visual model of the new trajectory of the asteroid, narrowly missing Earth.







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### TI-Nspire Navigator Opportunities

Make a student the Live Presenter to demonstrate his or her asteroid simulation graphs.

### Wrap-Up

Students will have various results depending upon the angle and/or speed they have selected. Have students compare their graphs and discuss why the results are different.

### Assessment

- Students will answer questions throughout the lesson to ensure they understand the concept of Newton's law of universal gravitation, density, and distance vs. time.