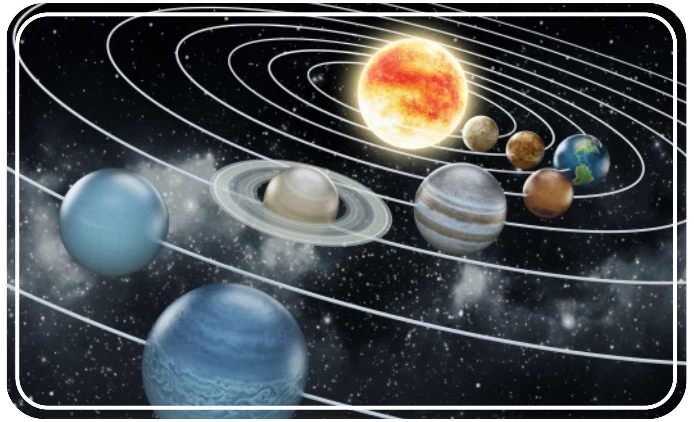
Experiment with the planetary pendulum

As you have already learned planet Jupiter is the largest and heaviest planet of our solar system. You also know that it is the fifth planet from the Sun. Our solar system consists of a star, called the Sun, and eight planets. Starting from the closest to the Sun, these planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The orbits of the planets differ. Planets in large distance from the Sun, the outer ones, need more time to make an orbit around the Sun compared to the inner ones. For instance, Mars is an inner planet and makes a shorter orbit compared to Jupiter which is an outer planet.



- Why do planets in large distance make an orbit in longer time compared to the inner ones?
- Which factors affect the period of a swinging pendulum?

Are you ready to discover how planets stay in orbit around the Sun?
Let's perform the next page's experiment to find out the answers for all these questions!
Get ready to discover circular orbits and Kepler's laws.

Learning about: Circular Orbits

Planetary pendulum
Planets orbit the Sun due to gravity, in almost circular orbits. We can simulate this motion with a conical pendulum. In this experiment, the tension of the string keeps the mass in orbit.

Discover:
- Which factors determine the period of a pendulum?
- Planetary orbits.

Level Of Difficulty ★★★☆☆

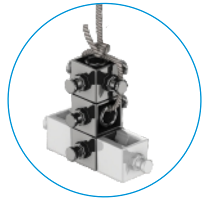
Materials Needed:
- Engino® (STH13).
- Long string (~3 meters), Ruler, Scissors, Stopwatch and Calculator.

Procedure:
1. Find the instructions and build the **Planetary pendulum Case A** model.

2. Follow the instructions of **exercises 1** and **2** to create a circular orbit and a pendulum.

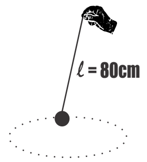
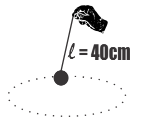
3. Hold the model above the circle and from the marked position of 80cm. Read **exercise 3** and complete the table. **Note** that one more person is needed to count the orbits.

1. Cut a string to have a length of 1 metre and tie it as it is shown on the right. Mark the locations on the string which lay at 40 cm and 80 cm from your model.



2. Cut a string of 90 cm long and tie it on its edges. Place it on the floor and stretch it to get a circular shape (see on the side).

3. Give your pendulum an initial pull and make it swing over the circumference of the circle. Use the stopwatch to measure the time it takes to make 10 orbits. Use your calculator to divide your finding by 10 in order to calculate the period. Repeat the same by holding the model from the 40cm.

Pendulum Length (cm)	Duration for 10 orbits (s)	Period (s) = Duration/10
	18	1.8
	14	1.4

Procedure:

4. Build **the Planetary pendulum case B** model, to increase the mass of your model. Hold the model from the marked position of 80 cm and repeat the same process to calculate the period for this case. Do **exercise 4**.

5. In exercise 3 the mass was kept the same and the length was increased while in exercise 4 the length was kept the same and the mass was increased. Write which factors affect the pendulum period on **exercise 5**.

