

## Ellipse - Teacher Notes

Students often confuse **planetary rotation** (spinning on its axis) with **planetary revolution**, orbiting a position in space. Although some textbooks refer to revolution, it is less confusing if we use the terms orbit and orbiting instead of revolution.

**Definition** - A planetary orbit is: **The gravitationally curved path of an object around a point in space.**



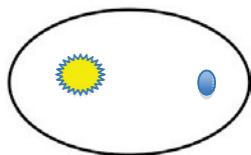
**Johannes Kepler** (1571-1780) was a German astronomer and mathematician. He used scientific observations and mathematics to disprove earlier ideas of planets being in simple circular orbits round the Sun. He proposed three laws that described planetary motion as observed.

Kepler's first law stated that:



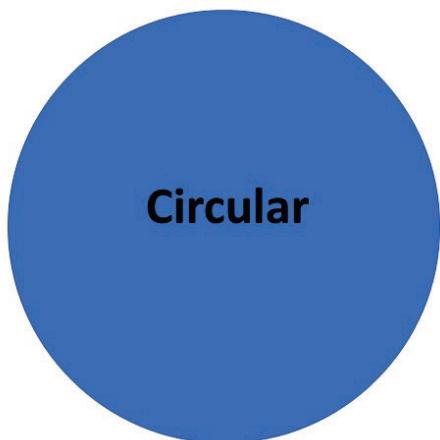
**PLANETARY ORBITS ARE ELLIPSES**

The English scientist and mathematician **Isaac Newton** (1643-1727) corrected some mathematical mistakes Kepler made and using his own and other's observations suggested that it was the **FORCE OF GRAVITY** originating from the huge mass of the Sun that deflected the straight paths of celestial objects into ellipses around the Sun.



The ellipse does not have one centre like a circle but two foci because it is the product of two competing factors (the motion of the planet and the pull of gravity). Because the Sun has over 98% of all the matter in the solar system its gravitational pull is MASSIVE!

**Student Activity** - To investigate the eccentricity of ellipses and discuss why it took astronomers so long to realise the planets were travelling in elliptical orbits

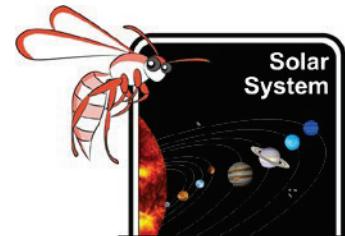


**Circular**



**Highly elliptical**

Figure 1. The more elliptical an object the higher its eccentricity

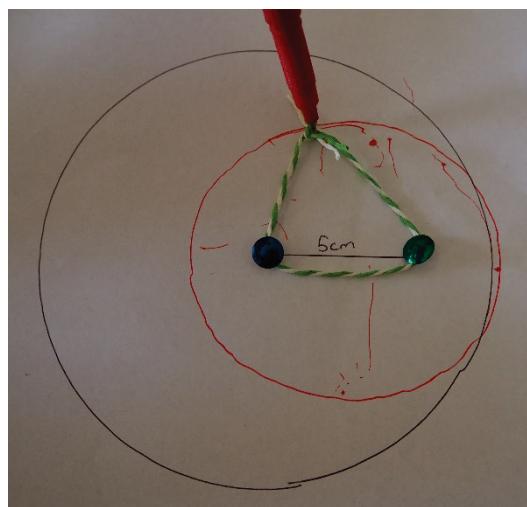
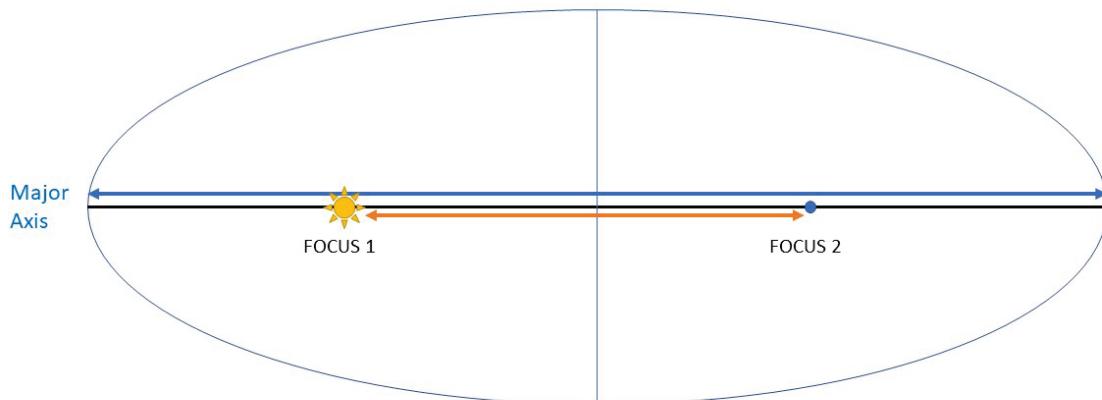


