National Aeronautics and Space Administration

STEMonstrations

Education in Action on the International Space Station

Classroom Connections

Orbits

For more STEMonstrations and Classroom Connections, visit www.nasa.gov/stemonstation.

Grade Level: **9th-10th**

Suggested Time: **50 minutes**

National Mathematics Content Standards:

Solve linear equations

Model and solve contextualized problems using representations

Understand relationships among angles, perimeters, lengths, areas and volumes

Build math knowledge through problem solving

Solve problems that arise in mathematics

Apply and adapt a variety of strategies to solve problems

Recognize and apply mathematics in contexts outside mathematics

Solve simple problems involving rates and derived measurements for such attributes as velocity and density

Background

The International Space Station (ISS) is a unique science laboratory in space and is also home to the crews of astronauts and cosmonauts who conduct this research. The ISS orbits Earth at an average of 400 km (248 miles) above the surface traveling approximately 8 km per second (17,900 mph). The ISS travels at this speed to maintain an orbit around the Earth. Orbits are elliptical (oval) in shape, but most spacecraft orbiting Earth travel in orbits that are as close to a circle as possible to keep a constant altitude (height) above the Earth.

While the primary purposes of the ISS include research and preparing for future deep space exploration (learn more at the ISS Homepage), one of the benefits of having the ISS travel 400 km above us is the ability for crewmembers to view the Earth from such a magnificent vantage point. Since early space missions, astronauts have photographed the Earth below – observing the world's geography and documenting events like storms, floods, fires, and volcanic eruptions. The early photography formed a foundation for Landsat and other Earth-observing satellites. Even as these satellites have become the most common way for scientists to collect data from orbit, crewmembers have continued to look out the windows of their spacecraft and photograph what they see. The view through human eyes remain priceless, as astronauts not only capture photographs, but can share their feelings related to each image. Astronaut Ron Garan expressed the following during a talk at Kennedy Space Center in 2012 following his mission aboard the ISS during Expeditions 27 and 28, "When you see the beauty of our planet, it is striking, it's sobering. For the 50 years that we've been flying humans in space, astronauts and cosmonauts have always commented about how beautiful, how fragile, and how peaceful our planet looks from space. Seeing this from space really had a big impact on me."

You can see the pictures that astronauts have taken from the ISS here and also join a Sally Ride EarthKAM mission to take your own pictures from the ISS.

Objective

Following this activity, students will be able to:

- Understand the relationship between speed, distance, and orbits.

Materials

- Pencil
- Student Activity Sheet
- Calculator (optional)

Procedure

- Inquiry Discussion:

Use the background information provided to help guide students in answering the following questions.

1. What is an orbit?
2. What type of spacecraft orbit the Earth?
3. What human made objects orbit the Earth?
4. What is the ISS??
5. How long does it take the ISS to orbit Earth?

- Watch and Discuss Video:

Watch the video STEMonstrations: Orbits

Reinforce how the ISS orbits Earth and include ISS facts located in the background information.

- Activity:

In this activity, students will use various formulas to help solve a challenge. An answer key is provided.

- Final Discussion:

Have students refer to the ISS orbit graphic found on their worksheet, and have students explain/discuss their answers using the image. You can also draw it on the board.

Extension Activities

Advanced students can use the following equation to calculate the period of the circularized orbit of the ISS. Compare the period obtained with this equation to the period obtained using the previous equations.

$$P = 2\pi\sqrt{\frac{r^3}{\mu}}$$

P = the period of the elliptical orbit

μ = Gravitational Constant times the Earth's mass = 3.99 x 105 km3/sec2

r = radius of circularized orbit that the ISS travels on

Extension Resources

What is an Orbit? (article)

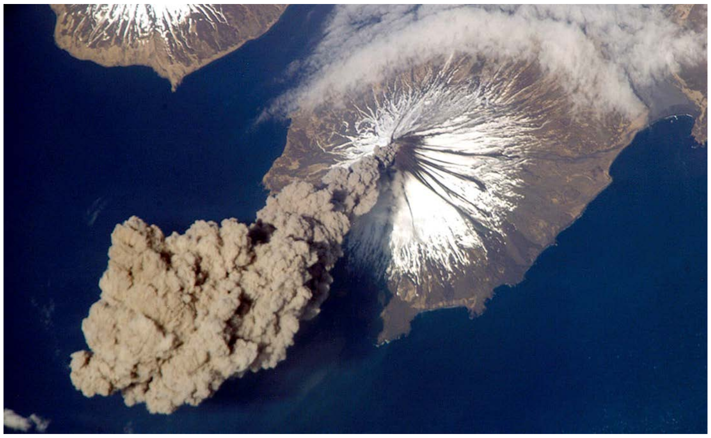
How Orbits Work (online activity)

Geostationary Orbits (article)

Astronaut Photography from Space Helped Discover Earth (article)

Sally Ride EarthKAM @ Space Camp (student activity – take photos from the ISS!)

Space Station Orbit Tutorial (article)



On May 23, 2006, Expedition 13 astronaut Jeff Williams contacted the Alaska Volcano Observatory to report that the Cleveland Volcano had produced a plume of ash. Shortly after the activity began, he took this photograph. Cleveland Volcano, situated on the western half of Chuginadak Island, is one of the most active of the volcanoes in the Aleutian Islands.

