

# Astronomy 142 — Recitation # 3

Prof. Douglass

February 14, 2025

## Formulas to remember

### Maximum fusion tunneling probability and tunneling rate

$$P(T) = De^{-(T_0/T)^{1/3}} \quad (1)$$

where  $T_0 = \left(\frac{3}{2}\right)^3 \left(\frac{8\pi q_1 q_2}{h}\right)^2 \frac{m}{k} = 1.565 \times 10^{10}$  K for proton-proton fusion,  $q_1$  and  $q_2$  are the electric charges (in cgs units) of the two fusing nuclei,  $m = \frac{m_1 m_2}{m_1 + m_2}$  is the reduced mass of the two fusing nuclei, and  $D$  is a constant.

### Pulsating stars

Adiabatic speed of sound:

$$v_s = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma k T}{\mu}} \quad (2)$$

$\gamma = 5/3$  for monatomic gases,  $7/5$  for diatomic gases at room temperature.

## Workshop problems

**Remember!** The workshop problems you will do in groups in Recitation are a crucial part of the process of building up your command of the concepts important in ASTR 142 and subsequent courses. Do not, therefore, do your work on scratch paper and discard it. Better for each of you to keep your own account of each problem in some sort of bound notebook.

1. Consider two protons ( $q = 4.8 \times 10^{-10}$  esu,  $m = 1.67 \times 10^{-24}$  g), separated by  $10^{-13}$  cm.
  - (a) Calculate the magnitude of the proton's electric repulsive force and gravitational attractive force. Can gravity hold the protons together?
  - (b) Calculate the electrostatic and gravitational potential energies. Compare these to the binding energy of the deuteron, 2.2 MeV ( $3.55 \times 10^{-6}$  erg). This binding energy is the opposite of the strong-interaction potential energy, and its relatively large value indicates the predominance of the strong interaction on nuclear size scales.
2. Assume that the Sun was initially composed of 70% hydrogen by mass.
  - (a) How many hydrogen nuclei,  $N$ , were there?
  - (b) What is the total nuclear energy supply,  $\frac{NE}{4}$ , where  $E = 0.03m_p c^2$ , if all of the hydrogen could be fused into helium?
  - (c) It turns out that only about 13% of the hydrogen in a solar-type star lies within the parts of the star hot enough to participate in fusion during the star's stay on the main sequence. Under these assumptions, what will the Sun's main sequence lifetime be?

3. The flux of pp-chain electron neutrinos from the Sun has been measured to be about half the flux that is expected at the temperature inferred for the Sun's center,  $T_{c\odot} = 1.57 \times 10^7$  K. (This is the deficit to which we used to refer as the "Solar neutrino problem.")
  - (a) What would the Sun's central temperature have to be in order to produce pp-chain electron neutrinos at half the rate that applies to  $1.57 \times 10^7$  K?
  - (b) Briefly review the means by which we inferred the Sun's central temperature. By how much would the accepted values of other measurable properties of the Sun need to be in error for the temperature to be off by this much? Is it likely that such differences lie within present observational uncertainties?

**Learn your way around the sky** (A feature *exclusive* of ASTR 142 recitations.) You may find the lab's celestial globes and the program Stellarium useful in answering these questions about the celestial sphere and the constellations.

4. Match the celestial object to the constellation to which it belongs.

Objects	Constellations
Brightest star in the sky	Andromeda
Most massive, luminous star visible to the naked eye	Ara
Nearest region of star formation	Canis Major
Nearest region of massive (O–B) star formation	Centaurus
Nearest open stellar cluster	Dorado
Nearest globular stellar cluster	Ophiuchus
Center of the Milky Way Galaxy	Orion
Nearest spiral galaxy to the Milk Way	Sagittarius
Nearest active galaxy (supermassive black hole, relativistic jets)	Taurus
Nearest rich cluster of galaxies	Virgo

**Intro to Python** (A feature *exclusive* of ASTR 142 recitations.)

5. Make a graph of the electrical potential energy between two protons as a function of their separation,  $r$ . Let  $r$  range from the size of a nucleus to ten times that.