Using Stefan's and Wien's Laws to Understand the Brightness and Size of Stars

Name______________

Purpose:
- To provide you with necessary skills to use Stefan's and Wien's Law to estimate star brightness
- To use the concepts of luminosity and surface area

Estimated Completion Time: 60 minutes
Resources needed:
- Calculator (preferably scientific)
- Textbook
- Web access is highly desirable

24

Applets that you will find useful:
Black Body Explorer
This applet tells you almost everything you need to know about b-b curves!
Star Maker
This applet will do the math that you encounter when comparing star brightness as a function of size and temperature

Questions

1. Determine the wavelength of maximum emission from stars of the following temperatures and also indicate what region of the spectrum and/or colour the light will be: (3 marks) (Show how you would use Wien's Law – write out the equations and put in the appropriate numbers but if you wish you can use an applet to do the calculations)
   a. Star A: T = 8000 K
   b. Star B: T = 3000 K
   c. Star C: T = 12 000 K

3

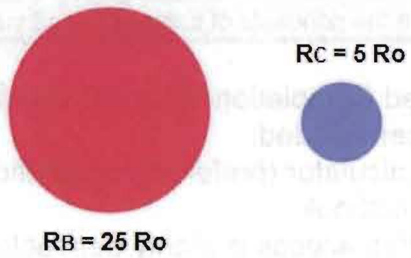
You can use Wien's Law $\lambda_{max} = \frac{3\times10^6 \text{ K nm}}{T}$
∴ $\lambda_A = 362$ nm; star bluish-white
$\lambda_B = 970$ nm; star is red
$\lambda_c = 242$ nm; star is blueish-white

2. Use stars A, B and C to determine the amount of energy being emitted per second per square meter from each star. Express your results in units of Watts per square meter (W/m^2). Why can't we decide which of the 3 stars is the brightest? What additional piece of information would be needed to allow you to do this? (4 marks) (Again – show how you would use Stefan's law to solve this but you can use an applet to answer if you wish).

4

You need Stefan's Law for this $I = \sigma T^4$ or you can calculate by hand or use the applet B-B explorer:
$I_A = 2.32\times10^8$ W/m^2
$I_B = 4.59\times10^6$ W/m^2
$I_C = 1.18\times10^{12}$ W/m^2
We can't tell which star is brightest because we don't know either their radii or distance from us.

3. Explain what is meant by the term **luminosity.** Suppose that star B has a radius of 25 times that of our sun while star C has a radius of 5 times the sun. Use this to determine the ratio of the luminosity of the two stars. What is L_B/L_C? (4 marks)



Luminosity is the total energy received from the star in 1 second.

$L = 4\pi R^2 \sigma T^4$ $\quad \frac{L_1}{L_2} = \left(\frac{R_1}{R_2}\right)^2\left(\frac{T_1}{T_2}\right)^4$ $\quad \therefore \frac{L_B}{L_C} = \left(\frac{25}{5}\right)^2\left(\frac{3000}{12000}\right)^4 = 0.098$

4/4

4. If stars B and C where both at the same distance how would their magnitudes compare? Which would be brightest and by how many magnitude units? (3 marks) The ratio in #3 tells us that star C is 10.24 times brighter than star B. Use the magnitude-brightness rule

$\Delta m = 2.5 \log\left(\frac{L_1}{L_2}\right) \Rightarrow \Delta m = 2.5 \log(10.24) = 2.5$!

Star C is 2.5 magnitudes brighter than star B.

3/3

5. Use Stellarium to find the B-V colour index and spectral type for the following stars and then use Black Body Explorer (use "filter mode") to estimate the temperatures of those stars: (10 marks)

Star	B-V	Temperature (K)	Spectral Type
Alnilam	-0.18 ~~B0 Ia~~	13 200	B 0 Ia
Arcturus	0.82	4610	K0 III
Mira	0.98	4170	M5/M6 e
Deneb	0.10	8480	A2 Ia
Mirphak	0.48	5850	F5 Ib

10/10

(Hint – once you locate the star click on it and read the information in the upper left hand corner of the screen) The temperatures are estimated use Black-Body explorer. If you used Wikipaedia you may have significantly different values. Colour-indices provide a crude (but still useful) measure of star temperature