# Lab #13c$_1$: Distance to the Moon (Apparent Size 1)

The distance from us to the Moon changes during the day as the Moon rises high up in the sky, as indicated on Fig. 1a. This results in the Moon appearing to be somewhat *smaller* when it is rising, contrary to everyday perception. The difference can be measured in a photograph and can be used to determine the distance to the Moon, provided we know how large Earth is.

Fig. 1a. The rising Moon is farther from the observer than the moon that is high up in the sky.

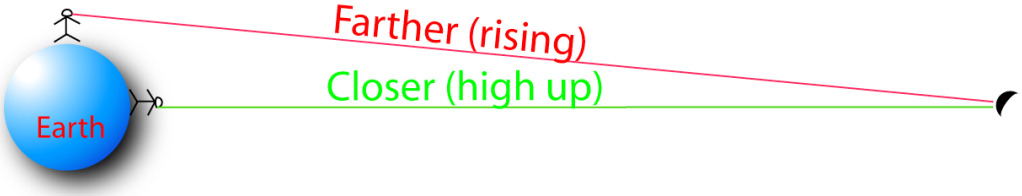
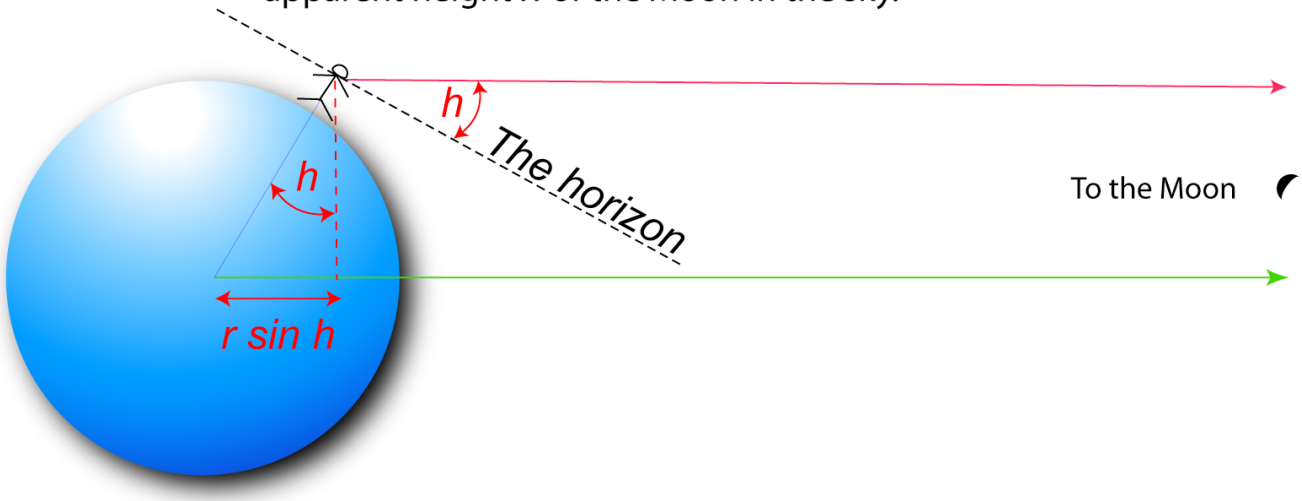



Fig. 1b. The distance to the Moon from the observer is related to the apparent height *h* of the Moon in the sky.




The Moon is closer to the observer than to the center of Earth by an amount ***r sin h.***

The two separately supplied laminated photographs of the Moon were taken October 27, 2004 by an amateur astronomer in Monterey, CA. The first one was taken of the eclipsed Moon at *7 pm*, just after moonrise, the other one was taken at *11 pm* when the Moon was high up in the sky. Comparing the size of the Moon on the two pictures we can tell us how far the Moon is.

A disturbing effect is what is called *refraction*. Light entering our atmosphere will be turned from its original direction. Any point on the Moon will appear to be higher up in the sky than it really is, by as much as a half a degree (Fig. 2). In addition, the bottom of the Moon is "raised" less than the top, and the shape of the Moon is distorted. The rising Moon looks as if someone hit its top and the vertical size is changed. In order to avoid the error this effect introduces into your measurement, you'll need to measure the horizontal diameter of the Moon, which is not affected by refraction.

