ASTR367 - HW3
September 8, 2023, Due September 15, 2023
2 pt for each question part

1. Compute the central pressure of the Sun by rearranging the equation of hydrostatic equilibrium to find an expression for dP/dM_r, the change in pressure with mass.

2. Eddington Luminosity
a. Compute the Eddington Luminosity – the maximum luminosity a star can have before pressure from fusion overcomes gravitational pressure – in terms of the Solar mass and Solar luminosity. Assume that the opacity is entirely due to Thompson scattering and that $\kappa = \frac{\sigma_T}{m_p}$ where σ_T is the Thompson cross-section and m_p the proton mass.
b. Stellar mass and luminosity are related via the mass-luminosity relationship:

$$L = M^{3.5} \, ,$$

where L is the luminosity in Solar luminosity units and M is the mass in Solar masses. Using the mass-luminosity relationship, what mass does the Eddington luminosity correspond to?

3. Energy Generation
a. Using equations from your book, calculate the temperature at which the energy generation rates of the P-P chain and CNO cycles are equal.
b. What are the CNO and P-P chain energy generation rates for the Sun? Use $T = 1.58 \times 10^7$ K, $\rho = 162 \, \mathrm{g \, cm^{-3}}$, $X = 0.34$, and $X_{\mathrm{CNO}} = 0.013$.

4. Lifetimes
a. At what rate is the Suns mass decreasing due to nuclear reactions? Express your answer in solar masses per year and please state all assumptions.
b. If the Sun is able to utilize 10% of it's fuel, estimate its lifetime.
c. Estimate the lifetime for 85 $M_\odot$ stars (assume they can also use 10% of their hydrogen).
d. Estimate the lifetime for 0.08 $M_\odot$ stars (Assume that the 0.08 M star is entirely convective so that, through convective mixing, all of its hydrogen, rather than just the inner 10%, becomes available for burning.)