Drawing Orbits
Key Stage 3

Topics covered: Planetary orbits, ellipses, Kepler's laws, foci

Teacher's Notes

This activity allows students to visualise the orbits of planets as ellipses rather than circles and allows for the further study of the geometry of these orbits through basic algebra using terms derived from the drawing exercise. Depending on student ability, you may choose to assign the full activity or the 'Drawing Orbits' segment on its own. The student instructions should be printed off for every student.

Equipment: Student instructions (pages 5-7 of this document), pencil, compass, length of string, two pins and ruler for every student

Questions to ask the class before the activity:

The Earth moves in two ways - what are they?
Answer: The Earth rotates on its axis and the Earth orbits (or goes around) the Sun

Which of the two motions defines a year for Earth and how long is that in days?
Answer: Earth's orbit around the Sun, 365.25 days.

Which of the planets in our solar system moves around the Sun the fastest and why?
Answer: Mercury – It is closest to the Sun.

Background science

In the early 17th century an astronomer called Johannes Kepler used detailed observations made by another astronomer (Tycho Brahe) to describe the paths of the planets as they go around the Sun. It was through these careful observations of the movements of the planets in the night sky that Kepler calculated that the orbits of the planets were elliptical, not circular in shape. As a result of this, Kepler also realised that the Sun was not directly at the centre of the orbit but at one of the two foci of this ellipse.

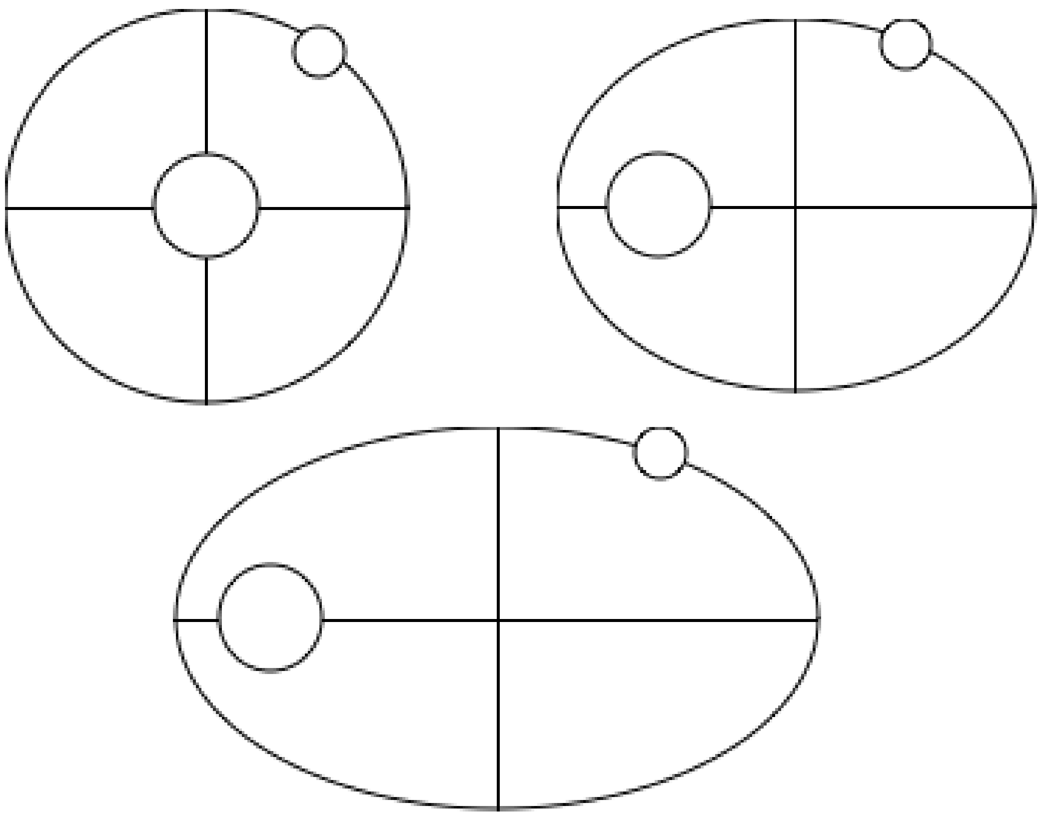
Kepler's work was entirely based on observation; he did not understand the physical causes of the motions he described. Later in the 17th century, however, his laws of planetary motion were correctly understood by Isaac Newton as the result of gravitational forces. Though Kepler's work was based entirely on observations within our own Solar System, his insights form the foundation for exploring the orbits of planets circling distant stars. Planets are bound in their orbits by the gravitational force of the star they orbit, just as the planets in our Solar System are bound to the Sun. Every planetary orbit has two foci – one that is empty and one that is occupied by the star.