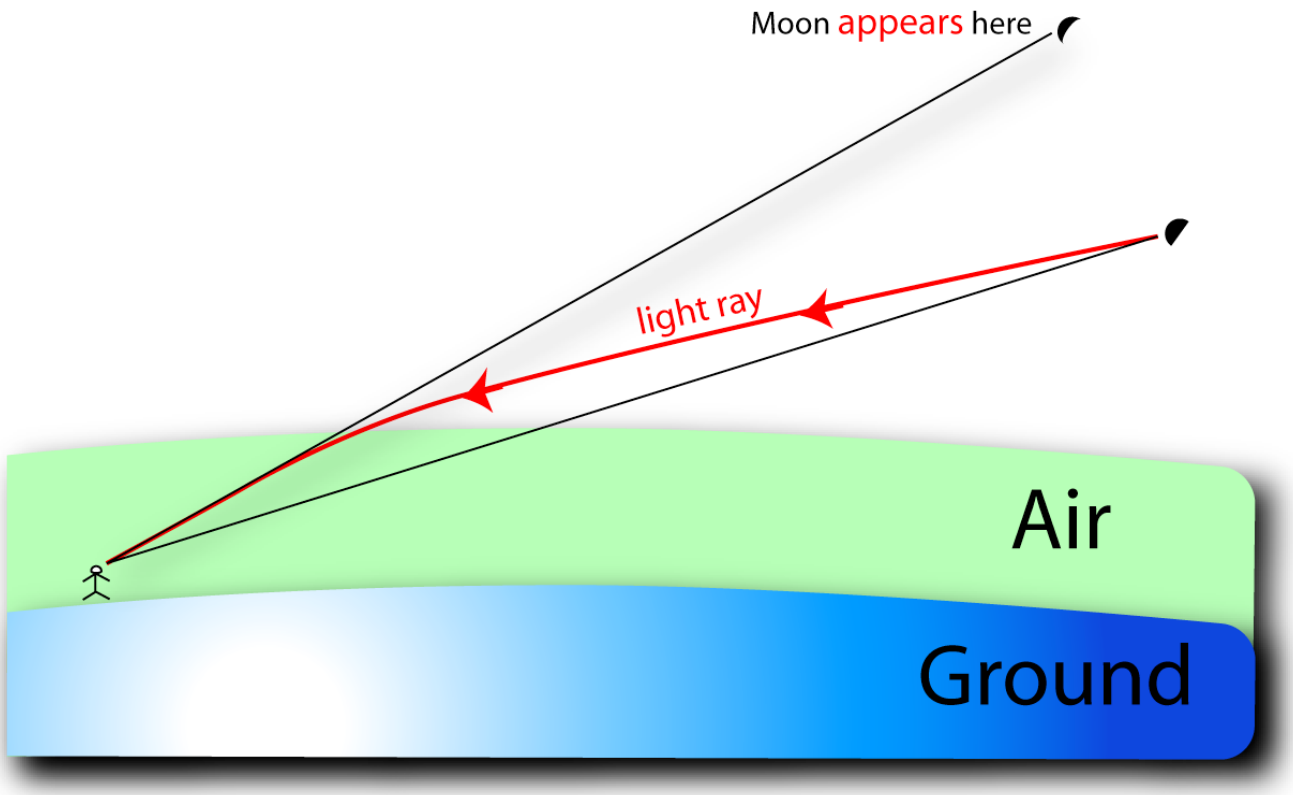



Fig. 2. Refraction: the rising Moon appears higher up from where it really is.

In Fig. 1b, the apparent angular height of the Moon over the horizon is denoted by the letter $h$. For example, the rising Moon would have $h=0^0$, the Moon in Zenith would have $h=90^0$. The distance between the observer and the Moon is shorter than the distance between the center of the Earth and the Moon, and this difference can be calculated. If you follow the trigonometry on Fig. 1b, you'll find that this difference is $r \sin h$, where $r$ is the radius of Earth. Using this information it is easy to see that the difference between the distances to the Moon at two different times will be $\Delta = r\,(\sin h_1 - \sin h_2)$. The height of the Moon over the horizon at each time is easy to measure.

# PROCEDURE AND LAB REPORT

**Date:_____ Your name: _____Partner's name: _____ Section: ___/___**

***Maximum two students may work together as partners!***

# *Read:*

1. ***Read the review.***
2. ***Follow the steps of the calculation:***

(1) On the two picture supplied, measure the size of the Moon with a ruler. You will need to do this very accurately, with a precision of a tenth of a millimeter. Your results are: the Moon is _____±___ *mm* in diameter on the picture when it is 67° up, and _____±___ *mm* in diameter on the picture when it is 6° up.

(2) Now calculate the difference. The Moon is ___*mm* in larger when it is high up, which constitutes a _____% difference. This is how many percent the Moon is closer to us when it is 67° up.

(3) Calculate how many *km*'s is the Moon actually closer at that time. The radius of Earth is 6340 *km*. Your result is Δ = _____ *km*.

(4) Now you know how many percent Δ constitutes of the total distance to the Moon, so you can calculate the distanced to the Moon. Your result is _____*km*.

(5) Compare this result with the actual distance to the Moon, measured more accurately through the time delay of radio signals, to be 384,400 km. How accurate is your result, and what do you think is the main reason for the difference:

_____.

(6) Measure the percent change refraction causes in the apparent vertical size of the Moon. Show your calculation below.

(7) These pictures have been taken at the full Moon. Pictures taken at any other time would not provide information that is accurate enough for even a crude estimate of the distance to the Moon. What disturbing effect do you think would introduce this large error? Describe your answer in words below.