PHYSICS 313 - Winter/Spring Semester 2017 - ODU

Astrophysics - Problem Set 6 – DUE Thursday, February 23

Please submit your solution using the following format. You can submit it as an email to skuhn@odu.edu anytime before midnight on the day on which the Problem Set is due; in this case, you **must** use an electronic file format (like MS Word, LaTeX, .pdf, Mathematica etc.) or simple text (follow the rules of some programming language like Fortran or C to write mathematical expressions like x**2 for the square of *x* etc.). Alternatively, you can write your solution by hand on paper and turn it in **in class** on the same day (no late submissions); please write clearly and cleanly!

For each problem (part), type the problem number (e.g., "1a." or "2c"), followed by a space, and then your solution. For "yes/no" questions, enter "Y" or "N", for multiple choice questions, enter the correct choices ("1" or "3" or…) without any additional characters, and for numerical questions, quote the result in the form "3.1415" or "3.1415e12". For conceptual questions, just write the text (no special formatting needed). Some problems require mathematical derivations or equations in addition to text or numbers (clearly stated in the problem text). **Only** for those cases may you use a **clean** scanned image of a handwritten derivation, included in your electronic submission (if you choose that route).

IN ALL CASES, make sure that your full name appears on all your submissions to guarantee you get credit for your work! Also, do NOT simply copy someone else's solution (honor code!) – you can ask for help if you get stuck, but you must submit your OWN work. (I will randomly ask questions during class to check whether you understand the solution you submitted.

Problem 1

Please answer the following questions with "Y" or "N":

1a) Do we need Quantum Mechanics to truly understand the final stages of a star's life?
1b) Do we need Special Relativity to understand the stability limit of white dwarfs?
1c) Do we need General Relativity to understand the final fate of the most massive stars?
1d) Do we need Nuclear Physics to understand the life cycle of stars?
1e) Do we need Particle Physics to understand supernovae?
1f) Do we need all of the above to understand proto-stellar clouds?

Problem 2

The following is a set of multiple choice questions. Answer each with one single digit:

2a) Which of the following objects is **not** stabilized through degeneracy/Fermi pressure (a.k.a. the Pauli principle)?

1 – Zero-age main sequence stars
2 – Carbon/Oxygen cores of giant stars
3 – Neutron stars
4 – White dwarfs

2b) Why are white dwarfs beyond a certain mass ("Chandrasekar limit") unstable?
1 – Because nuclear fusion stops when the mass is too high.
2 – Because degeneracy pressure becomes negligibly small at high density
3 – Because electrons become highly relativistic at large Fermi momenta (high density)
4 – Because they emit gravitational waves if they get too massive

Problem 3

(Numerical result only): Calculate the radius of a white dwarf with exactly one solar mass using a simple Fermi-gas model (ignoring relativity). Repeat the calculation with 1.2 times solar mass and show that the new radius is smaller (by how much?).

Note: In equilibrium, we have $R = \frac{\hbar^2 N_{tot}^{5/3}}{m_e G M^2}\left(\frac{9\pi}{4}\right)^{2/3}$

with $p_f = \hbar\left(3\pi^2\right)^{1/3} n^{1/3}; \quad n = \frac{N_{tot}}{V}; \quad N_{tot} = \frac{M_{star}}{1\text{ g}}\frac{N_A}{2}$

Problem 4

(Text only): In your own words, describe how and where the most heavy elements (beyond iron, all the way to uranium) have been (and still are being) produced. 3-4 sentences