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### Materials per student or group

- Two thumb tacks or nails. If neither is possible, one student can hold a pencil point down at each of the foci whilst the other draws the path of the ellipse.
- A large sheet of scrap paper newspaper or cardboard. Placing polystyrene or thick card beneath the paper permits the nails or tacks to be easily pressed in and prevents damaging the table beneath.
- A piece of string about 20 cm long
- Three different coloured pencils
- A ruler

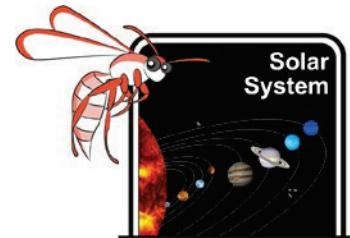
$$\text{Eccentricity} = \frac{\text{distance between foci}}{\text{length of major axis}}$$



### Method

1. Loosely tie the piece of string into a loop (note everyone's loop will end up being a slightly different length, meaning they will all have slightly different answers).
2. Fold your piece of paper in four to find the central point
3. Push the first tack into the centre
4. Place the loop over the tack and then stretch it using a pencil and draw the first ellipse. This should be perfectly circular.
5. Place the second tack 1 cm away from the other tack
6. Put the loop over the two tacks as shown in the picture above and use a different colour pencil

*An initiative supported by Woodside and ESWA*



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to mark out the ellipse.

7. Measure the length of the major axis and enter this in the table.
8. Repeat step 6 and 7 with the tacks 4 cm and 7 cm apart.
9. Calculate the eccentricity of the ellipses using the formula given above.

| Orbit of object  | Distance between foci (cm) | Length of major axis (cm) | Eccentricity |
|------------------|----------------------------|---------------------------|--------------|
| Orbit 1 (circle) | 0                          | Will vary                 | 0            |
| Orbit 2          | 1                          | Will vary                 | Will vary    |
| Orbit 3          | 4                          | Will vary                 | Will vary    |
| Orbit 4          | 7                          | Will vary                 | Will vary    |

### Observations

What happens to the shape as the distance between the foci increases? It becomes more elliptical (more squashed looking)

What happens to the eccentricity as the distance between the foci increases? It increases.

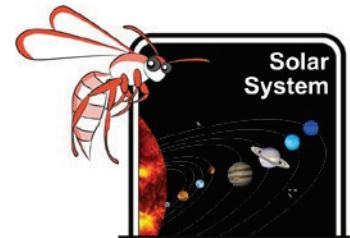
### Applying your knowledge

Below is a table of the eccentricity of different planets in the Solar System.

| Planet  | Major axis (AU) | Eccentricity |
|---------|-----------------|--------------|
| Mercury | 0.774           | 0.2056       |
| Venus   | 1.446           | 0.0068       |
| Earth   | 2               | 0.0167       |
| Mars    | 3.048           | 0.0934       |
| Jupiter | 10.406          | 0.0484       |
| Saturn  | 19.074          | 0.0542       |
| Neptune | 60.14           | 0.0086       |

1. Is there any relationship between eccentricity and distance from the Sun? No, in fact Mercury has the most elliptical orbit of all planets. However, comets and dwarf planets beyond Neptune can have highly elliptical orbits.
2. Which planet has the highest eccentricity? Mercury
3. Why do you think it took astronomers so long to realise that the planets were orbiting in ellipses? The eccentricity of most of the planets is so small their orbit is nearly circular. They would have had to take very detailed measurements and do lots of calculations to determine their orbit.

