AST 250 – Spring 2019
Homework Due: Wed. Feb. 13

15.   (a) Most of the Sun's energy comes from the fusion of Hydrogen in the Sun's core via the "p-p chain" of nuclear reactions ("proton-proton chain"). One cycle of the p-p chain of reactions "converts" mass into about 26.2 MeV of net energy that heats the Sun (1 eV = 1.602×10^{-12} erg = 1.602×10^{-19} J). Estimate how many times per second the p-p chain cycle is being completed in the Sun?

(b) The mass of the Eiffel Tower in Paris is about 7300 tons or 6.6×10^9 g. How many Eiffel Towers worth of mass is "converted" into energy every second in the Sun?

(c) Neutrinos are elementary particles that have a really, really tiny cross section for interacting with normal matter (i.e. the probability that a neutrino produced in the core is absorbed as it flies out of the Sun is $\sim 10^{-9}$!). Two neutrinos, $2\nu_e$, are produced for every cycle of the p-p chain. Estimate the particle flux of neutrinos at the distance of the Earth (neutrinos/s/cm^2) and how many are flying through your brain each second.

NEUTRINO FACTORIES

Neutrinos are everywhere, generated by a variety of processes

Fusion of hydrogen nuclei to form helium in the Sun.

Sun

Supernovae

Supernovae and collisions between cosmic rays and air particles in Earth's atmosphere.

Particle accelerators smashing protons into a target and fission from the radioactive decay of elements inside nuclear reactors.

Nuclear fission

© nature

WHERE THEY WILL BE DETECTED

Deep Underground Neutrino Experiment (DUNE), United States
Status: Planned
Cost: US$1 billion
Will make highest-energy neutrinos of any experiment.

Hyper-Kamiokande, Japan
Status: Planned
Cost: About $800 million
Will be the world's largest neutrino detector — it is 25 times bigger than its predecessor, Super-Kamiokande.

Jiangmen Underground Neutrino Observatory (JUNO), China
Status: Construction begun
Cost: $330 million
Sits under 700 metres of rock.

India-based Neutrino Observatory (INO), India
Status: Funding approved
Cost: $233 million
Will be largest experimental basic-science facility in India.