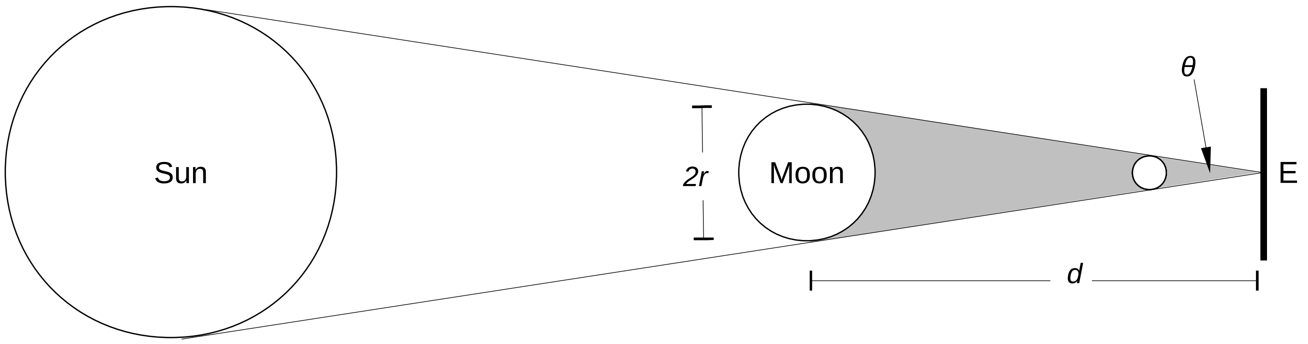
Eclipses - BACKGROUND

Consider the one-size-fits-all diagram below. It is very much not to scale!!



Suppose that the black line is the surface of the Earth, with E indicating the position of the observer's eye. Ignore the little circle for the moment. Notice the following facts:

- The eye at E cannot see the sun because it is exactly eclipsed by the moon. (This isn't quite true, because the corona, which is normally too faint to see against the bright background of the daytime sky, extends a long way each side of the sun's main globe, and the moon isn't big enough to cover this as well.)
- The eye cannot see the moon either, because its illuminated face is on the other side.
- Quite close to the moon, the moon's shadow is almost as big as the moon itself: but the shadow cone gets progressively narrower the further away from the moon you go. By the time you reach E, the moon's shadow has diminished to be only a few kilometres wide, which is why total solar eclipses are visible over such a small area. Remember the important fact that **an object's shadow diminishes by one Moon diameter over one Moon distance**.

Now consider the right hand little circle as well, and think of this as a 1p coin (remember that this diagram is not to scale!) held in such a position that it exactly blots out the Moon and the Sun. The Sun is enormous and a huge distance away, the Moon is very big and a long way off, while the coin is small and close. But because they all *appear* to be the same size as viewed by the eye at E, we can use a similar triangles argument to write:

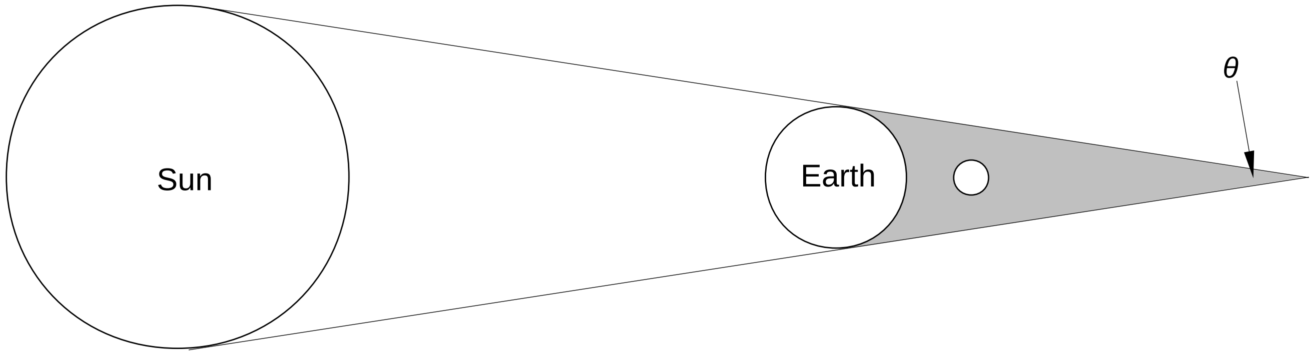
$$\frac{SunSize}{SunDistance} = \frac{MoonSize}{MoonDistance} = \frac{CoinSize}{CoinDistance} = \frac{2r}{d} = \theta$$

In elementary work, angles are measured in degrees, but these considerations allow us to see that a perfectly good way of measuring angles subtended by objects would be the ratio

$$\theta = \frac{ObjectSize}{ObjectDistance}$$

When we measure angles this way, we measure in radians: one radian is about 50°. The angle subtended by the Sun, the Moon and the coin held at the right distance is $^1/_{100}$ radian, or about ½°. We can obtain a value for this angle by sellotaping a coin to a window, retreating to such a distance that it just blots out the moon, and then measuring the diameter of the coin and how far we are from the window.

Now look at the diagram with fresh eyes. This is drawn to a different scale



The large circle on the left is still the Sun, but the middle circle is the Earth, while the small circle is the Moon. Notice the following facts:

- If you stand on the Earth and look (to the right) at the moon, you can't see it because it is in the Earth's shadow. (This isn't quite true because some sunlight is refracted by the Earth's atmosphere, which means that it bends round and faintly illuminates the moon. The light that does this is a coppery-red colour because the blue light has been scattered out of it while it passed through the atmosphere.)
- The moon is going round the Earth in an anticlockwise direction. Provided its orbit lies in the ecliptic plane (i.e the plane of the paper) it will spend some considerable time in the Earth's shadow, which is why lunar eclipses can be quite long.
- The Earth's shadow gets smaller the further away from the Earth you get. Close to the Earth, the shadow has the same diameter as the Earth. But by the time you reach the Moon – which, rather obviously, is one Moon distance away – the shadow has diminished by one Moon diameter (see the sentence in bold about half way down the first page).

So the fact is that the diameter of the Earth's shadow that the Moon passes through is given by

$$\textit{Diameter of Shadow} = \textit{Diameter of Earth} - \textit{Diameter of Moon}$$

The analysis of the Lunar Eclipse data can yield a value for the ratio of the Shadow's Diameter to the Moon's diameter. Let's say the ratio turns out to be 4. Then we could say say

$$\textit{Diameter of Shadow} = 4 \times \textit{Diameter of Moon}$$

Substituting the second equation into the first gives

$$4 \times \textit{Diameter of Moon} = \textit{Diameter of Earth} - \textit{Diameter of Moon}$$

which we can re-arrange as

$$\textit{Diameter of Moon} = {}^{1}/_{5} \times \textit{Diameter of Earth}$$

Since we know the diameter of the Earth, we can calculate the diameter of the Moon

THEN . . . . . .

If we've done the 1p coin measurement, so that we know the ${}^{1}/_{100}$ radian figure, we can use the equation on the first page to calculate the Moon's distance.

To have teased out the Moon's size and distance on the basis of one's night's observations will be no mean feat.