PHYSICS 313 - Winter/Spring Semester 2017 - ODU

Astrophysics - Problem Set 4 – DUE Thursday, February 9

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) The radiation pressure in an isotropic "photon gas" is 1/3 of its energy density. True?

1b) The (ordinary) pressure in an ideal gas is also 1/3 of its energy density. True?

1c) The larger the opacity, the longer the mean free path for photons. True?

1d) An optical depth of $\tau=1$ along some direction means that a photon going in that direction has a $1/e$ chance to escape unscathed. True?

1e) Sun glasses with strong UV protection tend to have a larger optical depth for $\lambda < 400$ nm than for $\lambda = 600$ nm. True?

1f) If a photon reaches the surface of the sun from an optical depth of $\tau=100$ in the sun's outer layers, its total travel path length will be equal to the straight-line distance from the depth it started at to the surface. True?

1g) Does pressure always have to increase as you go deeper into a star (i.e. with decreasing distance from its center)?

1h) Is there any other mechanism of energy transport in a star than radiation?

1i) The optical depth of some layer of material **only** depends on its opacity. True?

Problem 2

Answer the following questions with (brief) derivations and final numerical results.

Note: Use the fact that one Hydrogen atom has an atomic weight of roughly 1, meaning 1 g per mol or 1 kg per 1000 mol = $6\cdot10^{26}$ atoms. Using the mass of the sun, I find that it contains roughly $1.2\cdot10^{57}$ H atoms.

2a) Assume sun was powered by chemical instead of nuclear reactions. To simplify the calculations, assume that sun is made entirely of hydrogen atoms, and each atom undergoes a chemical reaction liberating 1 eV per atom. How long would sun be able to shine at its present luminosity under these assumptions?

2b) How would you answer change if the reaction is instead fusion into helium, with a total energy released pro hydrogen atom of 6.7 MeV? (Still assume ALL of the sun starts out as hydrogen and all of it gets converted to helium).

2c) Using the luminosity, mass and surface temperature of stars at either end of the main sequence, calculate their radii and their average densities as multiples of those of the sun. [Low-mass end: $M = 0.07\ M_{sun}$, $L = 5\cdot10^{-4}\ L_{sun}$, $T = 1700$ K
High-mass end: $M = 100\ M_{sun}$, $L = 10^{6}\ L_{sun}$, $T = 53{,}000$ K; $T_{sun} = 5800$ K]

Problem 3

Assume a star is surrounded by a thin, very low-density (dilute) spherical shell of gas (with a radius significantly larger than the star's), which it heats up to some high temperature. Under certain conditions, observers on Earth see this sphere as a shining ring surrounding the star (see photo). Using what you have learned about optical depth, opacity and radiation transport, how can you explain this?
(3-5 sentences)