PHYS 321: PROBLEM SET 7

Due April 9 @ 02:30 pm

*Solve the problems listed below, and **write up your answers clearly and completely**. Do not turn in rough work – instead, make a clean copy after checking your calculations. Use English sentences and phrases to explain your solution and describe your answers step by step. Even if you did not get the correct answer, you may get partial credits for these steps!*

1. (2 credits) In 1792 the French mathematician Simon-Pierre de Laplace (1749–1827) wrote that a hypothetical star, "of the same density as Earth, and whose diameter would be two hundred and fifty times larger than the Sun, would not, in consequence of its attraction, allow any of its rays to arrive at us." Use Newtonian mechanics to calculate the escape velocity of Laplace's star and verify Laplace's statement. Can such a star actually exist? Why or why not?

2. (4 credits) SN1987A was a type II supernova occurred in the Large Megellanic Cloud on February 24, 1987.
   (a) The neutrino flux from SN 1987A was estimated to be 1.3×10^{14} m^{-2} at the location of Earth. If the average energy per neutrino was approximately 4.2 MeV, estimate the amount of energy released via neutrinos during the supernova explosion. As noted in the textbook, most of the energy released in a supernova goes into neutrinos.
   (b) Using Eq. 10.22 in the textbook, estimate the gravitational binding energy of a neutron star with a mass 1.4 $M_\odot$ and a radius of 10 km. Compare your answer with the amount of energy released in neutrinos during the collapse of the iron core of Sk -69 202 (the progenitor of SN 1987A).

3. (4 credits) Based on the expression of the electron degeneracy pressure (Equation 16.12 in the textbook) and steps led to it,
   (a) Derive the expression for the neutron degeneracy pressure in the non-relativistic regime.
   (b) Estimate the neutron degeneracy pressure at the center of a 1.4 $M_\odot$ neutron star (take the central density to be 1.5×10^{18} kg m^{-3}), and compare this with the estimated pressure at the center of Sirius B (which can be found from Equation 16.1 in the textbook).
   (c) Derive the expression for the radius of a neutrons star (i.e., Equation 16.24 in the textbook).