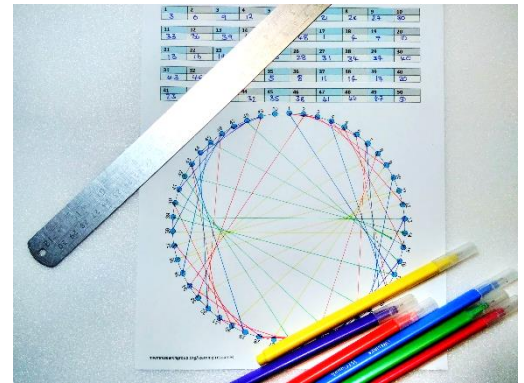You can draw your epicycloid, or make a string art one out of yarn or thread.

To Draw an Epicycloid:

You will need: coloured pens or pencils, a ruler and the 50 or 100 point template.

The 100 point template will give you a more detailed drawing, and will take a little longer to do.

1. Decide what mapping you are going to use. This is the rule which tells you which points to join together.
   - If you want to draw a **cardioid** you will map *n*➔*2n*. This means you will draw a line connecting each point with the point twice its number value (join 1 to 2, 2 to 4, 3 to 6 and so on).
   - Mapping *n*➔*3n* by joining each point to the point 3 times its value will give you a **nephroid**.
   - Mapping *n*➔*4n* will result in an **epicycloid of Cremona**.
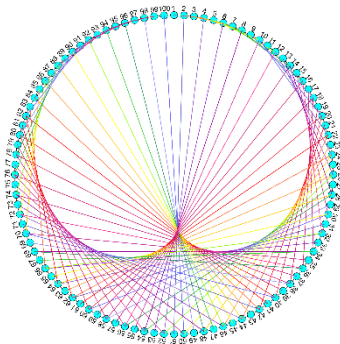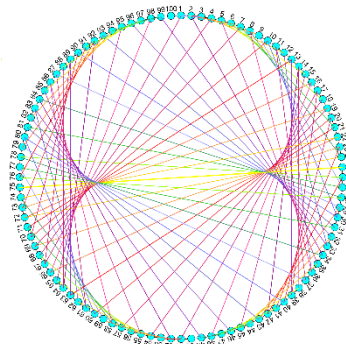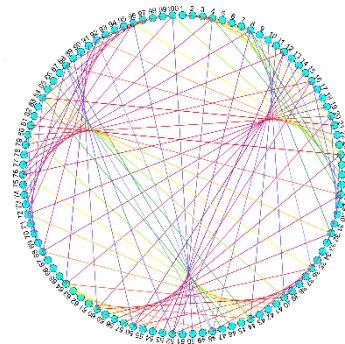
| **Cardioid** | **Nephroid** | **Epicycloid of Cremona** |

2. Fill in the table at the top of the sheet according to your mapping. You can cross the numbers out as you draw each line.
3. Using a ruler, join each point in turn to the point it maps to.
4. When you reach a point which maps to a number higher than the numbers on the circle, keep going round the circle, subtracting 100 from the number you need, to find the correct point. Point 2 is now point 102, point 22 is now point 122.
   - For the 50 point template, subtract 50 (point 2 becomes point 52 and so on).
   - This is called *modular arithmetic*. We use it every day when we convert between the 24 and 12 hour clocks!
5. Don't worry if you make a mistake. Small mistakes won't show up much, and mistakes can be beautiful!

To Make a String Art Epicycloid:

You will need: cardboard, scissors, glue and thread, string or yarn; and the 50 or 100 point template.

1. Decide what mapping you are going to use. Follow instructions 1 and 2 in *To Draw an Epicycloid* to fill in the table and plan your mapping. The steps that follow use **n → 2n** mapping, for a cardioid.
2. Glue the template onto cardboard and ask an adult to help you cut around the numbers in a circle.
3. Now cut a notch through each number to the dot.
4. Knot the end of your thread and starting at point 1 bring the thread out through the groove at 1, and into the groove at point 2.
5. For the next connection, we are going to work in the opposite direction: run the thread behind your work and bring it out at 4 and connect it to point 2.
6. Now bring the thread out at 3 and connect 3 to 6.
7. Working the opposite way, bring the thread out at 8 and connect it to 4.
8. Continue around the circle in this way, making every second connection in the opposite direction.

Download the templates and learn more about cardioids on our website:

www.mwmresearchgroup.org/draw-curves-with-straight-lines