# Astronomy 3 - Solution Set 1

1. **If sunlight takes 8 minutes to reach Earth, how long does moonlight take?**

   You can figure this out either of two ways:

   time from moon $= \frac{\text{distance to moon}}{\text{speed of light}} = \frac{3.84 \times 10^5 \text{ km}}{3.00 \times 10^5 \text{ km}} = 1.28$ seconds

   Or, using the given information:

   $\frac{\text{time from moon}}{\text{time from sun}} = \frac{\text{distance to moon}}{\text{distance to sun}}$

   time from moon $= \frac{\text{time from sun} \cdot \text{distance to moon}}{\text{distance to sun}}$

   time to moon $= \frac{(480 \text{ sec})(3.84 \times 10^5 \text{ km})}{1.5 \times 10^8 \text{ km}} = 1.28$ seconds

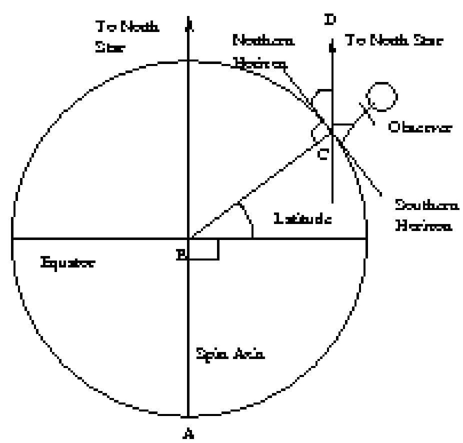
2. **As seen from your latitude, what is the angle between the north celestial pole and the northern horizon? Between the southern horizon and the noon sun at the summer solstice?**

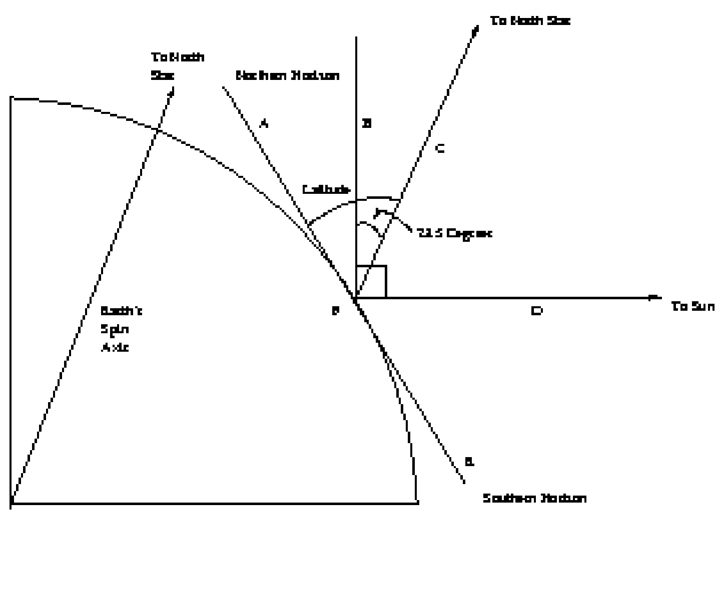
   The easiest way to answer this question may be by imagining you are at a place on the Earth where you already know the position of the sun, and then imagine yourself walking around the Earth and what happens to the sun as you do so. A globe may help you picture it. For the first part of the question, imagine you are at the equator or the north pole. For example, if you are at the north pole, where is the north star (north celestial pole)? It is directly overhead, 90 degrees from the horizon. Now imagine yourself walking south around the Earth. As you walk, the north star will start to move toward your horizon. For each degree of latitude that you walk south, the north star will appear to move toward your horizon by one degree. How many degrees do you have to walk to get to Santa Cruz? Since Santa Cruz is at a latitude of about 37 degrees, you need to walk $90 - 37 = 53$ degrees. As you make that walk, how many degrees has the north star moved toward your (northern) horizon? 53 degrees. Since it started out at 90 degrees from the horizon when you were at the north pole, it has gone down to $90 - 53 = 37$ degrees. (Try to see how this works if you start at the equator instead!)

   For the second part, note that during the summer solstice, the northern hemisphere is tilted toward the sun at 23.5 degrees. Where is the sun directly overhead? When you are at 23.5 degrees north latitude. (Does this make sense? Think it through before proceeding.) So the sun is 90 degrees away from the southern horizon at the summer solstice if your latitude is 23.5 degrees. Now imagine yourself walking north around the Earth. As you walk, since you are walking away from the sun, the sun will move toward your horizon. For every degree you walk north, the sun will appear to be one degree closer to your southern horizon. How many degrees do you have to walk to get from 23.5 degrees north latitude to our latitude? $37 - 23.5 = 13.5$ degrees. So the sun will appear to have moved 13.5 degrees toward the horizon as we walk from 23.5 degrees to 37 degrees north latitude. It started out at 90 degrees from the horizon, so now it is $90 - 13.5 = 76.5$ degrees from the (southern) horizon.

