PHYS 521 Homework 1: Astronomy Basics
Due Tuesday, Sep 10, *in class, or mycourses.*

Show work: equations, definitions, units (not arithmetic!)

NB: Our text, *An Introduction to Modern Astrophysics* (2nd Ed., by Bradley W. Carroll and Dale A. Ostlie), is on reserve at the Schulich Library. To give you time to acquire the text, I have scanned the first two chapters and posted them on MyCourses.

Week #1 Tutorial w/ Han, Magnus: *Python* Basics

Python set up and orientation for new *Python* users, or anyone who would like help with the first few *Python*-based homework problems!

Week #2 Exercises: Mechanics and Special Relativity

1. C&O Problem 2.3
2. C&O Problem 2.6
3. C&O Problem 2.8
4. C&O Problem 2.9
5. C&O Problem 2.10
6. Write out the derivation of the Virial Theorem. You can copy it from C&O Section 2.4, but I want you to OWN this derivation.

Homework Assignment:

1. The star α Centauri, has a parallax of 0.742 arcsec. What is its distance in parsec? If it has same diameter as the Sun ($D \sim 1.4\text{x}10^{11}$ cm) what is its angular diameter in radians and in arcseconds?

2. What is the definition of *Absolute Magnitude*? Derive the distance modulus formula, $m\text{-}M = 5 \log d - 5$ from the inverse square law $f = L / 4 \pi d^2$ and the definition of a magnitude $\Delta m = 2.5 \log$ (flux ratio).
    - Use the notation: luminosity L, apparent flux f, distance d (in parsec), apparent magnitude m, and absolute magnitude M.
    - What is the distance modulus to the center of the Milky Way galaxy?
    - What will be the apparent magnitude of a star like the Sun at the distance of the galactic center?

3. Many of us enjoyed the solar eclipse over North America this spring. Here are a few questions to get you thinking about eclipses more deeply:
    - During which phases of the moon can a Solar eclipse occur?
    - Why isn't there a Solar eclipse every Moon cycle?
    - Using trigonometry, estimate the "size of totality" of a Solar eclipse on Earth, i.e., the stretch of Earth in kilometers that experiences a total Solar eclipse. Start by making a drawing.

Python: If you are not yet a *Python* user, Han, Magnus and I are here to help. There are also numerous online resources to help you get started. Here are a few I like:

- Online textbook, *Python for Astronomers*, written by a couple of folks at Berkeley: https://prappleizer.github.io/index.html

- An online set of tutorials, *Practical Python for Astronomers*: https://python4astronomers.github.io/#

- The *Code Academy* Python course: http://www.codecademy.com/en/tracks/python

Write and run the following python scripts. Be sure to add comment lines, including identifying the relevant formula for the problem and all units. Turn in the scripts, the graphical output, and answers to any questions using **BOTH** hard copy (problem solutions and relevant plots) and MyCourses (plots and code). Code uploaded to MyCourses should run without errors. **NB**: Please DO NOT embed answers to questions in your code.

4. a. Write a python script, *magnitude.py*, that calculates the *flux ratios* for stars with a *magnitude difference* Δm of 1, 2, 3, 4, 5, 6, 10, 20, 30 mags. Present the results graphically. (Check out section 3.3 of *Python for Astronomers* if you aren't sure where to start!)

   b. The faintest stars we can observe with our 16-inch telescope are about V=16, while for the recorded with the Hubble Space Telescope its about V= 30. What is the brightness ratio?

5. The star Vega is the prime photometric standard in many astronomical filter systems. In the ***Johnson*** system, U B V R I J H K L M, Vega is (almost) zero magnitude at all wavelengths. The conversion from apparent magnitude in each filter to monochromatic flux density can be found at: https://irsa.ipac.caltech.edu/data/SPITZER/docs/dataanalysistools/tools/pet/magtojy/

   a. Run the conversion routine for each of the 10 Johnson filters at magnitude = 0, and record
      - $\mathbf{F_\lambda}$ in in Wm^{-2} $micron^{-1}$
      - $\boldsymbol{\lambda_c}$ central (effective) wavelength in micron.

   b. Write a plotting script in python with an array for magnitude, $\mathbf{F_\lambda}$ and $\boldsymbol{\lambda_c}$. Make two plots on one page. (You can stay in these units or convert to nm with 1000 nm = 1 micron).
      - The magnitude of each filter UBVRIJHK versus wavelength
      - Monochromatic Flux density at each filter versus wavelength

6. When planning an observing session you have to think of when the object you want to study will be visible from the site of the observatory you are using.
   a. To get you thinking about celestial coordinates: imagine you are the navigator on a ship without modern technology and you happen to know

that the declination of Rigel (one of the stars is Orion) is -8.2 degrees. How do you figure out the latitude you are sailing on?

b. Catalogs of astronomical objects typically list their right ascension and declination. Using the astropy library, write a function that takes the right ascension and declination of an object as input and plots the visibility of that object as a function of time (think of what coordinate determines the visibility of an object at any given time), for a given place on Earth (see http://docs.astropy.org/en/stable/coordinates/index.html to learn how you can use astropy to convert coordinates). Use the function to plot the visibility of the Triangulum Galaxy (M33) from Montréal on the night of September 13, 2024. You'll receive full marks for a correct plot of altitude vs. time.