Orbits are periodic phenomena – by observing the movements of the planets in the night sky, early astronomers worked out how long a year is on each of the planets in our solar system. Mercury, the closest planet to the Sun, only takes 88 days to orbit the Sun once, while Neptune takes 165 years. Students can research the orbital period of the other planets in our Solar System and compare and contrast these with the orbits of newly discovered exoplanets. Many of the first exoplanets discovered have relatively small orbital periods as they orbit very close to their parent stars.

Activity: Drawing Orbits

On an A4 page, ask students to draw a horizontal line with a shorter vertical line through its centre. Let students choose how much shorter they draw the vertical line so that every student will have a different ellipse. The horizontal line is the major axis and the shorter vertical line is the minor axis for the ellipse.

With students choosing an arbitrary ratio for the two axes length, they may produce a variety of different types of ellipses from near circular to highly elliptical.



Students can complete their orbits by adding in the star and planet. The planet can be anywhere along its orbit, but the star must occupy one of the foci that students marked earlier (see student instructions).

Further Activity:

Students can also work out the eccentricity (e) of the orbit – how elliptical the orbit is. If e is close to zero, then the orbit is almost circular. If the value of e is closer to one, then the orbit is highly elliptical.

Important information for the student:

The star would be positioned at one of the foci and the planet orbiting on the path drawn. The other focus is empty.

When the planet is closest to its star the distance from star to planet is called apoapsis, (r_a).

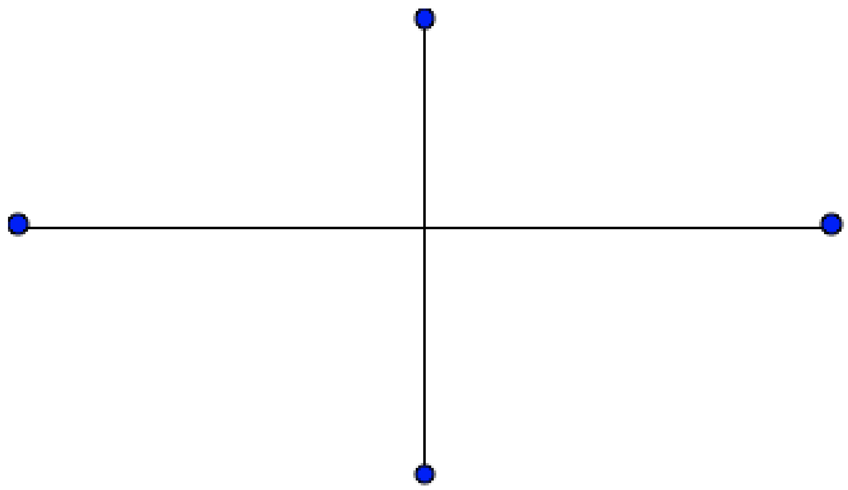
When the planet is furthest from its star the distance from star to planet is called periapsis, (r_p).

Students can work out the eccentricity (e) using the following small calculation:

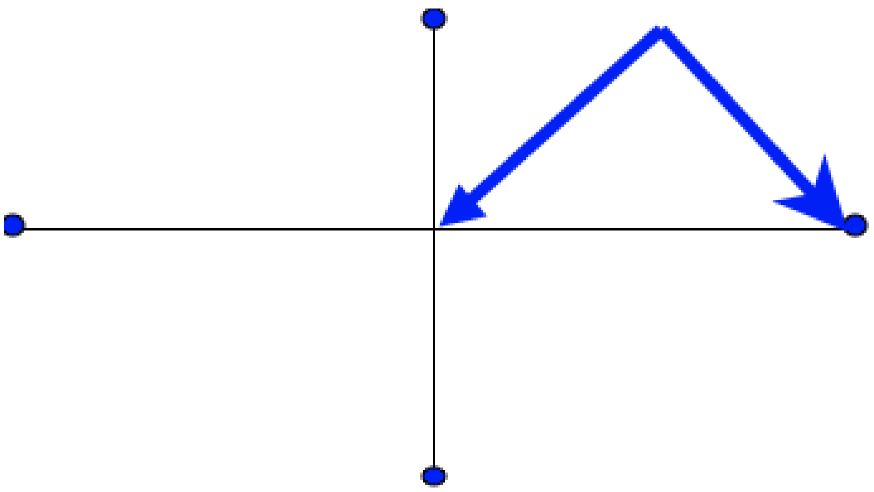
$$e = \frac{r_a - r_p}{r_a + r_p}$$

The value calculated by each student should be between 0 (circular) and less than 1 (highly elliptical).

