Altitude of the Moon and # of Hours it is Up

Puzzle to Solve:

On some days, the moon stays close to the horizon the entire time it is up. On other days, it travels so high in the sky that we have to crane our necks to see it. Why? And why is the moon out for a long time (more than 16 hours) on some days and out for a short time (less than 9 hours) on other days? Are these two phenomena related? Are they somehow related to the phases of the moon? If so, how?

1. Examine the graph below based on data from http://aa.usno.navy.mil/cgi-bin/aa_altazw.pl. Describe how the maximum altitude of the moon changed between Sept. 7 and Oct. 7, 2008.
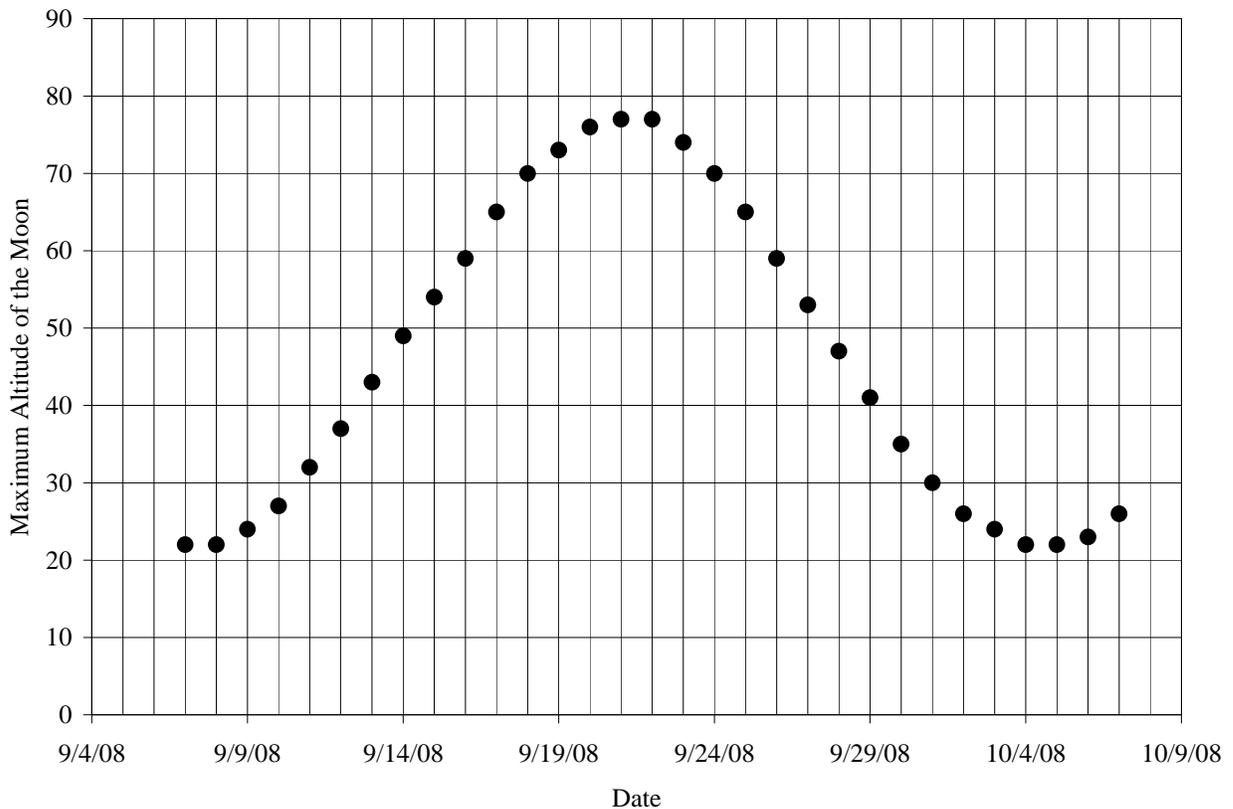
