HomeworkB-loops+lists

June 9, 2022

Due on Tuesday, June 14th by 5pm.

Please read the ***entire*** assignment before starting and complete all the requested steps. You can complete this assignment either using Jupyterhub on `Scorpius` or with your own computer. If you want help installing Python on your own computer, please check out the "Install scientific python on your own computer" document on `Canvas`. Come to office hours for help!

You should complete your assignment in a jupyter notebook (but will turn in an html version of your notebook for easier grading). Once you've created your notebook, change the name (up at the top) to "`homeworkB_{identikey}`", replacing "`{identikey}`" with your identikey (get rid of the squiggly brackets).

Include all the code you write as "Code" cells and any written responses as "Markdown/Raw NBConvert" cells or formatted print statments from within your code. Please indicate clearly at the start of a block of code or comment cell which part of the assignment or question it is in response to. You **MUST** use (at least some) comments throughout your code to explain how it works, variables, etc. While we will later teach you how to use more modules and packages to simplify your coding, please do not use any modules or packages not yet introduced in class.

This homework requires more substantial blocks of code than the previous assignment, but you have seen all the components in the class lectures & tutorials. Tackle it bit by bit. Good luck!

1 The Planck Function (Code 70%, Questions 30%)

Everything emits light at some wavelength. Hot things emit visible light, cooler things might emit mostly in the infrared. The Planck function describes the intensity of light from a thermally emitting source as a function of wavelength and the temperature of the source. This emission is sometimes referred to as "blackbody radiation."

We can write the Planck function as:

$$B(\lambda, T) = \frac{2hc^2}{\lambda^5(e^{\frac{hc}{\lambda kT}} - 1)}$$

where λ is a wavelength of light in meters (m), T is the temperature of the surface in Kelvin (K), $h = 6.626 \times 10^{-34}\ J \cdot s$ is Planck's constant, $c = 2.998 \times 10^{8}\ m/s$ is the speed of light, and $k = 1.381 \times 10^{-23}\ J/K$ is Boltzmann's constant. This intensity, evaluated at any particular λ and T has dimensions of "energy / time / area / wavelength / solid angle" and, when using the constants given above, has units of $J/s/sr/m^3$. This function encodes the fact that hotter surfaces are brighter than cooler ones and that hotter surfaces emit preferentially more blue light than cooler surfaces.

Wien's Law is an analytic expression indicating the wavelength where this blackbody emission peaks (is highest) for a given temperature:

$$\lambda_{max} = \frac{b}{T}$$

where λ_{max} is the peak wavelength in meters (m), T is the blackbody temperature in Kelvin (K), and b is Wien's displacement constant equal to $2.898 \times 10^{-3}\ m \cdot K$.

For this assignment, you will write code that numerically determines the wavelength where the peak of the Planck function occurs for a given temperature. You will compare your results to the analytic Wien's Law expression. The first equation above will be used in your loop to find the wavelength where the blackbody spectrum has its maxiumum value; the second will be used to check the wavelength that your loop identifies.

Your numerical solution will give you an approximate solution (limited by the step size) while Wien's law gives you an exact solution. While writing (and testing) your code, you should use Wien's law to get an idea of the approximate values your numerical code should be giving you. If they are not close, you've likely done something wrong! However, you should NOT use Wien's law to predetermine any values for your code!

2 The Algorithm

Your program **must** contain (at least) the following:

- A variable that represents the blackbody temperature, so your peak-finding algorithm can be applied to different blackbodies by modifying a single line of code (i.e. the line where the value of that temperature variable is set).
- A variable representing the initial wavelength guess.
- A variable representing the wavelength increment, or step size.
- A variable representing the current value of B.
- A variable representing the previous value of B (this could be zero at the start of the loop).
- A variable that keeps track of the step number.
- Lists to store the wavelengths and B values.

Here's a sketch of the procedure your code should follow to numerically identify the peak of the blackbody function. Your code should:

1. Calculate the intensity of light ($B(\lambda, T)$) for a given wavlength (λ) and blackbody temperature (T).
   - Confirm your calculation of B does the math correctly. For a wavelength of $\lambda = 700nm$ (red light) and a temperature of $T = 6000K$ (the temperature of the Sun), your calculation should yield $2.38 \times 10^{13} J/s/sr/m^3$.

2. Be able to start with an initial guess for a wavelength you think is close to (but definitely less than) the peak blackbody wavelength.
3. Use a `while` loop to increment your guess for the wavelength and recompute B_λ until you find the "turnover point," i.e. the point where the value of B_λ goes from increasing to decreasing.
   - You should **NOT** use Wien's law to predetermine the peak. The point is to find the peak numerically!
4. Store the wavelength and B values in a list (or two?) to help you verify that your algorithm finds the peak.
5. Use a compound conditional statement (Booleans!) to prevent the while loop from taking more than 1000 steps (otherwise, if you miss the peak, your code might keep running forever!).

Two hints on wavelengths:

1. Unfortunately you will not be able to use the word `lambda` as a variable name. It is a reserved word in Python, so your variable name will have to be something else.
2. Be sure to pay special attention to which units you're using for wavelengths!

3 Questions

Answer each question below in its own cell (or set of cells) using a combination of code cells and (if you wish) Markdown/RawNBConvert cells. It is perfectly fine to write code to print out the explanation parts of your answers but please format them so it is readable (and identifies the question number).

1. Using your numerical algorithm, what is the peak wavelength of a $T = 13,000K$ blackbody in nanometers? Use $10nm$ as your initial guess and a step-size of $+20nm$.
2. How many iterations did it take for your algorithm to find the blackbody peak?
3. How close is your result to the analytical result (Wien's Law)?
4. To confirm that you found the peak, print your list(s) of wavelength and B values. To make them print nicely, use a `for` loop to print one pair of wavelength and flux values per line. Make sure the wavelength prints in nanometers with the number taking up at least 5 characters, and with 0 digits after the decimal place. Make sure the blackbody flux prints in fixed-point notation (not exponential) with the number taking up at least 20 characters and with 1 digit after the decimal place. You should see the B values decrease after your peak wavelength.
5. In a new code cell, copy and re-run your algorithm for the same temperature, with a step-size of +1 nm. How many iterations did it take to find the peak? How close is your result to Wien's Law now? Again, print your list(s) of wavelength and B values.

4 Turn in your Assignment

Your final version of your assignment should run from top to bottom without errors. (You should comment out or delete code blocks that didn't work.) To create a clean version, rerun your notebook using "Kernel|Restart & Run All." Be sure to save this final version (with output). To submit, click "File|Download As >|HTML (html)" inside jupyter notebook to convert your notebook into an HTML web page file. It should have a name like "`homeworkB_{identikey}`". You can open this file in a browser to make sure it looks right! Please upload this HTML file as your homework submission to “HomeworkB” on `Canvas`.