Farnham Astronomical Society

Exercise: Estimating the Heights of Lunar mountains
Difficulty: Intermediate

OBJECTIVE

When Galileo first turned his telescope to the Moon in 1610, he was the first to show that the Moon was not a flat sphere, but was imperfect – its surface was blemished by mountains and craters. He sketched the appearance of parts of the Moon's surface at different times of the month so that the angle of illumination would be different. He showed that the changing light and shadow could be accounted for topographically. At that time it was believed that the variation in light arose from something within a perfect lunar sphere. He then went on to calculate the height of the lunar mountains by using their shadows. His estimates were quite good!

In this exercise you will use the lengths of shadows to calculate the height of some lunar features. This exercise involves just a little mathematics – to simplify this exercise we have provided simple formulae but have not attempted to show how these are derived. Mathematical proofs for this exercise can be found on the Internet if you want to know more.

EQUIPMENT

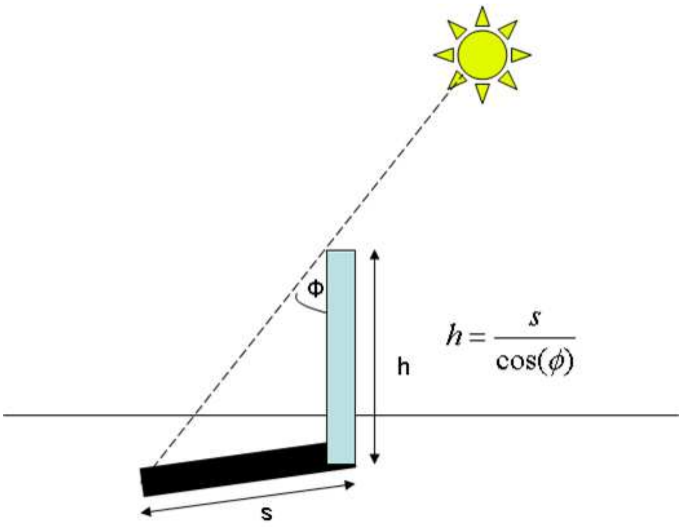
All you need to perform this experiment are:

- A small telescope
- A lunar chart (a map of the moon)
- A calculator with trigonometric functions
- A pencil and paper to record your observations

SOME BACKGROUND

The best time to observe the moon is generally considered to be the first quarter when the moon is just six to nine days past the new moon. When the moon is more fully lit, its features begin to be washed out by the brightness. At full moon the surface is so bright that through a telescope it can dazzle the viewer. Although less of the surface of the moon is visible, the sun's rays strike the surface at a shallow angle creating shadows and seemingly magnifying its features. Along the terminator, the line that delineates the lunar night and day, the Moon's surface becomes a magical 3-dimesional world.

If you know the angle of illumination of an object and the length of its shadow then you have two of the quantities needed to calculate the height of the object (see diagram below). For the lunar measurement, the problem is made just a little more complicated because we need also to adjust for the position of the object relative to the centreline of the moon (an imaginary line where the suns rays are perpendicular to the lunar surface).



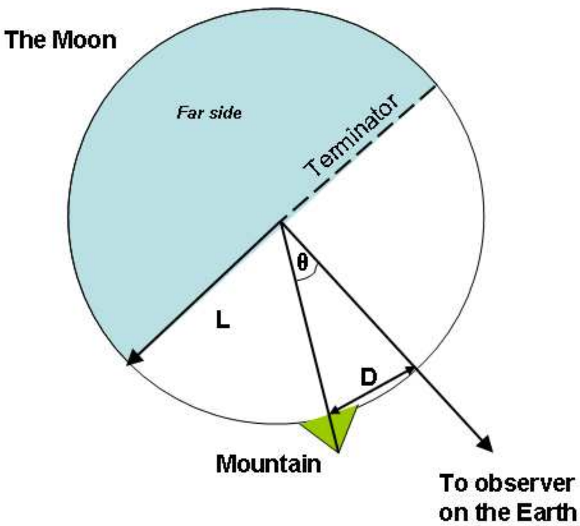
METHOD

For this exercise, the ideal time to make your observations is when there is a half moon. The shadows will still be clearly visible along the terminator but you will need to estimate the distance of the features casting the shadow from an imaginary centre line on the moon.