To learn more about the planets orbit and view them in 3D go to this website:  
<https://theskylive.com/3dsolarsystem>



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***These results and this equipment can be saved for the following “Rockets and Range” experiment.***

### ***EXTENSION - Further out - Apply your knowledge***

Out beyond the planets, right at the edge of our solar system lie two zones or belts of small icy objects that circle the Sun. The innermost is called the Kuiper Belt, which stretches out to about a billion kilometres from the Sun, and the outermost is called the Oort Cloud. Interestingly, astronomers Gerard Kuiper and Jan Oort each theorised that they must exist long before astronomers finally were able to see them. Oort suggested that as the solar system was forming, the large planets would move closer to the Sun under the influence of its gravity. This would push the smaller bodies further out into the Kuiper belt and the Oort Cloud. Objects within these belts can take thousands of years to orbit the Sun. Comets from the Kuiper Belt tend to have more rocky material than the “dirty ice” comets from the Oort cloud.

These zones are the sources of the comets that move across the night sky trailing tails of gas that point away from the Sun.

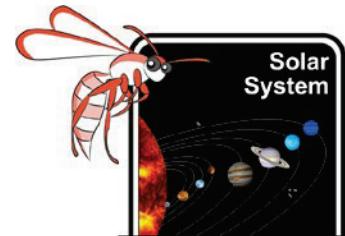
Because they exist far from the gravitational influence of the Sun, movement and changes elsewhere in the Milky Way Galaxy can affect objects in this zone. Every so often one becomes unstable and plunges down towards the Sun to orbit it and then swing back out beyond the planets again. We call them comets. (“Comet” comes from the Greek word for hair as when the icy object nears the Sun a stream of gas lies behind it). The comet will keep periodically orbiting until its forward motion slows down and gravitational pull will cause it to plummet into the Sun or a large nearby planet.



Comets are classified as long period comets and short period comets. Long period comets take more than 200 years before they return to pass the Earth and circuit the Sun.

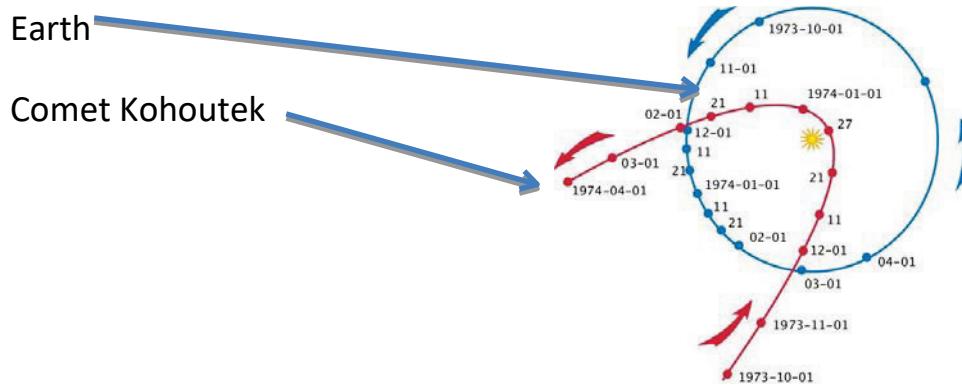
From which of these outer zones do you think that long period comets would come? Please explain your answer.

**Long period comets would come from the outer Oort Cloud as it would take longer to travel from there to the Sun.**



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This diagram describes the orbits of comet Kohoutek and Earth round the Sun in 1973 and 1974.  
Label the orbits of Earth and the comet.



On first sighting the comet was thought to be mostly ice and gas, however later spectral analyses demonstrated that it has quite a lot of rocky material in its core. Where would this comet have come from? [The Kuiper Belt](#).

### ***More information***

The effect of gravitational pull on a satellite does not always result in a simple elliptical orbit. Interested students might like to get information about a small object that is presently circling Earth in a very complex spiralling horseshoe pattern.

3753 Cruithne is probably an asteroid. It will share Earth's orbit round the Sun for the next 5,000 years and then leave to return to its point of origin in the Asteroid Belt. At present we are orbiting it while it is also orbiting us and both it and Earth are in co-orbit round the Sun. It takes nearly 800 years to complete its orbit round the Earth.

Astronomers are finding more and more of these small quasi-orbital satellites around Earth and other planets. There is much discussion on whether they can be called "moons" as their moon like status is temporary.