November 2008

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Exercise for Solar Physics (2008) - Part 1

Chapter 1: Introduction

How is the Sun related to (1) other fields of science and (2) other stars?
How does the Sun affect planets?

Chapter 2: Core and interior

2.1 Solar model

(A) Calculate the Sun's gravitational energy: the total work required to disperse the solar matter over distances $r \gg r_\odot$ ($G = 6.67 \cdot 10^{-11}\,\mathrm{m^3kg^{-1}s^{-2}}$, use the following solar model). Compare this to the total solar irradiance ($1366\,\mathrm{Wm^{-2}}$ at 1 AU) or to the energy in a solar flare (up to $6 \cdot 10^{25}$ J).

$m/m_\odot$	$r/r_\odot$	$T[K]$
0.000	0.000	1.5×10^7
0.125	0.124	1.2×10^7
0.250	0.170	1.0×10^7
0.375	0.210	8.9×10^6
0.500	0.254	7.7×10^6
0.625	0.306	6.6×10^6
0.750	0.367	5.4×10^6
0.875	0.470	4.2×10^6
1.000	1.000	5.8×10^3

(B) Assuming the Sun to be a perfect monatomic gas (pressure $P = \rho RT/\mu$, $R/\mu = 2C_V/3$, gas constant $R = 8.31\,\mathrm{J/(^\circ K\,mol)}$, μ is the mean molecular weight) in hydrostatic equilibrium, calculate the internal energy. (Hint: derive the virial theorem using integration by parts.) Find the mean mass-weighted temperature for such a gas and compare to that from the tabulated model.

2.2 Nuclear reactions

How does the nuclear energy content of the Sun compare to its gravitational and internal energies? (Assume all protons are converted to $\alpha-$particles via ppI. $1\,\mathrm{eV} = 1.602 \cdot 10^{-19}$ J, Avogadro's Number $N_A = 6.0 \cdot 10^{23}$)