

Astro 411
Fall, 2025
Dr. Guidry
Midterm Test

Do all problems. Points for each problem are given in parentheses. You may not work together, you may not get advice from any person except me, and you may not consult any solutions sheets for material in previous years for this class. You may, however, use generative AI like chatGPT or Google Gemini without restriction, except that if you use an AI, you must add a brief paragraph giving an overview of how it was used in working the problems. (You will not be graded on using an AI; this information is to help me understand how students are using AI for learning.)

1. Using the data from the Standard Solar Model in Table 10.1 at a solar radial distance of $R = 0.00650R_{\odot}$, and assuming that ionization of hydrogen in the Sun is purely thermal, what is the fraction of hydrogen ionization at the center of the Sun? In reality, the Sun is 100% ionized in the deep interior. If your result differs from that, explain. (20)
2. Repeat the derivation of the virial theorem in Ch. 4 for a star surrounded by a thin atmosphere so that the pressure at the surface P_0 is not zero. (20)
3. Derive a formula for the buoyancy acceleration a_b of a localized packet of gas with uniform density ρ immersed in a larger volume of the same gas having uniform density ρ' . What is the buoyancy acceleration of a layer of air at a temperature of 30°C if the surrounding air has a temperature of 28°C ? Neglecting complications like changing parameters, friction, ..., how fast and in what direction would this packet of air be moving due to the buoyancy acceleration after 10 minutes if it started from rest? (20)
4. Consider the burning of pure ^{28}Si as illustrated in Fig. 6.10. Using estimates from Figs. 6.9 and D.3 for the relevant rates, to what abundance does the α -particle population have to grow before the rate of α -capture on silicon, $\alpha + ^{28}\text{Si} \rightarrow ^{32}\text{S} + \gamma$, becomes equal to the rate for photodisintegration of silicon, $\gamma + ^{28}\text{Si} \rightarrow \alpha + ^{24}\text{Mg}$, assuming a density of 10^6 g cm^{-3} and temperature of $T_9 = 3$? *Hint:* Simplify by neglecting all reactions except the two listed above that change the ^{28}Si abundance directly. The relevant equations are given in §D.2.3, and note that the rates in Figs. 6.9 and D.3 are in different units. (25)
5. The formalism that we have developed for convection in stars can be applied with suitable modification to the atmosphere of a planet. Assume Mars to have a pure CO_2 atmosphere, a surface temperature $T = 220 \text{ K}$, and a surface atmospheric density $\rho = 0.02 \text{ kg m}^{-3}$. Calculate the gravitational acceleration and atmospheric pressure at the surface, and the scale height of the atmosphere. (15)

Describe briefly how you used AI on this test (indicate “No AI” if you didn’t use AI). This won’t be graded and won’t affect the grading of the problems; it is for my edification concerning how students are using AI.
