Level 2 Stars, Workshop 5

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Getting the Energy Out

a) For the proton-proton chain the typical energy of a photon is ~5 MeV. At the centre of the Sun the core temperature is T~1.57x10^7 K. Compare the energy of the photons produced in the proton-proton chain to the mean energy of photons produced at the core of the Sun from black-body radiation. What do you learn from this comparison?

b) Briefly describe the four dominant sources of opacity in stars. What source of opacity dominates in the atmosphere of the Sun (T~5,800 K)?

c) Calculate the initial intensity (i.e., the undiminished intensity) of the emission from a star with a measured intensity of $I_\lambda = 10^{-15} Wm^{-2}$ which is observed through a column of uniformly distributed material with an opacity of κ=0.030 m^2 kg^{-1}, density of ρ=2.0x10^{-4} kg m^{-3}, and length of s=10^6 m. Is the material optically thin or optically thick?

d) A hypothetical star has the following stellar-core properties: fully ionised hydrogen gas, a radius of r=2.0x10^8 m, a temperature of T=10^7 K, and gas pressure of P=10^{15} N m^{-2}.

   i. What is the dominant form of opacity (κ) in the stellar core? Explain your reasoning.
   ii. Calculate the opacity at the stellar core, assuming that all other forms of opacity are negligible.
   iii. Estimate the time it takes for a photon to escape the core, assuming that the pressure is well characterized by the ideal gas law and that the time taken for the scattering of a photon is 10^{-8} sec. Give your answer in years.

[$m_H = 1.67 \times 10^{-27}$ kg; $e_c = 1.60 \times 10^{-19}$ C; $\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}; $k = 1.38 \times 10^{-23}$ J K^{-1}; $\sigma_T = 6.65 \times 10^{-29}$ m^2; $h = 6.63 \times 10^{-34}$ J s; $c = 3.00 \times 10^8$ m s^{-1}]