6. To create another orbit, cut a new string with a length of 45 cm. Place it in such a way that both orbits will have the same centre. Read **exercise 6** and simulate the orbit of two planets.

7. We can simulate the distance from the Sun to the length of the pendulum.

4. a) How much time does it take to make 10 orbits?
b) Calculate the period.

a) It takes 18 s to make 10 orbits.

b) period = duration of 10 orbits /10

period = 18 /10

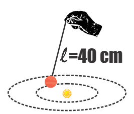
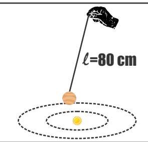
period = 1.8 s

5. a) Does the length affect the period of the pendulum? If yes, how?
b) Does the mass affect the period of the pendulum? If yes, how?

a) The length affects the period of the pendulum. The larger the length is the bigger the period.

b) The mass doesn't affect the period of the pendulum.

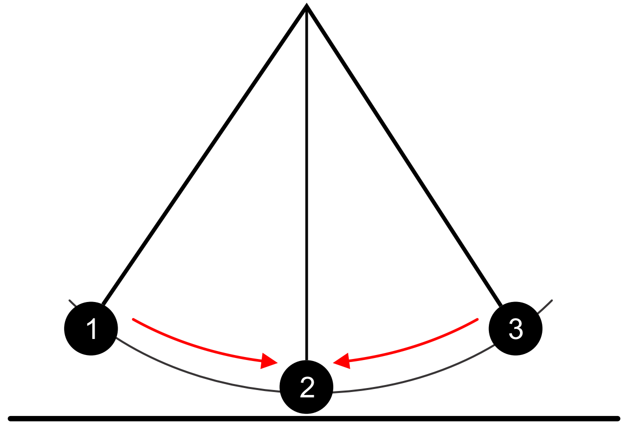
6. In this exercise we are going to imitate the orbits of Mars and Jupiter around the Sun. Can you measure the period of the two planets that orbit the Sun at different distances?
Tip: You know the period for Jupiter from previous task!

	Mars	**Jupiter**
Orbit	Small (45 cm)	Large (90 cm)
Distance		
Duration for 10 orbits	13	18
Period (s)	1.3	1.8

Theory

Circular Motion

Circular motion is defined as the rotation about a point following a circular path or a circular orbit. It can be uniform, that is with constant angular rate of rotation, or non-uniform, that is with a changing rate of rotation. For any object that moves in a circular path, there is a force acting on it causing it to change from its straight-line path, accelerate inwards and move along a circular path. An example of circular motion is the Earth orbiting the Sun. A fundamental element of circular motion is period and it is defined as the time needed for a complete revolution. For instance, the Earth's period around the Sun is 365 days.

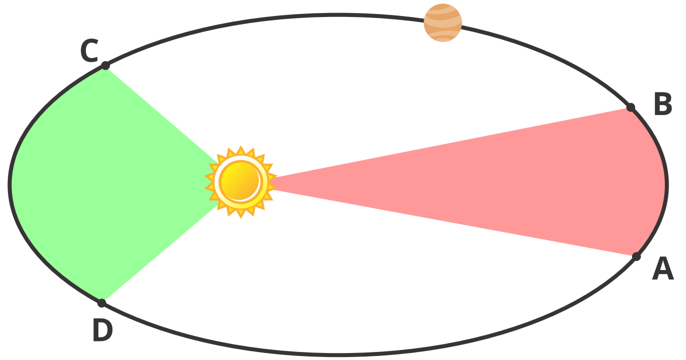


Any object moving in a circle experiences a **centripetal force**. That is, there is some force pushing or pulling the object towards the centre of the circle, the point about which it is rotating.

The pendulum is a mechanism found commonly in old wall clocks. It is a great example of circular acceleration and deceleration, even if it makes part of a circle. A chain or rod holds a heavy piece of metal vertical to the ground. The centripetal force causes it to move on a circular path up to a certain point.