Credits: NASA/Jeff Williams

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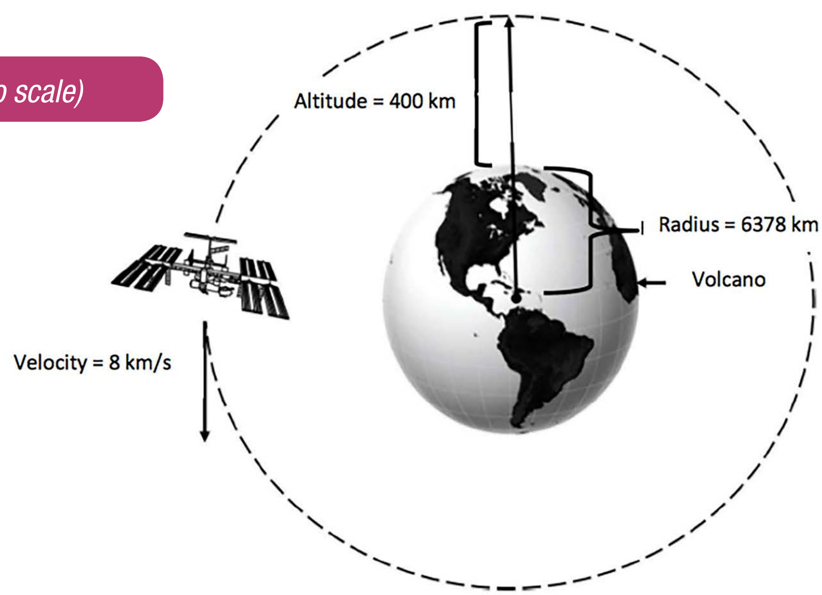
Name: ____

Challenge

You are the CAPCOM on shift in the ISS Mission Control Center at the Johnson Space Center in Houston, TX. It is your responsibility as CAPCOM to communicate information up to the crew on the ISS. The Flight Director, the leader of the mission and manager of the entire flight control team in Mission Control, has received word that a volcano is erupting and the ISS will be passing over that volcano in half an orbit. The Flight Director has asked you to tell the ISS crew to start setting up their camera equipment so they can photograph the eruption as they fly over. You quickly get the information up to the crew, and the crew starts the set-up process. If camera set-up takes the astronauts at most thirty minutes, will they be able to take photographs of the eruption? Why or why not?

ISS Orbit *(not to scale)*



Formulas

$$r = radius\ of\ earth + \ distance\ ISS\ is\ from\ earth's\ suface$$

$$C = circumference\ = \ 2\pi r$$

$$\pi = 3.14$$

$$speed\ of\ ISS = \frac{distance\ ISS\ travels\ in\ one\ orbit}{time}$$

$$Period = time$$

$$Time\ takes\ ISS\ to\ travel\ to\ Volcano\ location = \frac{Period}{2}$$

Name: ______________________________

Use the information from the previous page to help determine if the astronauts can take a picture of the volcano. **Be sure to show your work!**

1. Calculate the radius of the ISS orbit (in km).

2. Using the radius you just found, calculate the distance the ISS travels around the Earth in one full orbit.

3. Since you know the ISS is traveling at approximately 8 km per second, calculate how long it takes for the ISS to make one orbit. (The time it takes for an object to complete one full orbit is also known as the orbital period).

4. If the volcano is half an orbit away, it will take half of an orbital period to reach the volcano. Calculate how long it will take the ISS to reach the volcano.

5. Based on your calculations, will the astronauts be able to take pictures? Why or why not?

Answer Key

Answer 1

The radius of the circularized ISS orbit is equal to the radius of the Earth added to the distance from the Earth's surface to the orbit of ISS.

$$r = radius\ of\ earth + \ distance\ \ ISS\ is\ from\ earth's\ suface$$

$$r = 6378\ km + 400\ km = 6778\ km$$

Answer 2

Since the ISS travels around the Earth in a circular orbit, the distance the ISS travels is equal to the circumference C of its circular orbit.

$$C = 2\pi r = 2\pi(6{,}778\ km) = 42{,}565.84\ km$$

Answer 3

The ISS travels 42,650 km around Earth. The average speed of the ISS is equal to the total distance traveled in a certain period of time. Since we know the velocity of the ISS is 28,165 kilometers per hour (kph), we can solve for the time it takes to reach the volcano.

$$speed\ of\ ISS = \frac{distance\ ISS\ travels\ in\ one\ orbit}{time}$$

$$time = \frac{distance\ ISS\ travels\ in\ one\ orbit}{velocity\ of\ ISS} = \frac{42{,}565.84\ km}{8\ km/s}$$

$$Period = time = 5320.73\,\text{sec} = 88.68\,\text{min} = 1.48\ hours$$

Answer 4

The volcano is located half an orbit away which is half of the orbital period. It will take astronauts about 44 minutes to reach the volcano.

$$Time\ takes\ ISS\ to\ travel\ to\ Volcano\ location = \frac{Period}{2} = 0.74\ hours = about\ 44\ minutes$$

Answer 5

The astronauts will reach the volcano in about 44 minutes. Since set up will take no more than 30 minutes, they will have everything in place to take photos of the eruption.

Extension Answer

$$P = 2\pi\sqrt{\frac{r^3}{\mu}} = 2\pi\sqrt{\frac{(6778\ km)^3}{3.99\ x\ 10^5\ {km^3}/{sec^2}}} = 2\pi\sqrt{\frac{3.11\ x\ 10^{11}\ km^3}{3.99\ x\ 10^5\ {km^3}/{sec^2}}}$$

$$P = 5551\ seconds = 92.5\ minutes = 1.54\ hours$$

The more advanced equation should give roughly the same answer as the orbital period calculated in Answer 3 above. Answer 3 gives a period of 1.48 hours, while the extension answer gives a period of 1.54 hours.