1. Observe the Moon through your telescope looking carefully at features around the terminator Compare what you see with your lunar chart. Select two or three lunar mountains that are casting a clear shadow. Your results will be more accurate if your selected mountains are near the lunar equator.

2. Make a to-scale sketch of the mountains showing the location of your features and their shadows. Record carefully on your sketch the lengths of the shadows. Try comparing the lengths of the shadow with the sizes of nearby features such as lunar craters in order to record their lengths as accurately as possible.

3. For the first of selected lunar mountains, use your sketch to measure its distance from the Moon's centre line (D) in mm and the length of its shadow (s). If you are making your observations when the Moon is exactly at half phase <u>and</u> the mountain lays on the terminator then the mountain will lie on the centre line and D will be zero.



4. Lookup the radius of the Moon (L) on the Internet. Using L you can then calculate the scale of your sketch (e.g. 10mm = 200 km). You can then use this scale to estimate the value of D

and S (in km) from your sketch. Note: If your object is to the right of the centre line then the value of D will be negative.

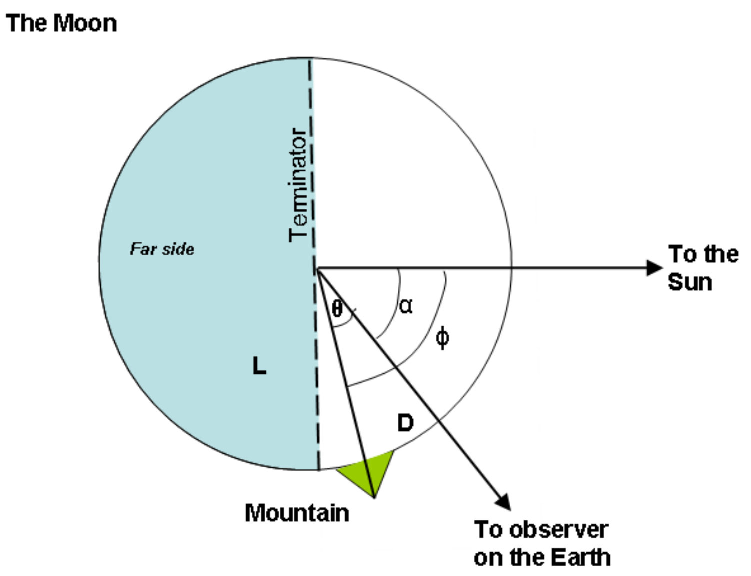
5. Determine the angle θ using the formula:

$$\theta = \arcsin\left(\frac{D}{L}\right)$$

6. Find the angle between the Earth, the Moon and the Sun (α) at the time of your observations. You can find this from various sources on the web. The following lunar phase applet will provide this information:

http://spacedata.agi.com/LunarPhase/Default.aspx

Be sure to provide the correct date and make the correct adjustment for GMT / BST depending on the date of your observation (BST = GMT + 1 Hr).



7. Once you have determined θ and α, you can then add them together to give you the angle of illumination (ϕ). Once you have determined these values you can calculate the height of the mountain using the following formula.

8. The height of the object casting a shadow of length s is calculated using the following formula:

$$Height = \frac{s}{\tan(\phi) \times \cos(\theta)}$$

9. Repeat the calculation for other second lunar feature9s).

ANALYSIS OF YOUR RESULTS

Do your heights look sensible?

If you can identify your feature on a lunar chart, try lookup its height on the internet. Does your estimated height agree? If they differ, why do you think this is? Where do the errors creep in and can you try to quantify them?