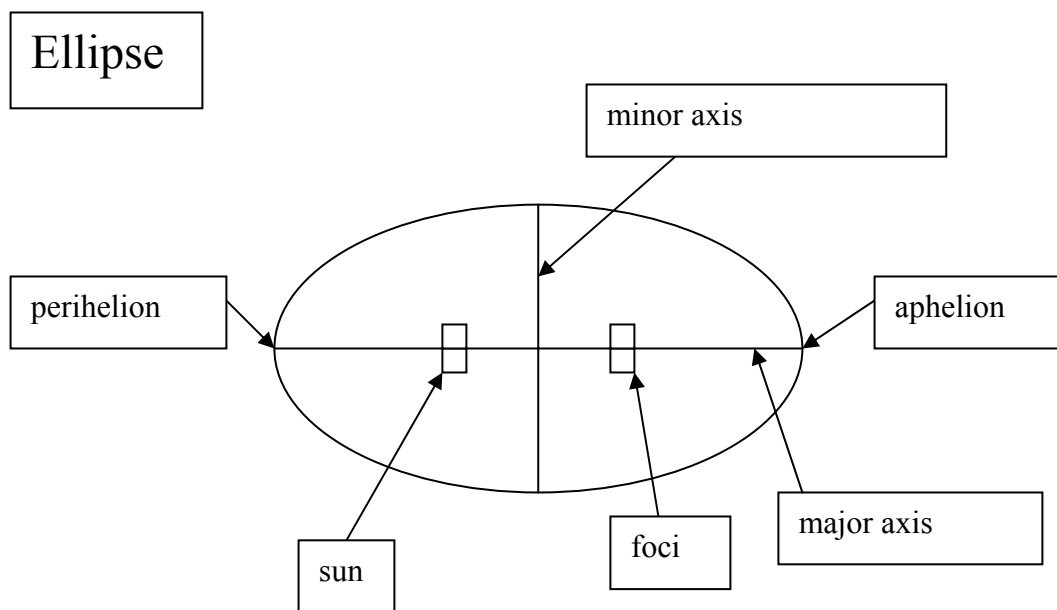


Materials needed: string, cardboard, two stick pins, paper, protractor, and metric ruler

Background: Kepler discovered that the orbit of Mars is elliptical. He plotted the orbits of the other planets and determined that they are also elliptical. Kepler then formulated his Law of Elliptical Orbits: Each planet moves around the sun in an orbit whose shape is an ellipse, with the sun at one focal point. From any point on this ellipse, the sum of the distances from that point to the two foci is constant in length. In each planet-sun system, the sun is at one focus while the other focus is a point in space not occupied by any astronomical body. Kepler came up with this theory by plotting the orbit of Mars, his assignment when he was invited to become one of Tycho Brahe’s assistants at his new observatory in Prague.



a = semi-major axis (one half of major axis)
 b = semi-minor axis (one half of minor axis)
 c = distance from one foci to the minor axis
 eccentricity = divide distance between foci by major axis length (circle’s eccentricity = 0)

$$\text{circumference} = 2 \pi \sqrt{((a^2 + b^2) / 2)}$$

$$\text{area} = \pi * a * b$$

$$a^2 = b^2 + c^2$$

Procedure:

1. Center a sheet of paper over the cardboard and tape it down.
2. Press 2 stick pins, exactly 5.00 cm apart and centered side to side and top to bottom, through the paper into the cardboard.

3. Cut a piece of string (dental floss works great) a length about 3 to 4 times the distance between the pins, plus enough for a knot.
4. Tie a knot to form a loop and lay the loop on the paper so that it encloses the two pins.
5. Place a sharp pencil inside the loop and stretch the loop taut against the pins (keeping the string flat on the paper surface). Draw an ellipse around the two pins by keeping the pencil point as far from the pins as the string will allow.
6. Remove the string and pins.
7. Draw the major axis through the two pinholes. This will be the longest distance across the ellipse.
8. Draw the minor axis through the shortest distance across the ellipse. It will be perpendicular to the major axis at its midpoint. Use a ruler and protractor.
9. Label the two foci. These are the holes left by the pins. By default the left is the sun and is labeled by placing a small circle around the pin hole. The other pin hole is labeled F.
10. Label the perihelion on your drawing. This is the point on the orbit closest to the sun (one of the foci). It is at one end of the major axis.
11. Label the aphelion on your drawing. This is the point farthest from the sun in the orbit of the planet. It also is at one end of the major axis.

Questions:

1. In cm and to the correct number of significant figures, record the:

length of major axis: _____ cm length of minor axis: _____ cm

2. The semimajor axis is measured from the midpoint of the major axis to the aphelion.

length of semimajor axis: _____ cm

3. Eccentricity equals the distance between the foci divided by the length of the major axis.

eccentricity = $\frac{\text{distance between foci}}{\text{length of major axis}}$ = _____ (no units here)

4. The eccentricity of a circle is zero. Look up the eccentricity of the orbit of the earth around the sun.

List it: _____ (for bonus)

5. Calculate the circumference of your ellipse: _____

6. Calculate the area of your ellipse: _____

7. Confirm the ellipse by solving: $a^2 = b^2 + c^2$ Was your ellipse drawn correctly? (Show all work here).

Part 2:

From any point on this curve, the sum of the distances from that point to the two foci is constant in length. In each planet-sun system, the sun is at one foci. The other foci is a point in space, not occupied by any astronomical body.

1. Draw and label the major axis as AB. Label the center of the ellipse as C.
2. Draw and label the minor axis as GH.
3. Indicate the position of a planet in its orbit at two different times (any two places on the ellipse). Label one position P_1 and the other P_2 . Draw in the lines: $P_1\odot$, P_1F , $P_2\odot$, and P_2F
4. Measure the following lengths:

length of $P_1\odot$ = _____ cm

length of P_1F = _____ cm

length of $P_2\odot$ = _____ cm

length of P_2F = _____ cm

length of $P_1\odot + P_1F$ = _____ cm (remember: when adding, it's decimal places)

length of $P_2\odot + P_2F$ = _____ cm

Are the sums $P_1\odot + P_1F$ and $P_2\odot + P_2F$ equal or unequal? If the difference between the two is greater than 0.1 cm you need to locate new points and try again or do another ellipse.

Part 3 – Construction of another ellipse

Construct an ellipse whose major axis is 16 000 000 km and whose eccentricity is 0.5 (hint: let 1 cm = 1 000 000 km)

- a) If this ellipse were the orbit of a planet, what would be the aphelion distance of the planet?

_____ km

- b) What is the length of the minor axis of this ellipse?

_____ km