   If that wasn't clear, there are other ways to see this; there's a nice figure on page 18 of the text (2nd edition) that shows you how to figure it out.

   In the first figure on page 2, the two lines labeled "To North Star" are parallel since the north star is so fantastically far away. You may remember from high school geometry that angle ABC equals angle


To North Star
D
Northern Horizon
To North Star
Observer
C
Southern Horizon
Latitude
B
Equator
Spin Axis
A


To North Star
To North Star
Northern Horizon
A
B
C
Latitude
23.5 Degrees
Earth's Spin Axis
F
D
To Sun
E
Southern Horizon

also know that angle BFD is 90 degrees. So angle DFC is 90-inclination. We're after angle EFD. Therefore:

Angle between noon sun and southern horizon
= angle EFD
= 180 degrees - angle DFC - angle CFA
= 180 - (90 - 23.5) - latitude
= 90 + inclination - latitude
$\simeq$ 75 degrees for Santa Cruz.

3. **About how many days must elapse between the first quarter moon and the third quarter moon?**

   The first quarter moon is when the moon is one quarter of the way through it's cycle, and the third quarter moon is when it's three quarters of the way through its cycle. The length of one complete cycle is $\sim$28 days, so there are $\sim$14 days between the first and third quarter.

4. **If a planet has an average distance from the sun of 4 AU, what is its orbital period?**

   Using Kepler's third law:

   $\text{Period} = \left(\sqrt{\frac{\text{distance}}{1\ \text{AU}}}\right)^3$ years = 8 years

   Note that the answer is *not* 4 years (reasoning that the planet has to travel four times as far as the Earth). Planets that are farther away from the sun take longer to go around the sun because they're "running on a bigger track", but they *also* experience a weaker gravitational force. Therefore they take *even longer* to go all the way around the sun.

5. **Compare the force of gravity on the surface of the moon with the force of gravity at Earth's surface.**

   The force of gravity due to the Earth at the Earth's surface is:

   $F_{Earth} = \frac{GM_{Earth}m}{R^2_{Earth}}$

   The force of gravity due to the moon at the moon's surface is:

   $F_{moon} = \frac{GM_{moon}m}{R^2_{moon}}$

   The ratio of the two is: $\frac{F_{moon}}{F_{Earth}} = \frac{M_{moon}/R^2_{moon}}{M_{Earth}/R^2_{Earth}} = \frac{7.4x10^{22}\ \text{kg}/(1700\ \text{km})^2}{6.0x10^{24}\ \text{kg}/(6400\text{km})^2} \simeq 1/6.$

   So you would, for example, be able to jump six times higher on the moon than you can on the Earth.

6. **From what locations on Earth is the north celestial pole not visible? The south celestial pole? The celestial equator?**

   See **Figure 2-11** (in the **2nd edition**) for visual aids, or use a globe to visualize it. The north celestial pole is directly above the North Pole of the Earth, so it can only be seen from points north of the equator. Anywhere south of the equator, you would need to look through the Earth in order to see the north celestial pole. For the south celestial pole, the reverse is true; you can only see it from north of the equator. The celestial equator is a ring around the earth's equator. Since it goes all the way around the Earth, you can look up to see it from anywhere on Earth (some would argue that you can't see it if you're at exactly the north or south pole of the Earth, since it would be right on your horizon).

7. **How do seasons in Earth's southern hemisphere differ from those in the northern hemisphere?**

   When the northern hemisphere is tilted toward the sun, in our summer, the southern hemisphere is tilted away from the sun, so it is winter there. When the southern hemisphere is tilted toward the sun it is summer there, but we in the northern hemisphere are tilted away from the sun so it is winter for us. Thus, in the southern hemisphere the seasons are the reverse of what we experience.

8. **Suppose you lived on the Moon, near the center of the face that we see from the Earth. a) During the phase of full moon, what phase could you see for Earth? Would it be daylight or dark where you live? b) On Earth, we see the Moon rise and set each day. If you lived on the Moon, would you see Earth rise and set? Why or why not? c) What would you see when people on Earth were experiencing either a solar or a lunar eclipse?**

   a)During the phase of full moon, the Earth is in a "new Earth" phase, ie you see the dark side of the Earth. Where you live on the Moon, it will be daylight. b) Since the Moon spin synchronously with its orbit around the Earth, the position of the Earth in the sky as viewed on the Moon is fixed. On the face closer to the Earth, the Earth will always be in the same position in the sky. On the other side of the Moon, you cannot see the Earth. c) When people on Earth see a solar eclipse, you (living on the face of the Moon closer to the Earth) will see a full Earth with a small dark spot moving across it. When people on Earth see lunar eclipse, you (living on the face of the Moon closer to the Earth) will see a total eclipse of the Sun by the Earth.