2. Examine the graph below, based on data from the *Old Farmer's Almanac*, showing the number of hours the moon was out each day during September and October, 2008. Describe any correlations between this graph and the graph on the previous page.
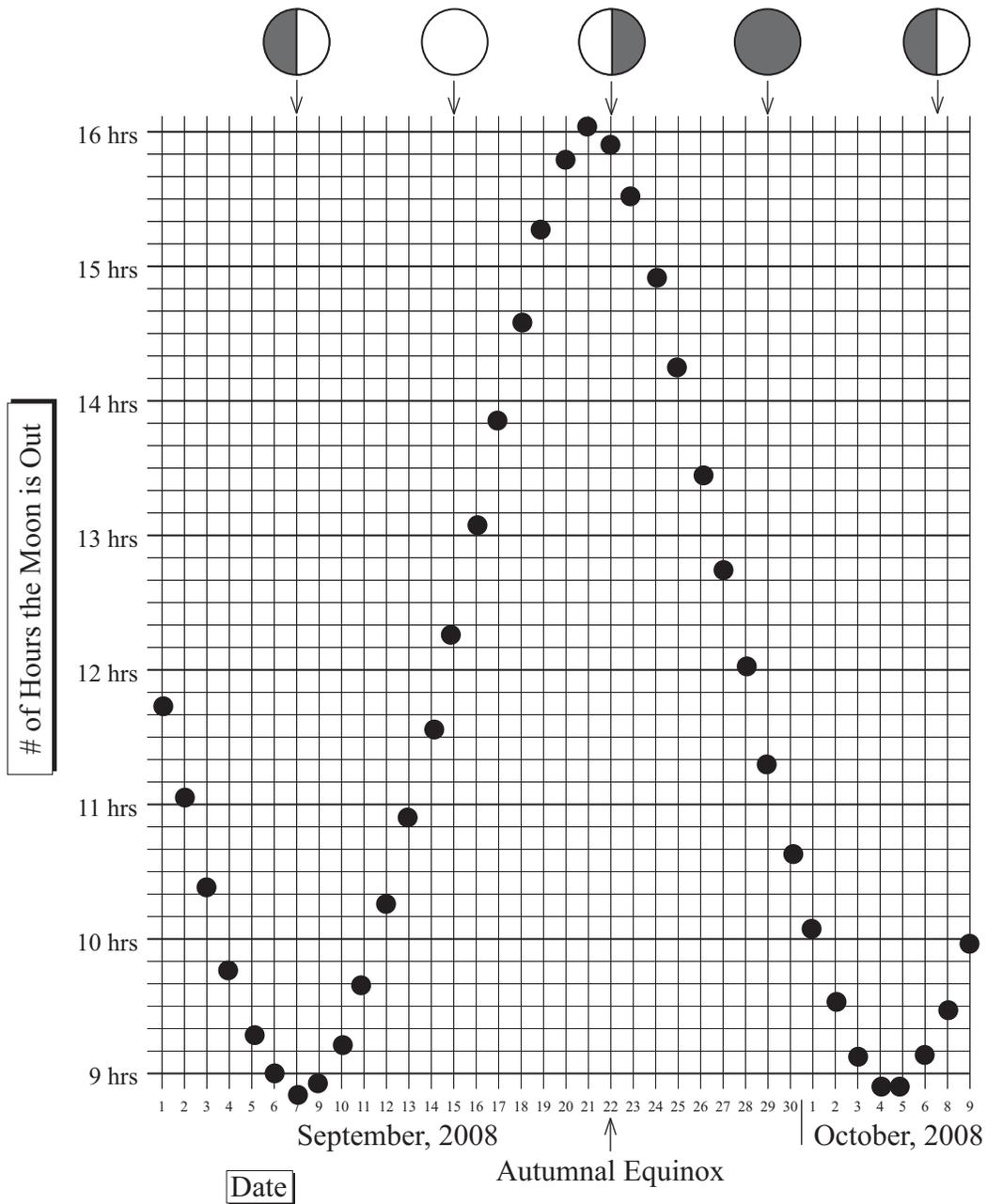
Symbols for the moon phases:

⬤ New Moon   ◑ 1ˢᵗ Quarter   ◯ Full Moon   ◐ 3ʳᵈ Quarter

3. Study the diagram below. If we were to add the moon to this diagram, at the correct scale, the moon would be 0.4 inch across and 40 inches past the left edge of this page. At that distance, the rays of light coming from the moon would be lined up parallel to each other as shown by the "moon rays" below.

