Lesson 1 - Charting the Heavens

READING ASSIGNMENT

- Chapter 1.1: Our Place in Space
- Chapter 1.2: Scientific Theory and the Scientific Method
- Chapter 1.3: The "Obvious" View
  - More Precisely 1-1: Angular Measure
- Chapter 1.4: Earth's Orbital Motion
- Chapter 1.5: The Motion of the Moon

MATH NOTES

Units

Standard Prefixes

- nano (or n) = 0.000000001 (or 10^{-9})
- micro (or μ — Greek letter "mu") = 0.000001 (or 10^{-6})
- milli (or m) = 0.001 (or 10^{-3})
- centi (or c) = 0.01 (or 10^{-2})
- kilo (or k) = 1,000 (or 10^{3})
- mega (or M) = 1,000,000 (or 10^{6})
- giga (or G) = 1,000,000,000 (or 10^{9})

Standard units and conversions

- Length: meters (or m)
  - Example: 1 centimeter (or cm) = 0.01 meters (or 10^{-2}m)
  - Note: Micrometers (or μm) are also called microns.
- Mass: grams (or g)
  - Example: 1 kilogram (or kg) = 1,000 grams (or 10^{3} g)
- Time: seconds (or sec or s)
  - 1 year (or yr) = 365.24 days (or dy)
  - 1 day = 24 hours (or hr)
  - 1 hour = 60 minutes (or min)

  - 1 minute = 60 seconds

- Angle: degrees (or deg or $^\circ$)
  - 1 degree = 60 arcminutes (or arcmin or $'$)
  - 1 arcminute = 60 arcseconds (or arcsec or $''$)
  - 360 degrees = 2π radians (or rad)

Unit conversion

- Example: How many nm in 1 km?
  - Long answer: 1 km
    $= 1 \text{ km} \times 1 \times 1$
    $= 1 \text{ km} \times (10^3 \text{ m} / 1 \text{ km}) \times (10^9 \text{ nm} / 1 \text{ m})$
    $= 1 \cancel{\text{km}} \times (10^3 \cancel{\text{m}} / 1 \cancel{\text{km}}) \times (10^9 \text{ nm} / 1 \cancel{\text{m}})$
    $= 1 \times 10^3 \times 10^9 \text{ nm} = 10^{12} \text{ nm}$
  - Short answer: 1 km
    $= 1 \text{ km} \times (10^3 \text{ m} / 1 \text{ km}) \times (10^9 \text{ nm}) / 1 \text{ m})$
    $= 10^{12} \text{ nm}$

- Example: How many sec in 1 yr?
  - Long answer: 1 yr
    $= 1 \text{ yr} \times 1 \times 1 \times 1 \times 1$
    $= 1 \text{ yr} \times (365.24 \text{ dy} / 1 \text{ yr}) \times (24 \text{ hr} / 1 \text{ dy}) \times (60 \text{ min} / 1 \text{ hr}) \times (60 \text{ sec} / 1 \text{ min})$
    $= 1 \cancel{\text{yr}} \times (365.24 \cancel{\text{dy}} / 1 \cancel{\text{yr}}) \times (24 \cancel{\text{hr}} / 1 \cancel{\text{dy}}) \times (60 \cancel{\text{min}} / 1 \cancel{\text{hr}}) \times (60 \text{ sec} / 1 \cancel{\text{min}})$
    $= 1 \times 365.24 \times 24 \times 60 \times 60 \text{ sec} = 31,556,736 \text{ sec}$
  - Short answer: 1 yr
    $= 1 \text{ yr} \times (365.24 \text{ dy} / 1 \text{ yr}) \times (24 \text{ hr} / 1 \text{ dy}) \times (60 \text{ min} / 1 \text{ hr}) \times (60 \text{ sec} / 1 \text{ min})$
    $= 31{,}556{,}736 \text{ sec}$
  - Note: 31,556,736 happens to be approximately $\pi \times 10^7$, which is how I remember approximately how many seconds are in a year.

