Homework #1

① Copper data: Atomic (molar) mass 63.546 g/mol
Atomic number (number of protons) 29
Avogadro number $6.022 \cdot 10^{23}$ /mol

Number of atoms in 1 kg of copper

$$= \frac{1\ kg}{63.584\ g/mol} \times 6.022 \cdot 10^{23}/mol = 9.476 \cdot 10^{24}$$

For the most common isotope ^{63}Cu there are 29 protons and 34 neutrons in a copper nucleus

a) Total number of neutrons $= 34 \times 9.476 \cdot 10^{24} = 3.22 \cdot 10^{26}$

b) Total number of electrons $= 29 \times 9.476 \cdot 10^{24} = 2.748 \cdot 10^{26}$

c) Total charge of electrons $= 2.748 \cdot 10^{26} \times (-1.6 \cdot 10^{-19}\ C) = -4.39 \cdot 10^{7}\ C$

$-4.39 \cdot 10^{7}\ C$

② $c = 3 \cdot 10^{8}\ m/s$

$$distance = ct = 3 \cdot 10^{8}\ m/s \times 4\ yrs \cdot \frac{365\ day}{yr} \cdot 24 \frac{h}{day} \cdot 3600\ s/h$$

$$= 3.784 \cdot 10^{16}\ m = 3.784 \cdot 10^{13}\ km$$

③ Sun produces $\sim 10^{38}$ neutrinos/s emitted in all directions. → Surface of the sphere with Sun at its center and radius equal to the distance Sun–Mercury ($62.043 \cdot 10^{6}$ km)

$$4\pi r^2 = 4\pi (6.2043 \cdot 10^{10}\ m)^2 = 3.85 \cdot 10^{21}\ m^2$$

Number of neutrinos crossing a surface of 1 m²/s on Mercury

$$N(neutrinos) = 10^{38} \cdot \frac{1\ m^2}{3.85 \cdot 10^{21}\ m^2} = 2.597 \cdot 10^{16}/s$$

④ General info:

mass of the Sun $m_{SUN} = 1.989 \times 10^{39}$ kg

mass of the proton $m_{proton} = 1.67 \times 10^{-27}$ kg

approximate $m_p \approx m_n = m_{baryon}$

number of baryons in the Sun $= \frac{m_{SUN}}{m_{proton}} = 1.19 \times 10^{57}$

diameter of the proton $d = 1.6 \times 10^{-15}$ m

Speculation

In absence of charges and repulsive force all "neutrons" will fall on each other creating a neutron "ball"

For a scenario using approximation of a proton represented by a cube with side equal to proton's diameter, the length of such cube is

$$\sqrt[3]{n_{protons}} \times d = \sqrt[3]{1.19 \cdot 10^{57}} \times 1.6 \cdot 10^{-15} \text{ m} \sim 17 \text{ km}$$

For packing fraction of 0.75, this reduces to ~12.7 km

Note: this speculation ignores Pauli principle and assumes ~~rota~~ random spin orientation for each neutron.

(5) Minimum c.m. energy is equal to the sum of masses of final state particles. The minimum is attained when all particles are at rest in the c.m. reference frame

$$E_{min} = 2m_p + 4m_K + 2m_\pi =$$

$$= 2 \times 938.3 \text{ MeV}/c^2 + 4 \times 493.7 \text{ MeV}/c^2 + 2 \cdot 139.6 \text{ MeV}/c^2$$

$$= 4.131 \text{ GeV}/c^2$$