Moon Rays

Horizon

Can see   Cannot see
the Moon   the Moon
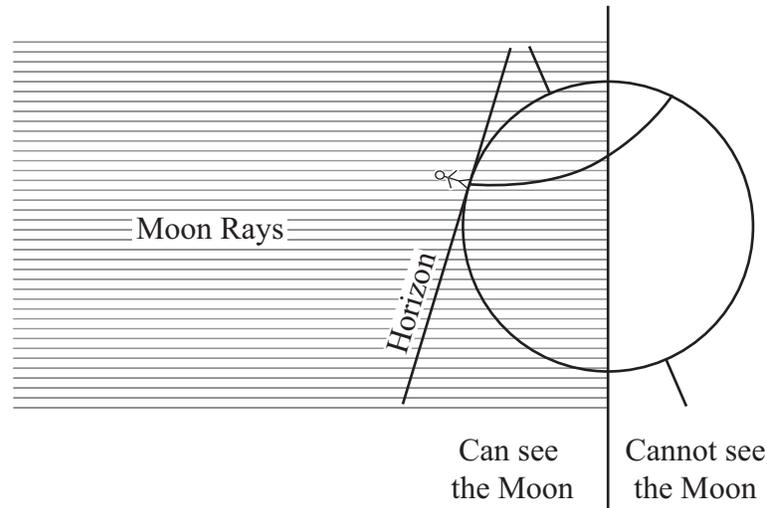
a. The person drawn on Earth is at 40° N Latitude, viewing the moon at its highest point that day; the moon is in the southern part of the sky. Determine the altitude of the moon at that time for a person at that location. Explain how you arrived at your answer.

Altitude of the moon: _____

b. The person drawn on Earth completes a full circle around Earth's axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

4. Two weeks later, the moon has gone half way around Earth and is now on the other side.

Horizon

Moon Rays

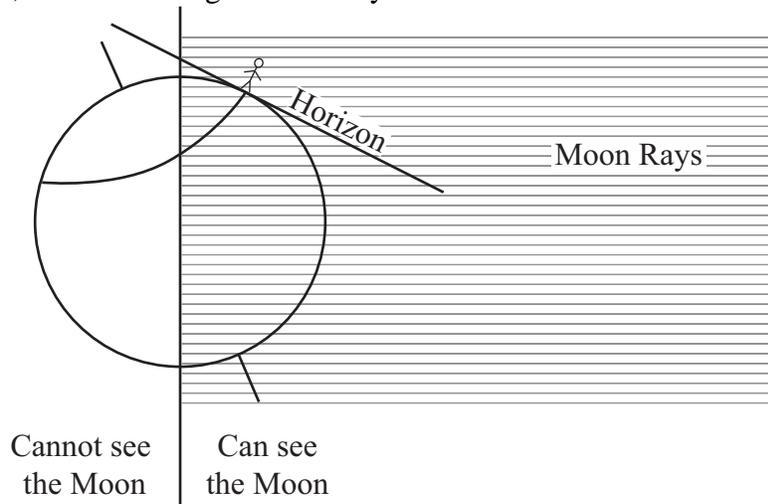Cannot see | Can see
the Moon | the Moon

    a. The same person is still at 40° N Latitude. S/he is viewing the moon at its highest point that day; the moon is in the southern part of the sky. Determine the altitude of the moon at that time for her location. Explain how you arrived at your answer.

Altitude of the moon: _____

    b. The person drawn on Earth completes a full circle around Earth's axis every 24 hours along the line shown. From measurements you make on the diagram, calculate (approximately) the number of hours the moon is out that day. Explain how you arrived at your answer.