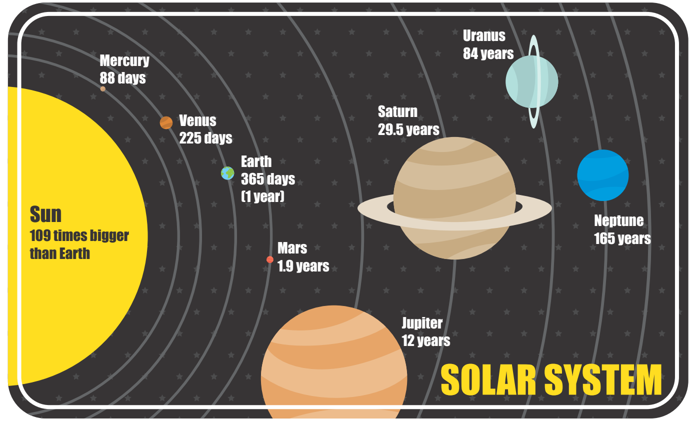
Kepler's Laws

The German astronomer and mathematician Johannes Kepler (1571 - 1630) is considered the first modern astrophysicist. His deep interest to understand the way that planets orbit the Sun made him move from Germany to become an assistant astronomer in Denmark. Kepler analysed the recorded observations of planets to discover three of the most fundamental laws in celestial mechanics.



Kepler's 1st Law - The Law of Orbits: *All planets move in elliptical orbits, with the sun at one focus.* An ellipse is a shape that is best described as a squished circle, similar to an oval and planets orbit the sun in that shape (see on the right)!

Kepler's 2nd Law - The Law of Areas: *A line that connects a planet to the sun sweeps out equal areas in equal times***.** Thus, planets orbit faster when they get close to the Sun (C-D) compared to when they are far away (A-B) as it is shown above.



Kepler's 3rd Law - The Law of Periods: *The square of the period of any planet is proportional to the cube of the distance of its orbit.* In other words, the larger the distance between a planet and the Sun, the longer it takes to make a full orbit. Mercury, the closest planet to Sun, makes one orbit in every 88 days. Jupiter which is 13 times further than Mercury makes a full orbit in 12 years!

Quiz

Exercise

a) Read the following statements. Put a ✔ into the correct box to state whether the statement is true or false.

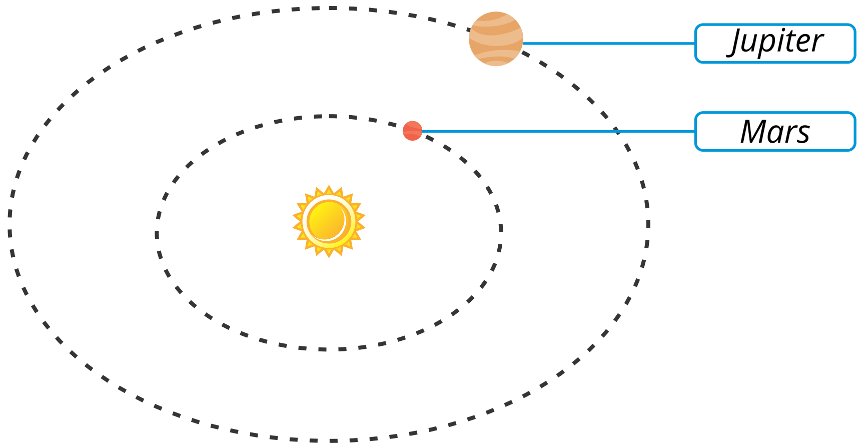
1. The eight planets of our Solar system move in circular orbits around the Sun.

☐ True ☑ False

2. Planets orbit faster when they are far away from the Sun.

☐ True ☑ False

b) Complete the boxes with the words **Jupiter** and **Mars** in order to identify the planets orbiting the Sun.



Knowledge check: check what you have learned.

- ☐ What is **circular motion**?
- ☐ What is **centripetal force**?
- ☐ How does a **pendulum** work?
- ☐ Who is **Kepler**?
- ☐ What do **Kepler's laws** state?