**ACTIVITY: Scale model for satellite orbits**

**Activity idea**

In this activity, students use a scale model of the Earth and identify altitudes of various satellites. They then use a smaller object on a string to model gravity and satellite motion.

By the end of this activity, students should be able to:

* describe how far above the surface of the Earth satellites orbit
* demonstrate different types of orbit
* explain that the attraction of gravity always pulls satellites towards the centre of the Earth and that this force causes circular motion
* demonstrate how a satellite will move in a circular orbit only if it is travelling at the right speed.

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**Introduction/background**

In this activity, students use a ball as a model of the Earth. In the first part of the activity, students guess the distance above the ball’s surface to various satellites and then compare these to values provided in an Excel spreadsheet. Students can enter any size value for the diameter of the ball used as the Earth, and the spreadsheet calculates scale distances automatically.

In the second part of the activity, students learn how gravity is attracting all satellites towards the centre of the Earth. The circular motion is compared to a ball on a string. They learn that, whenever an object is moving in a circular motion, the force is always towards the centre of the circle.

For the final part, another small object is suspended from a string and made to orbit the Earth. At the right speed, the object will move in a circular motion. This shows students that satellites will only stay in orbit around the Earth if they are travelling at the right speed for that orbit.

**What you need**

* Any sized ball as a model of the Earth (for example, a basketball or large exercise ball)
* Small ball as a model of a natural or artificial satellite
* String
* Access to the Excel spreadsheet [Scale distances in space](https://www.sciencelearn.org.nz/resources/291-scale-model-for-satellite-orbits) (note that this spreadsheet has three worksheets, select a tab to switch between them)
* String
* Copies of the articles [Gravity and satellite motion](https://www.sciencelearn.org.nz/resources/268-gravity-and-satellite-motion), [Natural satellites](https://www.sciencelearn.org.nz/resources/271-natural-satellites) and [Artificial satellites](https://www.sciencelearn.org.nz/resources/269-artificial-satellites)

**What to do**

***Modelling distances in space***

1. Hold up the ball you will use to model the Earth. (For demonstration purposes, this activity uses a 55 cm exercise ball.) Explain that the students are to guess the following distances in space, in relation to the model Earth ball. Ask students to record their guess and then demonstrate the measurement with a physical hand gesture.
2. Ask students the following questions:
* In relation to this ball representing the Earth, what would the thickness of the Earth’s atmosphere be? Show me what this distance would look like using your thumb and forefinger.
* What is the distance from the surface of the Earth to the edge of space? Model the distance with your thumb and forefinger.
* What is the distance from the Earth to the altitude of the International Space Station? Model the distance with your thumb and forefinger.
* What is the distance from the Earth to the altitude of a GPS satellite? This time, model the distance with both hands.
* What is the distance from the Earth to the altitude of geostationary TV and communication satellites? Model the distance with both hands.
* What is the distance from the Earth to the Moon? Model this distance with a friend.
* What is the distance of the Earth to the Sun? Can you model this distance with a friend?
1. Download the Excel spreadsheet on this page [Scale distances in space](https://www.sciencelearn.org.nz/resources/291-scale-model-for-satellite-orbits) and enter the diameter of your model Earth ball into the Satellite scale differences tab. Compare the students’ answers with those in the spreadsheet. For example, if a 55 cm diameter exercise ball is used as the Earth, the scale distances for each of the above are:



1. To reinforce the differences in distance between the Earth, satellites mentioned in the table, the Moon and the Sun, ask students to draw a line on the whiteboard and place dots where each object would be using the scale model distances. This should give some perspective on where these objects are in space! (Chances are the Moon is outside the classroom. Use Google Maps to see where the Sun would be in relation to the whiteboard.)



***Modelling how gravity attracts all satellites towards the centre of the Earth***

1. Place the large ball representing the Earth on a table. Attach the smaller ball to a string. Secure the string to the ceiling or other fixture. Suspend the string directly above the large ball and adjust it so the smaller ball hangs at the same height as the centre (equator) of the large ball when pulled slightly to one side (see diagram below).
2. Discuss the following:
* What keeps the Moon and other satellites in orbit around the Earth?
* In what direction does gravity act?
* If an object is released at an altitude of 400 km above the Earth, what will happen? (It will fall straight back to the Earth. Demonstrate this concept by holding the smaller ball out and letting go so that it swings (falls) back to the Earth.)

***Modelling the importance of speed to circular motion (orbit)***

1. Discuss that, for an object to stay in orbit around the Earth, it also needs to have the correct horizontal speed for that altitude.



1. Demonstrate this concept with the model Earth and suspended ball:
* Hold the small ball a short distance from the Earth. Let the ball go. What happens? (It falls toward the centre of the Earth.)
* Throw the ball slowly forwards as shown. What happens? (It falls but travels further sideways before hitting the Earth.)
* Throw it with more speed. What happens? (It still falls towards the Earth, but misses!)
* Try to throw the ball with enough speed so that it moves in a circle around the Earth. This is a model of circular satellite motion.

**Discussion points**

* For an object moving in circular motion, the force is always towards the centre of the circle.
* All satellites orbiting Earth are attracted towards the centre of the Earth.
* Satellites closer to the Earth need to travel faster to stay in orbit.
* Geostationary satellites orbit the Earth once in 24 hours so that they appear to stay above the same point above the Earth as it rotates
* Gravity keeps the Moon and artificial satellites orbiting the Earth, so why do astronauts appear weightless? See [Gravity and satellite motion](https://www.sciencelearn.org.nz/resources/268-gravity-and-satellite-motion).

**Extension ideas**

***Solar system scale distances***

Click on the second tab in the spreadsheet – Solar system scale differences – to create a scale model of planet sizes and distances in space for the whole solar system.

The first table on this page provides information for the diameters of the various planets based on the diameter for the ball you use to represent the Earth.



The second table provides a scale model distance from the Sun to the planets in our solar system. If students use a 1 cm diameter marble as the model of the Earth, they can model the distances from the Sun to Mercury, Venus and possibly the Earth on a playing field. They can use Google Maps to locate where the rest of the planets would fit on their scale model. This should to help visualise how vast our solar system really is!

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***Times for light to travel***

To further emphasise how vast space is, show students the third tab in the spreadsheet – Times for light to travel. Discuss how these times relate to their understanding of distances.

Visit the [Heavens Above](http://www.heavens-above.com/SolarEscape.aspx?lat=-37.79161&lng=175.31811&loc=Unspecified&alt=0&tz=CET) website to see where the five spacecraft (Pioneer 10, Pioneer 11, Voyager 1, Voyager 2 and New Horizons) are in their voyages to escape from our Solar System.