5. Why are your answers to questions 3 and 4 above so different? What factor determines both the number of hours the moon is out and the maximum altitude of the moon? Explain.

6. The diagram below shows Earth, tilted toward the right side of the page, in four different positions around the sun. You are looking down on the sun's North Pole. Use a globe, polystyrene ball, and light bulb as needed to help you visualize each situation.

    a. Complete the diagram. In each "date" blank, enter in the appropriate solstice or equinox.

Moon
Phases: _____

_____

_____

Date: _____

Moon
Phases: _____

_____   _____

Date: _____

Sun

Moon
Phases: _____

_____   _____

Date: _____

Moon
Phases: _____

_____   _____

_____

Date: _____
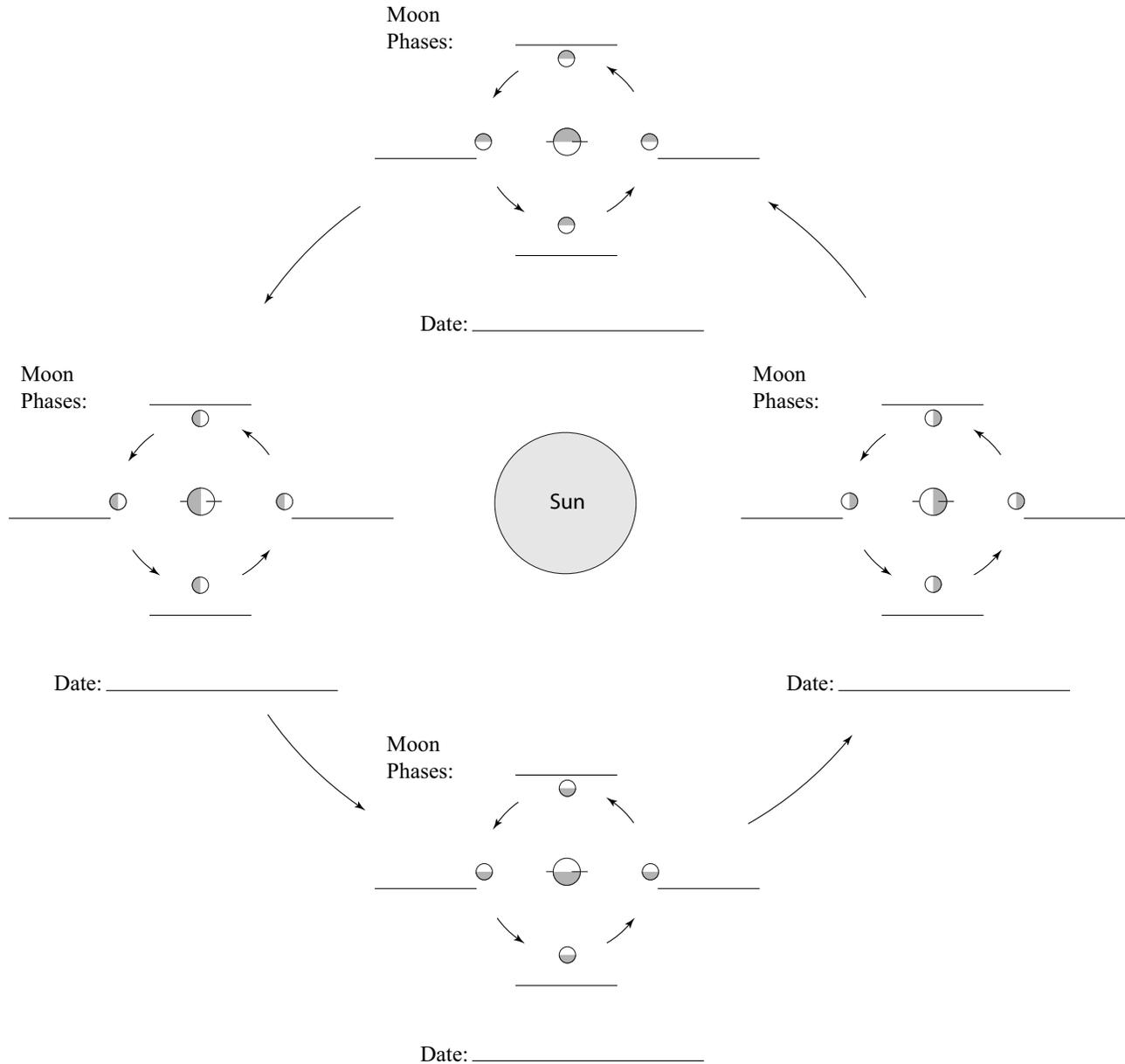
    b. For each position of Earth above, circle the moon phase that is out the longest.

