13 Oct, 2020 **Ph 136a** E.S. Phinney

Applications of Classical Physics

Problem Set 2

Due **before 1:00pm** Wednesday 21 Oct, 2020

Readings: Reading for this week are Sections 3.1-3.6 of Chapter 3 of Thorne & Blandford *Modern Classical Physics*, hereafter called TBMCP.

Non-Collaboration Problem Notice that problem 2 is a non-collaboration problem: you must solve this problem on your own (as if it were an untimed quiz), without discussing it with other students, or with the TA (see the collaboration and grading policy for how these will be graded and used: http://www.its.caltech.edu/~esp/ph136a/Policies.pdf)

Submitting your homework Please upload your completed homework solutions as a `pdf` file to Canvas. If that fails to work, you may instead email the file to the TA, `twang3@caltech.edu`, with the subject line `ph136 homework 2`. Note that Caltech email will reject attachment sizes larger than 10Mbyte, so be conscious of scanning parameters!

Homework Problems: (50 points total)

1. **TBMCP Problem 3.2 (7 points: 3+4)** *Distribution Function for Particles with a Range of Rest Masses*
2. **TBMCP Problem 3.3 NONCOLLABORATION (8 points: 4+4)** *Regimes of Particulate and Wave-Like Behavior* [hint: do NOT forget the solid angle factor!]
3. **TBMCP Problem 3.7 (10 points: 4+2+4)** *Observations of Cosmic Microwave Radiation from Earth*
4. **TBMCP Problem 3.10 (10 points 8 (textbook problem)+1+1 (two parts below))** *Equation of State for Relativistic, Electron-Degenerate Hydrogen*
   a) Actual white dwarfs are not made of hydrogen (which would undergo fusion), but of helium 4, carbon 12, or magnesium 24. *Show that for any of those elements, equation 3.53a should be replaced by* $\rho \simeq 2m_p n_e$.
   b) It is found that at densities above $\rho_{nt} = 3 \times 10^9 \text{g cm}^{-3}$ (reached near the center of $> 1.410 M_\odot$ cold white dwarfs) $^{24}_{12}\text{Mg}$ undergoes electron capture: $^{24}_{12}\text{Mg} + e^- \rightarrow {}^{24}_{11}\text{Na} + \nu_e$ (followed by another electron capture to $^{24}_{10}\text{Ne}$). At this density ρ_{nt}, what is the electron Fermi energy above rest mass, $E_F = \mathcal{E}_F - m_e c^2$, in MeV? Beware: equations 3.50–3.52 all assume the speed of light $c = 1$, as commonly done by Relativists. To restore c and make the equations dimensionally correct replace p_F/m_e in 3.52b and the integrands of 3.52c and 3.52d by $p_F/(m_e c)$, and replace m_e by $m_e c$ on its last appearance on the right side of 3.52a, and by $m_e c^2$ in equation 3.50, the first two appearances of m_e in equation 3.52a, and by in the numerators of the fractions in 3.52d.)
5. Do ONE of the following two problems (whichever is more interesting to you):
   a) **TBMCP Problem 3.12 (15 points: 2+3+3+2+5)** *Specific Heat for Phonons in an Isotropic Solid* (note for part c: in actual solids, longitudinal and transverse waves do not have the same speed, but you may ignore this complication to simplify the problem).
   b) **TBMCP Problem 3.15 (15 points: 3+3+3+3+3)** *Solar Heating of the Earth: The Greenhouse Effect*