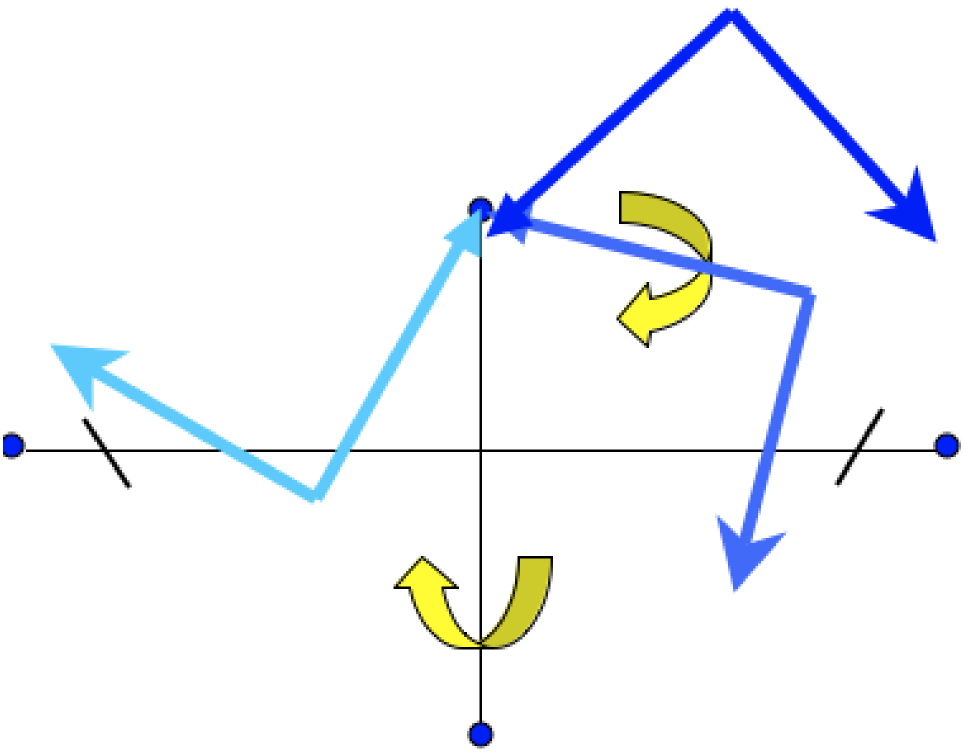
Activity: Drawing Orbits



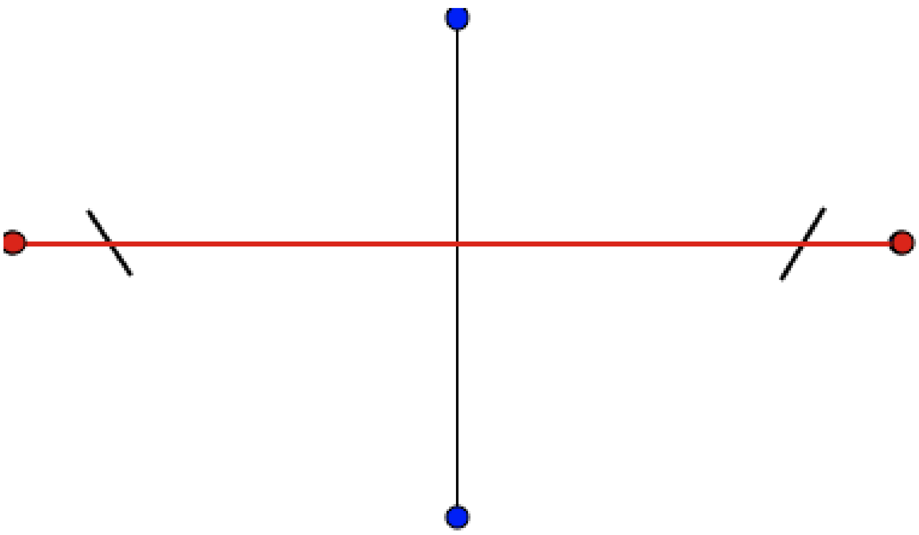
To start drawing the ellipse, stretch the compass from where the axes intersect to the end of the major axis.