    c. For each position of Earth above, explain why that particular moon phase is up the longest.

    d. For each position of Earth on the above, state which moon phase should have the highest maximum altitude and explain why this is so.

Answers to the Questions

1. The maximum altitude of the moon was just over 20° on September 7. It gradually increased each day until September 21 and 22, when the maximum altitude of the moon was nearly 80°. For the next 13 days, the maximum altitude of the moon gradually decreased each day, reaching an altitude of just over 20° on October 4th. The maximum altitude of the moon began to increase again on October 6th.

2. There is a direct correlation between the number of hours the moon is up and its maximum altitude. On the day that the longest (more than 16 hours, just before the 3rd quarter phase), the moon's maximum altitude also peaked. On the days when the moon was out for the shortest time (just under 9 hours, around the time of the 1st quarter phase), the moon's daily maximum altitude also reached its minimum value.

3. a. The angle between the horizon line and the moon rays is 73°, which is the altitude of the moon.

    b. If you look at the curved line on which the person is standing, you see that 70% of it is hit by moon rays while 30% of it is not. So the person spends 70% of a 24-hour day on the part of Earth that can see the moon. 70% of 24 hours is 16.8 hours. So the moon is out for approximately 16.8 hours on that day.

4. a. The angle between the horizon line and the moon rays is 27°, which is the altitude of the moon.

    b. If you look at the curved line on which the person is standing, you see that 30% of it is hit by moon rays while 70% of it is not. So the person spends 30% of a 24-hour day on the part of Earth that can see the moon. 30% of 24 hours is 7.2 hours. So the moon is out for approximately 7.2 hours on that day.

5. The tilt direction of Earth determines both the number of hours the moon is out and the maximum altitude of the moon. If the northern end of Earth's axis is tilted toward the moon, the moon will be out for a long time and reach a high maximum altitude. If the northern end of Earth's axis is tilted away from the moon, the moon will be out for a short time and never reach a high altitude.

6. a. See diagram on next page.

    b. See diagram on next page.

    c. The moon is out for a long time (for people living in the Northern Hemisphere anyway) whenever the northern end of Earth's axis is tilted toward the moon. On the diagram, the northern end of Earth's axis is tilted toward the right, so it is always the moon phase shown directly to the right of Earth that is out the longest. On the summer solstice, it's the new moon; on the autumnal equinox, it's the 3rd quarter moon; on the winter solstice, it's the full moon; and on the vernal equinox, it's the 1st quarter moon. The phase that is out the longest changes with the seasons because the phase of the moon is determined by the relative positions of the sun, Earth and moon, no just Earth and the moon.

d. For a fixed location on Earth, there is a direct correlation between the maximum altitude of the moon and how long it is up. So, the phase that is out the longest also reaches the highest maximum altitude.

Moon Phases:

Full

3rd quarter   1st quarter

New

Date: Vernal Equinox

Moon Phases:

1st quarter

Full   New

3rd quarter

Date: Summer Solstice

Sun

Moon Phases:

3rd quarter

New   Full

1st quarter

Date: Winter Solstice

Moon Phases:

New

1st quarter   3rd quarter

Full

Date: Autumnal Equinox