UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Physical Astronomy (ASTR 391) — Prof. Crossfield — Spring 2024

Problem Set 1
Due: Wednesday, Jan 31, 2024, at the start of class (1100 Kansas Time)
This problem set is worth **36 points**.

1. **Astronomical Concepts [20 pts].**

   (a) In a galaxy far, far away, the gas giant Endor orbits a Sun-like star at a distance of a_E. Endor (mass m_E) is orbited by a Forest Moon (m_m) with the same separation as found in the Earth-Moon system ($a_{☽}$). What is the ratio (an algebraic expression, not just a number!) of the gravitational forces (i) between Endor and its star (mass m_*) and (ii) between Endor and its moon? Estimate which Force is stronger. [6 pts]

   (b) You have invented a matter-antimatter reactor that converts physical material (matter) into energy with 100% efficiency. Congratulations, Zefram: you're a shoo-in for the Nobel Prize. (i) If you put 1 kg of matter (and an equal amount of antimatter) in your reactor, approximately how much energy ($E_{\rm reactor}$) is released when the mass is converted directly into energy? (ii) If the reactor takes 2 s to use that fuel, what was its approximate power output, in Watts and in Solar Luminosities ($L_\odot$)? (iii) How does $E_{\rm reactor}$ compare to the total amount of energy used on Earth in a year? [7 pts]

   (c) Write the astronomer's version of the Ideal Gas Law. Explain each term (including its physical units), and how it might be used [7 pts].

2. **Order-of-Magnitude Estimation [16 pts].** Strive to do as many of these calculations in your head (or with pencil and paper) as possible, aside from looking up any necessary physical constants.

   (a) **City on a Hill [5 pts.]** Roughly estimate the mass of Mount Oread, in kg and in $M_\oplus$ (Earth masses).

   (b) **How Big? [5 pts]**. The French revolutionaries of the late 18th century defined the meter by setting the Earth's equator-to-pole distance to be 10,000 km. Estimate the radius ($R_\oplus$), volume ($V_\oplus$), and mass ($M_\oplus$) of the Earth, in SI units.

   (c) **How Big?! [3 pts]** Jupiter is roughly $10\times$ larger (in physical size) than the Earth (i.e., $R_{Jup} \approx 10 R_\oplus$), and the Sun is roughly $10\times$ larger than Jupiter ($R_\odot \approx 10 R_{Jup}$). Roughly estimate the volume of both of these objects, *relative to the volume of the Earth* (i.e., in units of $V_\oplus$).

   (d) **In an Age Before Spotify... [3 pts].** Pick your favorite over-the-air radio station. What is the frequency at which it broadcasts its signals? Estimate the approximate wavelength of the station's radio wave signals.