Physics 5150

Homework Set # 3

Due 5 pm Thursday 2/8/2018

Problem 1: Thermonuclear fusion in stars

A 5 billion year old main-sequence star called Sol, belonging to the spectral type G2, has a mass $M_\odot = 2 \times 10^{33}\,\mathrm{g}$ *and a total luminosity* $L_\odot = 4 \times 10^{33}\,\mathrm{erg/s}$. *The star is powered by the pp chain thermonuclear reaction, the net result of which is that 4 protons are turned into a* He^4 *nucleus (an* α*-particle) releasing 26.7 MeV of energy in the process.*

(a) Assuming that the star's parameters have not changed appreciably since it was born, how much hydrogen (by mass) has the star consumed over its lifetime?

(b) In addition to producing helium, each pp chain reaction also produces 2 neutrinos that fly out of the star freely, without interacting with anything (they carry only 2% of the total fusion energy, so the corresponding energy losses can be neglected). How many neutrinos fly each second through a $1\,\mathrm{cm}^2$ *thumbnail of John Bahcall standing on a seashore on a small rocky planet called Terra, 150 mln km from the star?*

Problem 2: Fusion power plant

What is the annual tritium mass consumption of a continuously (24×7) *operating D-T thermonuclear fusion reactor with the total (*α*-particles plus neutrons) fusion power output of 1 GW?*

Problem 3: Tokamak plasma density:

Equilibrium and stability consideration limit the total (electrons + ions) plasma pressure inside a tokamak to be less than about 10% of the pressure of the confining magnetic field. What is the maximum plasma electron density in a tokamak with a magnetic field of 5 Tesla and temperature $T_i = T_e = 10$ *keV?*