

UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Physical Astronomy (ASTR 391) — Prof. Crossfield — Fall 2025

Problem Set 1

Due: Wednesday, Sep 3rd at the start of class (1200 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_\oplus). 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_{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_{reactor} compare to the total amount of energy used on Earth in a year? [7 pts]
- (c) Explain how the wavelength, frequency, and energy of a photon are related to each other and to the speed of light, c . [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., $R_{Jup} \approx 10R_\oplus$), and the Sun is roughly $10\times$ larger than Jupiter ($R_\odot \approx 10R_{Jup}$). 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.