UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Astrophysics I (ASTR 691) — Prof. Crossfield — Fall 2026

In-Class Problems 14 [25 pts]
You may use your OoMA Sheet, your handwritten notes, and a scientific or graphing calculator – and you may work in a group. As always, be sure to: show your work, circle or highlight your final answer, list units, use the appropriate number of significant figures, and write your name.

1. **Applied Radiative Transfer [12 pts]** Consider a cloud bank: it extends all the way to the ground (z=0) and up to an altitude of Z; above this the cloud is gone and the sky is perfectly clear. The cloud is homogeneous and has a constant extinction coefficient α_λ throughout. A young child is standing on the ground and shining a laser pointer upward with initial, emitted intensity $I_{\lambda,0}$. The beam is pointed up at an angle θ from zenith (so $\theta = 0$ would indicate straight up). Derive:

   (a) a general expression for $\tau_\lambda(z, \theta)$, for any altitude $z \leq Z$ and angle $0 \leq \theta \leq \pi/2$ [6 pts];

   (b) a general expression for $I_\lambda(z, \theta)/I_{\lambda,0}$ for any arbitrary value of θ. [6 pts]

2. **Line Locations vs. Line Widths. [13 pts]** A number of students at times have expressed confusion that although for, e.g., spectral line wavelengths and frequencies $\lambda = c/\nu$ (clearly true!) it is nonetheless *not* the case that the *widths* of these lines are related by $\Delta\lambda = c/\Delta\nu$.

   (a) Pick your favorite spectral absorption line in the UV, optical, or infrared. Write its wavelength λ (in nm) and frequency ν (in Hz). [1 pt]

   (b) Assume that when observed in a particular spectrum, this absorption line (shown in Fig. 1) has a fractional full-width of 0.2% – i.e. $\gamma \equiv 0.002$ (this "line width" γ has nothing to do with the speed of light).
   Calculate the full line width, $\Delta\nu$, along with the max. and min. frequencies of the absorption line profile (marked by the vertical dashed lines in Fig. 1). Don't even think about wavelengths yet! [3 pts].

   (c) Use those the maximum and minimum frequencies to calculate the minimum and maximum wavelength, respectively, of the line profile, as well as the line width in wavelength, $\Delta\lambda$. [3 pts]

   (d) Compare your calculated $\Delta\lambda$ to the result you get by naively calculating $c/\Delta\nu$. Explain why they are not the same, and why the second value would be incorrect. [6 pts]

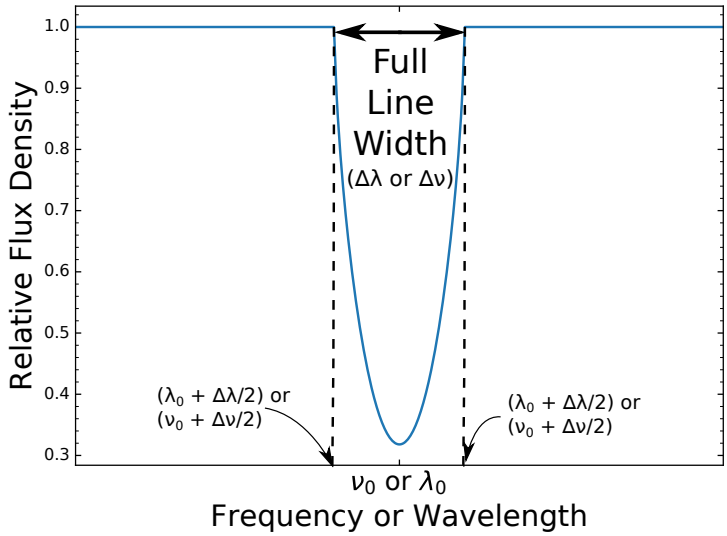


Figure 1: Arbitrary absorption line profile with central frequency and wavelength ν_0 and λ_0 and width $\Delta\nu$ or $\Delta\lambda$.