Astro C10, Quiz 1

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To receive credit, you **must show your work and/or explain your reasoning.** The quiz is out of 50 points.
May the odds be ever in your favor.

1. (10pts) I stand behind a cloud of cold hydrogen gas and shine a flashlight onto the gas. You stand on the other side of the cloud, exactly opposite me and facing the cloud. You look through a diffraction grating (a miniature-spectroscope – we used these for the arclamp demo) at the gas.

   (a) Describe in a few sentences what you would see and why. What kind of spectrum is this?

   Absorption!

   Would see a rainbow with a few dark lines.
   Flashlight emits continous distribution of light (white light = mix of all wavelengths).
   Dark lines from specific wavelengths absorbed by the cold H in between.

   (b) Explain how this situation is analogous to viewing the Sun.

   The inner part of the sun is the "flashlight", emitting light over a whole range of wavelengths (according to the thermal emitter distribution).

   The outer layers are the "cold Hydrogen" which absorb some of the light from the hot inner layers.

   So, when we look at the Sun, we see an absorption spectrum.

2. (15pts) Stars Dorian and Bryce are at the same distance, but Star Bryce is twice as hot as Star Dorian and half the diameter of Star Dorian.

   (a) Which star is brighter and by what factor?

   $$L_B = 4\pi R_B^2 \sigma T_B^4 = 4\pi \left(\tfrac{1}{2} R_D\right)^2 \sigma (2T_D)^4$$

   $$L_D = 4\pi R_D^2 \sigma T_D^4$$

   Divide: $$\frac{L_B}{L_D} = \frac{4\pi \left(\tfrac{1}{2}R_D\right)^2 \sigma (2T_D)^4}{4\pi R_D^2 \sigma T_D^4} = \frac{1}{4} \cdot 16 = \boxed{4}$$

   (b) By what factor is the peak wavelength of Star Bryce longer/shorter than that of Star Dorian? Which star is bluer?

   $$\lambda_{peak} \propto \frac{1}{T} \longrightarrow \frac{\lambda_{peak,\,Bryce}}{\lambda_{peak,\,Dorian}} = \frac{\frac{1}{T_B}}{\frac{1}{T_D}} = \frac{T_D}{T_B} = \boxed{\frac{1}{2}}$$

   Bryce is bluer, because $\lambda_{peak,\,Bryce}$ is lower (because Bryce is hotter).

3. (15pts) Stars Alex and Ben are *exactly* the same, except that Star Ben has half the diameter of Star Alex. Suppose we use Telescope A to collect photons from Star Alex, and register 10 photons per second.

   $L \propto R^2$, therefore $\frac{L_B}{L_A} = \frac{1}{4}$

   Therefore, we need a telescope with 4 times the light gathering power to observe Ben & get the same # of photons per second.

   $$LGP \propto A_{telescope} \propto D^2_{telescope} \qquad \frac{LGP_{Ben}}{LGP_{Alex}} = 4 = \frac{D_B^2}{D_A^2} \rightarrow \boxed{D_B = 2D_A}$$

(a) How much larger must the diameter of Telescope B be to observe Star Ben and still register 10 photons per second?

See below #3

(b) Which telescope will do a better job of observing a "close binary system" (a system of two stars orbiting very close to each other)? Briefly explain why.

Telescope A will. To observe a close binary, you need good resolution in your telescope. The resolving power is higher in larger telescopes $[\theta = \frac{\lambda}{D}]$.

4. (10pts) Consider a hypothetical atom with allowed energy levels $E_1 = 2$, $E_2 = 5$, $E_3 = 8$, $E_3 = 12$, $E_4 = 13$, and $E_5 = 15$. The atom's electron is in an unknown energy level.

(a) A photon with energy $E_p = 3$ hits this atom. What transition(s) might occur and why?

Transitions with an energy difference of $\Delta E = 3$ can occur.
These are: $E_1 \to E_2$, $E_2 \to E_3$, $E_3 \to E_5$

(b) Consider the transitions from E_3 to E_1 (transition A) and E_5 to E_4 (transition B). What is the ratio of the **energies**, **frequencies**, and **wavelengths** of the photons emitted from transition A to transition B?

$E_3 - E_1 = 6$

$E_5 - E_4 = 2$

$\frac{E_B}{E_A} = \frac{2}{6} = \boxed{\frac{1}{3}}$

$\boxed{\frac{\lambda_B}{\lambda_A} = \frac{f_A}{f_B} = 3}$

$\frac{f_B}{f_A} = \frac{E_B}{E_A} = \boxed{\frac{1}{3}}$

5. (500pts) Who's the best GSI you've ever had?

answer carefully :)

A smattering of stuff you may or may not need: $\lambda_{\text{peak}} T = .002898$ meter-Kelvin

$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

$\vec{F} = m\vec{a}$

$A_{\text{circle}} = \pi R^2$, $A_{\text{sphere}} = 4\pi R^2$

$\theta = \frac{\lambda}{D}$

$\hat{H}\psi = E\psi$

$L = A\sigma T^4$

$E = hf$

$c = \lambda f$

$< f >= \int f(x)P(x)dx$

LGP $\propto$ $A_{\text{telescope}}$