

# PHYSICS 313 - Winter/Spring Semester 20176 - ODU

## **Astrophysics - Problem Set 2 – DUE Thursday, January 26**

### *GENERAL INSTRUCTIONS:*

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 answer the following questions with “Y” or “N”:

- 1a) Do we need Quantum Mechanics to truly understand the light spectra emitted by stars?
- 1b) The Wien displacement law states that there is a cutoff frequency (above which no electromagnetic radiation can be emitted), depending on the temperature of a body. True?
- 1c) Two different transitions to the ground state of some atom yield light of 121.6 nm and 102.6 nm wave length. Should there (in principle) also be light emitted by this atom with a wave length of  $(1/102.6 - 1/121.6)^{-1}$  nm = 656 nm?
- 1d) The dark lines observed in the light spectrum emitted from stars are unrelated to the bright lines observed in discharge lamps filled with a gaseous element. True?
- 1e) A perfect blackbody radiator does not have any dark lines in its light spectrum. True?
- 1f) The line spectrum emitted from a discharge lamp is due to the atomic electrons spiraling into the atomic nuclei, continuously losing energy. True?

### **Problem 2**

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

- 2a) Which of the following properties determines the details of the light spectrum of a star?
  - 1 – Its core temperature (at its center)
  - 2 – Its size

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- 3 – Its mass
- 4 – Its surface temperature and chemical composition

2b) Which of the following equations is NOT relevant to the question: “At which wave lengths does a given element (e.g., hydrogen) emit light?”

- 1 –  $E = mc^2$
- 2 –  $E = hf$ .
- 3 –  $c = f\lambda$
- 4 –  $\mathbf{H}\psi = E\psi$ .

### **Problem 3**

Assume the sun’s photosphere has a temperature of 5800 K. Answer the following questions just with numerical results (including units where appropriate); you may write down intermediate results for partial credit:

- 3a) What would be the “apparent red magnitude”,  $m_{\text{red}}$ , of sun if watched through a red filter that only allows light with wave lengths between 650 nm and 660 nm to pass?  
(*Hint*: Use the ratio of the intensity within this wave length range according to the Planck blackbody radiation formula = second to last equation below, and compare to the total intensity according to the Stephan-Boltzmann law = last equation below. Don’t confuse the Stefan-Boltzmann constant  $\sigma$  with the Thompson cross section! Since the brightness  $F$  as measured from Earth is directly proportional to the intensity  $I$ , you can simply replace the ratio of brightnesses with the ratio of intensities  $dI/I$  to calculate  $m_{\text{red}}$  from the last equation in the first line below.)
- 3b) Repeat for the “apparent violet magnitude”, with a filter from 420 nm to 430 nm.
- 3c) How would your answer for 3b) change if the sun’s temperature were raised to 11,600 K?  
(*Hint*: Calculate the Planck blackbody radiation intensity within this wave length range due to the new temperature – but to calculate the apparent magnitude, you can still compare to the total luminosity of our “real sun”!)
- 3d) By comparing the known luminosity of the sun (see below) to the Stephan-Boltzmann law, derive the radius of the sun.

**Note:**  $L_{\text{sun}} = 3.84 \cdot 10^{26}$  W,  $m_{\text{sun}} = -26.74$  and  $m_2 - m_1 = 2.5 \lg(F_1/F_2)$  with

$$F = \frac{L}{4\pi d^2}, \quad L = 4\pi R^2 \sigma T^4, \quad dI = \frac{\Delta E}{\Delta \text{area} \Delta t} (\lambda \dots \lambda + d\lambda) = \frac{2\pi hc^2}{\lambda^5} \frac{d\lambda}{(e^{hc/\lambda kT} - 1)}, \quad I_{\text{tot}} = \sigma T^4$$

### **Problem 4**

(Text only): In your own words, describe how scientists first determined that certain bright emission lines in the spectrum of the sun indicated the presence of a **new** element, not yet observed on Earth. Relate your narrative to information covered in class, explaining the reasoning why it had to be a **new** element. Do NOT copy verbatim from the web, each other or a book - use your own words! (2-3 paragraphs)