UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Physical Astronomy (ASTR 391) — Prof. Crossfield — Spring 2020

Problem Set 2
Due: Wednesday, February 5, 2019, in class
This problem set is worth **75 points**.

As always, be sure to: show your work, circle your final answer, and use the appropriate number of significant figures.

1. **Angles, Distance, and Magnitudes [27 pts].**
   (a) Explain why an ordinary lightbulb can appear much brighter than a star, even though the lightbulb emits far less light. [3 pts]
   (b) Astronomers have measured the parallax to the stars Polaris and γ Vel to be about 7.5 mas (milli-arcsec) and 2.9 mas, respectively. Calculate the distance to each star. [2 pts]
   (c) In the old (pre-*Gaia*) Hipparcos astrometric catalog, the uncertainty on measured parallax was about $\pm$0.5 mas; what distance uncertainty does this translate into for Polaris and γ Vel? [4 pts]
   (d) You observe a binary star system (two stars orbiting each other) and infer that the stars are separated by 100 au and are 500 pc away. What is the parallax to the binary system? What is the maximum angular separation of the two stars as viewed from Earth? [3 pts]
   (e) For the same binary, how much brighter does one of the stars look when viewed from the other star as compared to when it's viewed from Earth (in both magnitudes and as a ratio)? [3 pts]
   (f) Describe how you might estimate the distance to a star whose parallax is too small to measure. [6 pts]
   (g) Explain why most of the stars you can see with your own eyes in the night sky are giants and supergiants (10s to 100s of $R\odot$), even though these stars account for only $\sim$1% of all stars (most stars are $< 1R_\odot$). [6 pts]

2. **Stars - classification & spectral types [15 pts].** Consider two stars with different magnitudes in the B and R photometric bandpasses. Star one has $B - R = 1.2$ mag and star two has $B - R = 0.0$ mag (here B and R are shorthand for apparent magnitudes m_B and m_R).
   (a) Which star is hotter and which cooler? Explain. If one can't tell from the information given, describe what additional information you would need. [5 pts]
   (b) Which star is (intrinsically) brighter and which fainter? Explain. If one can't tell from the information given, describe what additional information you would need. [5 pts]
   (c) Which star is more massive and which less? Explain. If one can't tell from the information given, describe what additional information you would need. [5 pts]

3. **Energy - gravitational vs. nuclear [17 pts].**
   (a) Estimate the gravitational binding energy of the Sun. [3 pts]
   (b) Estimate the total energy available in the Sun for nuclear fusion. [3 pts]
   (c) How long would each of these energy sources sustain the Sun's current luminosity? Comment on whether these seem like plausible lifetimes for the Sun. [5 pts]
   (d) Now consider a small, cool, low-mass M dwarf (the most common type of star) with $R_* = 0.1R_\odot$, $M_* = 0.1M_\odot$, $T_{\rm eff} = 3000$ K. Estimate the size of both energy reservoirs compared to the Sun's, and estimate the corresponding timescales for this red dwarf. [6 pts]

4. **Order-of-Magnitude Estimation [12 pts].**

(a) You observe a giant star that is twice the size of the Sun but has the same effective temperature. What is the star's luminosity in $L_\odot$?

(b) You observe a star that is half the size of the Sun but just 2% as luminous. What is the star's approximate $T_{\rm eff}$?

(c) You observe a hot star that is just as luminous as the Sun but $10\times$ hotter. What is the star's approximate size in $R_\odot$ and in $R_\oplus$?

(d) What are the approximate stellar type and luminosity class for these three stars?

5. **Devise your own mnemonic for remembering the stellar spectral sequence.** [1/2 pt per spectral type]