- Example: How many arcsec in 1 deg?
  - Long answer: 1 deg
    $= 1 \text{ deg} \times 1 \times 1$
    $= 1 \text{ deg} \times (60 \text{ arcmin} / 1 \text{ deg}) \times (60 \text{ arcsec} / 1 \text{ arcmin})$
    $= 1 \cancel{\text{deg}} \times (60 \cancel{\text{arcmin}} / 1 \cancel{\text{deg}}) \times (60 \text{ arcsec} / 1 \cancel{\text{arcmin}})$
    $= 1 \times 60 \times 60 \text{ arcsec}$
    $= 3,600 \text{ arcsec}$
  - Short answer: 1 deg
    $= 1 \text{ deg} \times (60 \text{ arcmin} / 1 \text{ deg}) \times (60 \text{ arcsec} / 1 \text{ arcmin})$
    $= 3,600 \text{ arcsec}$

Speed of Light (c)

- $c = 3 \times 10^8$ m/s
- $c = 3 \times 10^5$ km/s

Light-Year (ly)

Read Chapter 1.1

- 1 ly is the distance that light travels in 1 yr.

$$\text{distance} = \text{speed} \times \text{time} \tag{1}$$

- 1 ly $= c \times$ 1 yr
  $\approx (3 \times 10^5 \text{ km/s}) \times (\pi \times 10^7 \text{ s})$
  $\approx 10^{13}$ km
  $= 10$ trillion km
- distance to nearest star = 4.3 ly

Earth's Motion

Read Chapter 1.4.

- Earth *rotates* 360° once every *sidereal* day.
- 1 sidereal day = 24 sidereal hours = 23:56 *solar* hours
- 1 solar day = 24 solar hours
- Earth *revolves* 360° around the sun once every 365.24 days. This is called a *tropical* year.
- Earth's rotation axis *precesses* 360° once every 26,000 years.

The Moon's Motion

Read Chapter 1.5.

- The moon revolves 360° around Earth once every 27.3 days. This is called a *sidereal* month.
- Due to tidal locking, the moon also rotates 360° once every 27.3 days, which is why we always see the same side of the moon.
- The moon's phase cycle repeats once every 29.5 days. This is called a *synodic* month.

The Saros Cycle

Read Chapter 1.5.

- Since the *line of nodes regresses*, one *eclipse* year is only ≈ 346 days.
- 19 eclipse years happen to be ≈ 223 synodic months, or ≈ 6585 1/3 days.
- Consequently, the same cycle of eclipses, called the Saros cycle, repeats itself every ≈ 6585 1/3 days (which is just over 18 tropical years).
- Because of the extra $\approx 1/3$ day, Earth rotates an additional $\approx 360^\circ/3 = 120^\circ$ and consequently the eclipses do not reoccur at the same longitudes compared to the last cycle
- However, after three cycles Earth rotates an additional $\approx 360^\circ$ and consequently the eclipses do reoccur at approximately the same longitudes (and latitudes) compared to three cycles ago.

EXERCISE 1

On a clear night, look at the constellations, or patterns of stars, in the northern and southern skies. Make careful sketches to help you remember their locations with respect to the horizon. Check back a few hours later (the longer you wait, the better). How have the constellations in the northern sky moved? How have the constellations in the southern sky moved?

EXERCISE 2

Keep track of roughly how high the sun is in the sky around midday as the semester progresses. **Do not look directly at the sun!** Also keep track of roughly how long the day is as the semester progresses. (If you are not up for sunrise, keep track of the time from midday until sunset and then double it. Since it will probably take a month or two to notice either of these trends, you need only try this once every week or two.)

EXERCISE 3

Your thumb at arms length subtends about one degree. (There is some variation from person to person, but people with bigger thumbs tend to have longer arms and vice versa, so these differences tend to cancel out.) Using your thumb, measure the angular size of the moon and check and see if the textbook is right.

HOMEWORK 1

Download Homework 1 from WebAssign. Feel free to work on these questions together. Then submit your answers to WebAssign individually. Please do not wait until the last minute to submit your answers and please confirm that WebAssign actually received all of your answers before logging off.