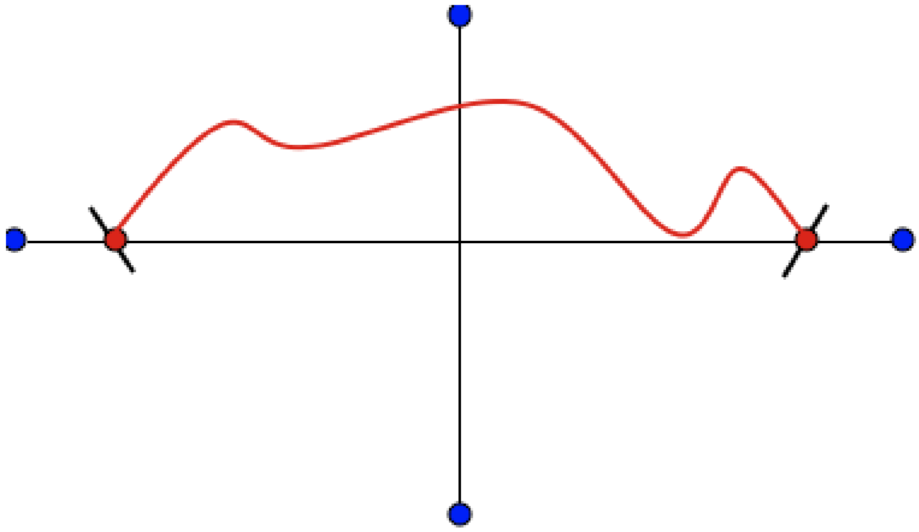
Next move the compass straight up the minor axis. Keep the point of the compass at the top of the minor axis and swing the pencil down and around (as in the diagram overleaf) and make a mark with the compass pencil as shown. Keeping the point in the same place, move it all the way around to mark the other side of the major axis as shown. These are the foci of the ellipse. For a planet orbiting a star, the star would be at one of these foci.



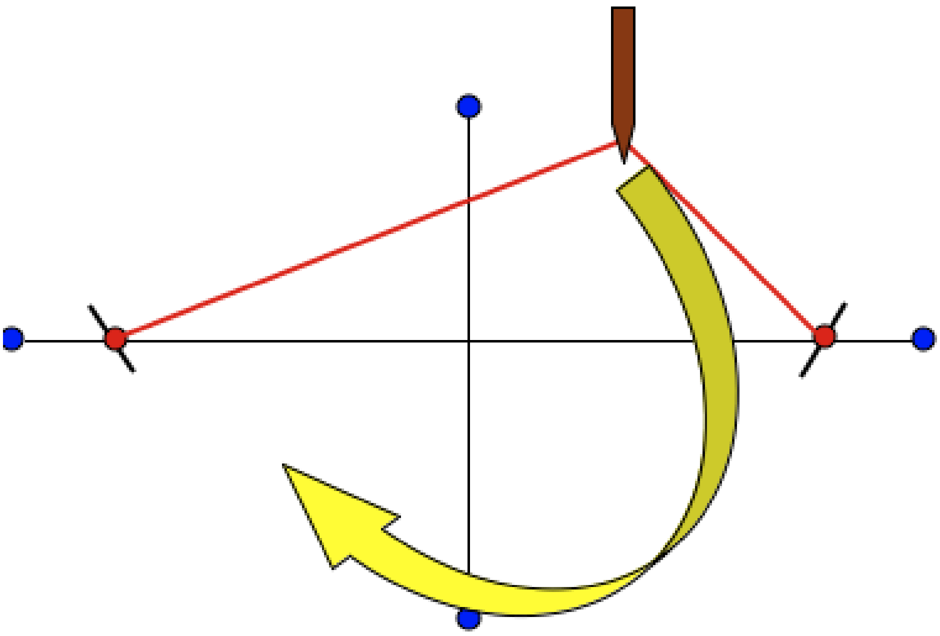
Now pin down your string tight along the major axis as shown.



Move the pins to the foci marks made earlier so the string is no longer taut.



Take a pencil and stretch it so the string is taut again and move the pencil all the way around to draw the elliptical orbit.



Your ellipse should be now be complete – simply add the star at F1 and the orbiting planet.