

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

Physics 8.282

February 8, 2006

Problem Set 1

Due: Wednesday, February 15 (in lecture)

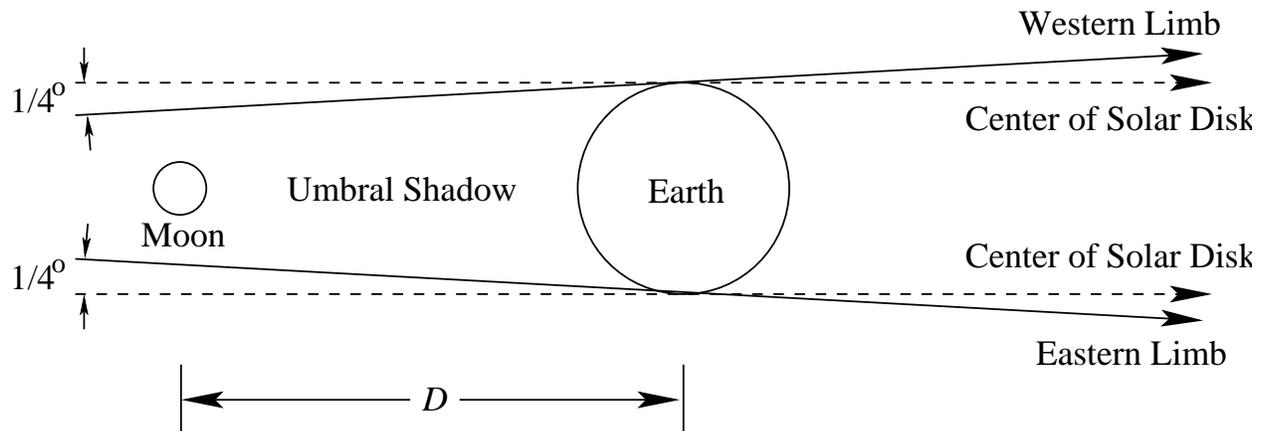
Reading: Light reading of Zeilik & Gregory Chapters 1-1, 2, 3, and 4.

Problem 1

“Aristarchus’ Method of Determining the Distance to the Moon”

Use **Chis Cook's** composite photograph of a lunar eclipse* to determine the radius of the moon and its distance from the earth (in units of the radius of the earth). The sketch below illustrates the appropriate geometry to use. Make use of small angle approximations.

- Assume that only the darkest part of the Earth’s shadow (umbra) corresponds to total eclipse. Draw a circle (with a compass if you have one) that best represents the umbral shadow.
- Note that the center of the shadow does not lie on the line connecting the path of the center of the moon. Explain why not.
- Measure the diameter of your circle as well as the diameter of one of the lunar images.
- Estimate the percentage error by which you might have under- or overestimated the size of the earth’s shadow.
- Compute the radius of the moon compared to that of the earth. Be sure to take into account the proper geometry of the umbral shadow at the distance of the moon. (For this purpose you can take the angular size of both the sun and the moon to be $1/2^\circ$.) Estimate the uncertainty in your answer. Compare to the known value of $6378/1738 = 3.67$.
- If the angular size of the Moon is $1/2^\circ$, calculate the Earth–Moon distance, D , in terms of the radius of the earth, R_\oplus .



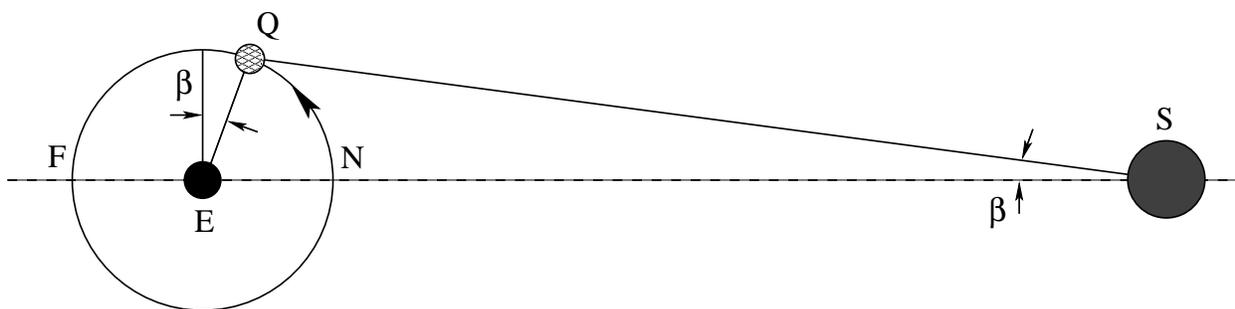
Note that there are two parallel vectors, displaced by one Earth's diameter, both pointing toward the center of the Sun. This is a reasonable approximation since the diameter of the Sun is ~ 100 times that of the Earth.

* <http://www.abmedia.com/astro/planets/lunar-eclipse110803-composite.html>

Problem 2

“Aristarchus’ Method of Determining the Distance to the Sun”

At the first quarter of the Moon (at position Q), the angle $\langle EQS \rangle$ equals 90° (see the sketch below). Modern observations show that the interval from new Moon (near position N) to first quarter (at Q) is 35 minutes shorter than that from first quarter to full Moon (near position F). Given that the lunar synodic period (the interval between two identical lunar phases) is 29 days and 12.73 hours, estimate the Earth–Sun distance (ES) in terms of the Earth–Moon distance.



Problem 3

"Accuracy of Parallax Measurements of Stars"

The uncertainties in the parallax measurements of stars made in the optical with the Hipparchos satellite were typically $0.001''$ (0.001 arc seconds). How far out into space can we measure stellar distances with $\sim 10\%$ accuracy? Radio astronomers are developing techniques that will make possible position measurements with an uncertainty of only $0.0001''$. By how much will these new techniques increase the *volume* of space over which distances of objects can be determined to $\sim 10\%$ accuracy?

Problem 4

"Distances to the Four Closest Stars"

The following Table from Allen's *Astrophysical Quantities* lists the 100 nearest stars and some of their properties. In particular, the first column gives the star's name while the tenth column, labeled " π ", represents the measured stellar parallax (in units of 0.001 seconds of arc). Identify the four closest stars. What are their distances (in parsecs)? See Chapter 19 in *Allen's Astrophysical Quantities*. 4th ed. Edited by Arthur N. Cox, AIP Press (Springer-Verlag), New York, 2000 [1976]. ISBN: 0387987460.

Problem 5

"Practice with Angles"

Find the angle subtended by the Sun for an observer on Pluto (at ~ 40 AU).
 Find the angle subtended by the nearest star (see Prob. 4) as viewed from the Earth.
 How wide is a laser beam, collimated to $1''$, when it reaches the Moon (at $d = 4 \times 10^8$ m)?
 Find the angle subtended by a basketball in Cambridge viewed from California.

Problem 6 (Optional)

"Solar Power"

The solar flux (power per unit area) on the Earth's surface is approximately one kilowatt per square meter. If the distance to the Sun is 1.5×10^{13} cm, find the total power generated by the Sun. Use Einstein's relation $E = mc^2$ to compute the rate at which matter in the sun is being converted to energy. (In this expression, m is mass and c is the speed of light.)

Problem 7 (Optional)

"Power Output"

Use the results of Problem 3 to compute the average power output of the Sun per gram of its mass ($M_{\odot} = 2 \times 10^{33}$ grams). Compare this to the power output per gram of your own body. (Assume that at rest you generate 100 Watts of power.)