

# PHYSICS 313 - Winter/Spring Semester 2017 - ODU

## **Astrophysics - Problem Set 5 – DUE Thursday, February 16**

Please submit your solution using the following format. You can submit it as an email to [skuhn@odu.edu](mailto: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 mark each of the following statements with “Y” or “T” if it is correct, and with “N” or “F” otherwise:

- 1a) A protostellar cloud produces its luminosity by nuclear helium burning.
- 1b) Planetary nebulae are the early stages of star evolution
- 1c) Initially, a protostar’s luminosity is due to gravitational potential energy being converted to heat
- 1d) A massive protostar takes a longer time to reach the main sequence than a less massive one.
- 1e) Once on the main sequence, a massive star spends much less time there than a less massive one.
- 1f) Stars much lighter than sun will become supernovae eventually.
- 1g) Red giants are what sun-like stars become after hydrogen burning has stopped in their core.
- 1h) Without the “convenient” (Hoyle) resonance in Carbon-12 we would not exist.
- 1i) **All** heavier elements are produced in red giants (with mass comparable to that of the sun).

**Problem 2**

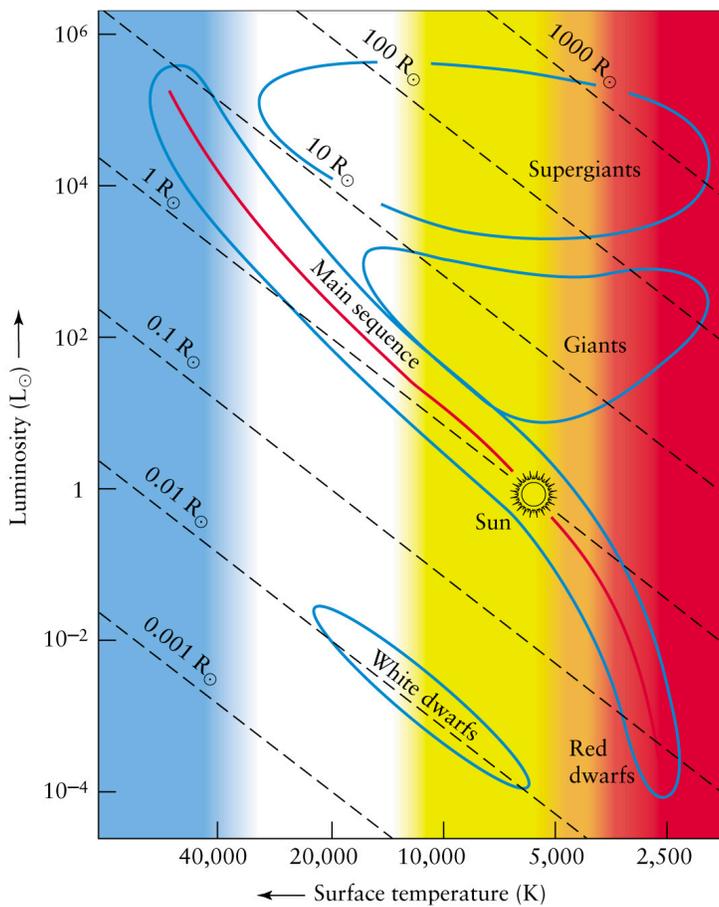
Answer the following questions with (brief) derivations and final numerical results:

- 2a) How much brighter would the sun have to shine (by what factor would its luminosity have to increase) before it would exceed the Eddington luminosity limit,

$$L_{\max} = \frac{4\pi GMc}{\bar{\kappa}} \quad ? \quad \text{Assume that the average opacity is } \bar{\kappa} = \frac{0.03}{\text{kg/m}^2} .$$

- 2b) The nuclear fusion reaction called “hydrogen burning” converts 0.68% of the mass of the initial hydrogen into energy (the rest remains in the form of helium-4 mass). Assuming sun has done this with its present luminosity,  $L_{\text{sun}} = 3.84 \cdot 10^{26}$  W, for the last 4.5 billion years, how much mass has it lost overall? Compare to the mass of Earth ( $6 \cdot 10^{24}$  kg)!
- 2c) Continuing with the discussion in 2b), which fraction of its initial hydrogen inventory (assume 73% of its total mass of  $M_{\text{sun}} = 1.989 \cdot 10^{30}$  kg) has Sun already converted to Helium?

**Problem 3**



This figure shows the present location of Sun on the H-R diagram. In your own words (and using the information from lecture), explain where Sun started out, how it moved to its present position, and what it is going to do in the future, including its end stage. Indicate size, temperature, luminosity and predominant mode of energy production at each stage. Provide sufficient detail – at least 5 different stages with at least a sentence or two each!