Name_____ Date _____

Lab #3 The Moon's Orbit

These instructions supersede the instructions in the *Sky and Telescope* "Moon's Orbit" lab.

The Moon's orbit is complicated but it is approximately an ellipse with the Earth-Moon center of mass at one focus; since the center of mass is inside the Earth, this is almost the same as an ellipse centered on the Earth. The Moon is periodically closer and further away than its average distance, and the closer it is, the larger it looks. Using these variations in apparent size and approximating the Moon's orbit as an offset circle around the Earth you can estimate the shape and eccentricity of the Moon's orbit. You'll use photos of the Moon provided in the *Sky and Telescope* "Moon's Orbit" lab.

First, measure the apparent diameter (*d*) of each of the given images of the Moon, using a vernier caliper and reading to 0.05 mm. Measure each image twice and average your results. Record your measurements in the table below.

Image	Date (Nov.)	Long. (°)	Lat. (°)	*d* 1st	*d* 2nd	*d* ave (mm)	*R* (calc)
1	7.44	270	+1.5				
2	8.46	283	+2.6				
3	10.46	309	+4.3				
4	12.46	336	+5.2				
5	14.46	5	+5.8				
6	15.81	27	+3.9				
7	17.84	57	+1.6				
8	19.94	87	−1.2				
9	22.92	127	–4.3				
10	24.79	151	–5.1				
11	26.90	176	–5.1				
12	29.92	212	–3.5				
						R ave:	_____

The size of the image is inversely proportional to the Moon's distance away from us. Using the arbitrary scaling equation $R = 4000/d$, calculate relative distances *R* in mm and enter these values in the table as well as their average.

Put a dot at the center of a sheet of paper to represent the Earth and label it. Draw a straight line from the dot to the right side of your paper. This will be 0° ecliptic longitude. Let longitude increase counterclockwise. Plot each of the relative distances at the appropriate *R* from the Earth and at the angle that corresponds to the longitude associated with that measurement.

Approximate the Moon's orbit as a circle with the Earth off center. On a second sheet of paper draw a circle of radius equal to the average *R*. Mark the center. Either cut out this circle or, if you've drawn it dark enough, slide it under the paper on which you've drawn the orbit. Line the circle up with the orbit and mark the center of the circle on the orbit plot. Label the Earth, orbit center, and 0° longitude.

Draw the major axis of the Moon's orbit through the Earth and the orbit center. Draw the minor axis through the orbit center at right angles to the major axis. Label the axes. Label perigee and apogee (the near and far ends of the major axis).

Interpolate between the given dates and longitudes to determine the date and longitude when the Moon was at perigee:

Date:_____ Longitude:_____

Now calculate the eccentricity of the Moon's orbit by dividing the center-focus distance by the orbit radius and compare your result with the accepted value of 0.055:

measured *e*:_____ % error:_____

Recall that $b = a\sqrt{1-e^2}$; compute the ratio *b/a* using the measured value of *e*:

b/a (measured *e)* :_____ How far is this from circular?_____

You can also check Kepler's second law—equal areas in equal times—from your plot. Choose two consecutive points near perigee and estimate the area between them in mm^2 using $\frac{1}{2} R_1 R_2 \Delta\theta \, \pi/180$.

Estimated area:_____

Divide the area by the time between the two points (in days) to obtain an areal velocity.

$V_{perigee}$:_____ mm^2/day

Repeat these calculations for two points near apogee:

Est. area:_____ V_{apogee}: _____mm^2/day

Are they close? Calculate the percentage difference between the two velocities:_____

The ascending node of the Moon's orbit is where the Moon moves from below to above the ecliptic; the descending node is on the other side of the orbit, where the Moon moves from above to below. Use the dates and longitudes around the location where the Moon's ecliptic latitude changes sign to estimate the date and longitude of the descending node of the Moon's orbit (in Nov. 1918—the orbit wobbles and so the location of the nodes changes with time).

Date:_____ Longitude:_____