PH 203 HW9

1. Bertulani 12.2

2. Bertulani 12.3

SP3

A neutron star is a compact, dense object made of degenerate neutrons having a density similar to that in the central part of a heavy nucleus.

(a) If the density of nuclear matter is 0.17 nucleons/fm^3 or 2.8×10^{17} kg/m^3, what is the radius of a neutron star having a mass one and a half times that of the sun? (One solar mass $= 2.0 \times 10^{30}$ kg.)

(b) A neutron star is one of the possible remanents of a supernova explosion such as SN 1987a, the one which took place in the Large Magellanic Cloud 160,000 light years away and was first observed on earth on February 24, 1987. When the core of a large star exhausts its nuclear fuel, there is no longer the thermal pressure to counterbalance the gravitational force, and the core of the star collapses. For simplicity, we can consider that all the material in the core of the collapsing star is in the form of ^{56}Ni made of 28 neutrons and 28 protons. Because of the tremendous gravitational force, the protons in ^{56}Ni change into neutrons by capturing atomic electrons through the reaction

$$p + e^- \rightarrow n + \nu_e$$

Calculate the number of neutrinos released in converting 1.5 solar mass of ^{56}Ni atoms into neutrons during the gravitational collapse.

(c) If the total cross section for a neutrino to interact with each nucleon is 10^{-48} m^2, how many reactions due to the neutrinos from such a gravitational collapse can one expect in a detector on earth made of 3000 tons of water? Compare this with the number of events (12) observed with such a detector at Kamioka due to supernova SN 1987a.

(d) Assuming that the average energy of each neutrino is 10 MeV in such an event, calculate the total amount of energy carried away by the neutrinos from the gravitational collapse. Compare this value with the rest-mass energy of the sun.