HomeworkF-slicing+indexing

July 6, 2022

Due on Saturday July 9, at 5pm.

In this homework, you're going to practice playing with arrays, Boolean indexing, slicing, and numerical differentiation. Please read the instructions *carefully* and complete all the requested steps. Please submit a `jupyter` notebook that responds to all steps of the Coding Assignment outlined below. Include all the code you write as "Code" cells and any written responses as "Markdown/Raw NBConvert" cells.

In your notebook, please indicate clearly at the start of a block of code which part of the assignment you are responding to..

Be sure to use comments throughout your code to explain how it works, variables, etc. You don't need to include full docstrings for any functions you write, but it *is* good practice! (1 pt)

As much as possible, make sure you're having Python do your calculations/limits/scaling for you. Anywhere you find yourself hardcoding a number, think about whether or not you could have Python calculate it dynamically for you. If you find yourself doing the same calculation many times but changed a single variable (or two or three), use a loop!

1 Physics Background: The Spectrum of the Sun

Recall the Planck function (how could you not at this point?), which tells us an object's thermal emission spectrum can be represented as

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

where h is Planck's constant, c is the speed of light, k is Boltzmann's constant, λ is the emission wavelength, and T is the temperature of the emitting surface. You've seen this in many tutorials, and in HomeworkB, you used a loop to determine the peak of Planck function by where its values turned from increasing to decreasing. In this homework, we'll use numpy arrays to calculate the derivative of the Planck function and of a slightly more realistic spectrum of the Sun.

2 Coding Assignment: Finding local maxima

Throughout this assignment, you must comment your code and be sure to label the axes on all your plots. Please indicate clearly at the start of a block of code which part of the assignment it is responding to.

1. Plot the Planck function for a temperature of $T = 5800$ K (you may use the function you defined in previous tutorials, either by pasting the code into your notebook or by importing it as a module). Use a range of wavelengths (plotted in nm) that includes the peak of the thermal emission spectrum and sample the curve with enough points that it looks smooth.

2. Compute the derivative of the Planck function $dB/d\lambda$ over your range of wavelengths using a *central difference scheme*:

$$f'(x_0) = \frac{f(x_0 + h) - f(x_0 - h)}{2h}$$

   Using a step size of 0.1 nm, evaluate this derivative at exactly the same wavelengths as before, and plot it on a new set of axes.

3. Estimate visually the wavelength where the derivative $dB/d\lambda$ crosses zero (it may help to plot a straight line at $y = 0$ using `plt.axhline`). Does it correspond to the wavelength where the emission spectrum peaks? Should it?

4. Plot the Planck function you plotted in Q1. This time, color the points or curve so they are one color when the derivative $dB/d\lambda$ is positive and another color when the derivative is negative. *Hint: use Boolean selection arrays!*

5. Write code to find the wavelength location of the spectrum's peak, λ_{peak} by computing where the derivative (as calculated via central difference formula above) changes sign from positive to negative (this method is more robust than looking for an exact zero). Do the same for 9 stars with temperatures spaced every 1000 K between 2000 and 10000 K, inclusive. Plot λ_{peak} as a function of temperature, and overplot the result expected from Wien's Law (HomeworkB) on the same axes. Do your results (roughly) agree?

6. Load the data in the file `model_5800K.txt` (available on both Canvas and Scorpius under `/home/hama2717/astr2600/shared/`) into two arrays, one for wavelengths and the other for fluxes. This is a model spectrum of a Sun-like star. Plot this spectrum with wavelength on the x-axis and flux on the y-axis. In the same axes, overplot the Planck function for a 5800K object.

7. Calculate the derivative of this model spectrum with respect to wavelength. This time, use a forward differencing scheme and calculate the derivative (slope) using the GIVEN x- and y-values. *The step size will now be set by the x-spacing of the model spectrum.* Make a plot of the model solar spectrum flux, and do what you did before: color the points where the derivative is positive as green and those where the derivative is negative as red. Set the x-limits of the plot to zoom into a 50nm chunk of the spectrum so you can see what is happening.

8. Discuss why the method we used to find the peak of the Planck function would not work to find the peak of the actual Sun-like spectrum.

9. How might you fix the problem you identified in the previous question? (You don't need to show the code you would write but rather, speak in pseudocode or generalities about what you might do to overcome the issue.)

3 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 were just used for testing purposes.) **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 `homework#_{identikey}.html` (where # is the appropriate letter for this week's homework). Please upload this HTML file as your homework submission on Canvas.