# PHY 150 - Astronomy
# Homework Assignment #2
# September 25, 2007

1) What is meant by the frequency of light? How is frequency related to wavelength?

Light is a traveling transverse wave in which the electric field can be written as $E(x,t) = E_o \sin\left(2\pi\frac{x}{\lambda} - 2\pi ft\right)$. Frequency f is the number of wave crests that pass a fixed location x per second. Wavelength $\lambda$ is the distance between crests at a fixed instant.

2) At what configuration (for example, superior conjunction, greatest eastern elongation, etc.) would it be best to observe Mercury or Venus with an Earth-based telescope. At what configuration would it be best to observe Mars, Jupiter, or Saturn? Explain your answers.

The inferior planets, Mercury and Venus, are inside the orbit of the Earth, therefore, they never appear beyond some maximum angular separation from the sun. Most of the time they are obscured by the sun itself; thus, to best observe them they should be at their greatest eastern or western elongation just after the sun sets or before the sun rises. At these points they will only appear to be partially lit, but at least they will be in the night sky.

The superior planets, Mars, Jupiter, and Saturn, are outside the orbit of the Earth; therefore, they can appear fully illuminated at their opposition to the sun. Best observation would be in the middle of the night.

3) What is your weight in pounds and in Newtons? What is your mass in kilograms?

If W is your weight in pounds, then your weight in Newtons is given by $W(\text{lb})\ \text{x}\ \frac{1\ \text{N}}{0.225\ \text{lb}}$. For a person weighing 200 lb the weight corresponds to 889 N. Your mass in kilograms is your weight in Newtons divided by the acceleration due to gravity, g = 9.8 $\frac{\text{m}}{\text{s}^2}$. Thus, the 200 lb person has a mass of 90.7 kg.

4) One trajectory that can be used to send spacecraft from the Earth to Venus is an elliptical orbit that has the Sun at one focus, its aphelion at the Earth and its perihelion at Venus. The spacecraft is launched from Earth and coasts along this ellipse until it reaches Venus, when a rocket is fired either to put the spacecraft into orbit around Venus or to cause it to land on Venus.
   (A) Find the semimajor axis of the ellipse. (Hint: Draw a picture showing the Sun and the orbits of the Earth, Venus, and the spacecraft. Treat the orbits of the Earth and Venus as circles.)
   (B) Calculate how long (in days) such a one-way trip to Venus would take.

(A) If the aphelion of the ellipse is the Earth and the perihelion is Venus then the Earth and Venus are on opposite sides of the Sun. Their distance apart is the distance between Earth and the Sun added to the distance between Venus and the Sun. At the same time, from an inspection of an ellipse (Fig 4-11), this distance must be twice the semi-major axis. From Table 4.3

$$2a = 1.00\ \text{AU} + 0.72\ \text{AU} = 1.72\ \text{AU}$$
$$\Rightarrow\ a = 0.86\ \text{AU}$$

(B) Kepler's 3rd Law says that $T^2 = a^3$ when T is measured in years, a in AU. Substituting a into this equation we find that T $\cong$ .8 years. Half the trip is .4 years or 146 days.

5) What are Kepler's three laws? Why are they important?

Kepler's first law says that all objects in the solar system orbit the sun in an elliptical path with the Sun at one focus. While not particularly important for the planets which have roughly circular orbits, elliptical paths explain the orbits of comets and other objects such as Pluto.

Kepler's Second Law says that all objects sweep out equal areas in equal time intervals. While not particularly important for the planets which have roughly circular orbits, orbits of comets are generally ellipses with large eccentricities. They spend much of there orbital time far away from the sun moving slowly and very little of their time near the sun where they are moving rapidly.

Kepler's Third Law, the Law of Periods or Law of Harmonics, says that the period or an object squared is proportional to the cube of the semimajor axis of the object. Using this law one can show that the planets move more slowly the further away from the Sun they are.

6) The bright star Aldebaran in the constellation Taurus (the Bull) has a surface temperature of 3850 K. What is its wavelength of maximum emission in nanometer? What color is this star?

The relationship between temperature and maximum emission wavelength is known as Wien's Law and

$$\lambda_{max} = \frac{.0029}{T} \text{ meters} = \frac{.0029}{3850} \text{ m} = 7.53 \text{ x } 10^{-7} \text{ m}$$
$$= 753 \text{ nm} = 7530 \text{ angstroms}$$

The star looks reddish.

7) What is the temperature of the Sun's surface in degrees Fahrenheit?

$T_{sun}$ = 5800 K
$T_F = (9/5)T_C + 32$
$T_C$ = T - 273 = 5800 - 273 = 5527 ºC
$T_F$ = (9/5)5527 + 32 = 9981 ºF

8) The bright star Deneb in the constellation Cygnus (the Swan) has a surface temperature of 8700 K. How much more energy is emitted each second from each square meter of Deneb's surface than from each square meter of the Sun's surface?

The relationship between energy density and temperature is known as Stefan's Law, $F = \sigma T^4$, where $\sigma$ = 5.67 $W/m^2K^4$. Thus, $F_\odot = \sigma (8700)^4$. We can find Deneb's energy density by taking ratios, i.e.

$$\frac{F_{Altair}}{F_{Sun}} = \frac{\sigma (8700)^4}{\sigma (5800)^4} = (1.5)^4 = 5.06 \text{ times brighter}$$

9) You are given a traffic ticket for going through a red light (wavelength 700 nm). You tell the police officer that because you were approaching the light, the Doppler effect caused a blueshift that made the light appear green (wavelength 500 nm). How fast would you have had to be going for this to be true? Would the speeding ticket be justified? Explain.

This says that the change in wavelength is $\Delta\lambda = \lambda_{green} - \lambda_{red} = -200\,\text{nm}$, where the negative sign says that you are approaching the source of red light. The Doppler shift formula says that you would have to be approaching the red light at a velocity

$$v = \frac{\Delta\lambda}{\lambda} c = \frac{(-200\text{ nm})}{(700\text{ nm})}\left(3\text{ x}10^{8}\ \frac{\text{m}}{\text{s}}\right) = -8.6\text{ x}10^{7}\ \frac{\text{m}}{\text{s}}$$

This seems a little unreasonable since it is close to the speed of light. In any case you should be getting a ticket!

10) Starry Night project

(A) You should easily be able to see four satellites circling Jupiter.
(B) The closest is Io, followed by Europa, Ganymede, and Callisto. Io orbits the fastest and Callisto the slowest.
(C) If we believe most of the objects in our solar system are formed in or around the ecliptic, then it should come as no surprise that the moons of Jupiter are also in the ecliptic. Thus, when they rotate about Jupiter they can be eclipsed by Jupiter in our line of sight.