Problem set 3

Problem 1

The net reaction in the *pp* cycle is $4p + 2e^- \rightarrow {}^4\mathrm{He}^{++} + 2\nu_e + Q$. Knowing that the binding energy ($\mathcal{B}$) for ^{4}He is 28.3 MeV, show that the Q-value of the reaction (energy produced in the process) is 26.7 MeV.
Given the solar luminosity $L_\odot = 3.828 \times 10^{26}$W and the Earth orbit radius of 150×10^9 m, compute the flux of solar neutrinos on Earth.

Problem 2

Compute the minimum energy ("GZK cutoff") at which a proton interacting with the cosmic microwave background (CMB) at 2.725 K can produce pions in the reaction:

$$p + \gamma_{\mathrm{CMB}} \rightarrow n + \pi^+$$

Problem 3

Assuming a total absorption cross-section of $\sigma \approx 10^{-44}\,\mathrm{cm}^2$ for neutrinos in matter, constant with neutrino energy.

(a) Determine the thickness of a wall of lead ($\rho = 11\,\mathrm{g/cm}^3$) able to reduce the flux of a beam of neutrinos by 50%.

(b) Estimate how many solar neutrinos are absorbed in your body every day, knowing that the flux of solar neutrinos from the *pp* cycle is $6 \times 10^{10}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$.