

UNIVERSITY OF KANSAS
Department of Physics and Astronomy
Astrophysics I (ASTR 691) — Prof. Crossfield — Fall 2024

Problem Set 2

Due: Monday, Sep 16, 2024, before the start of class (by 1000).
This problem set is worth **42 points**.

As always, be sure to: show your work, circle or highlight your final answer, list units, use the appropriate number of significant figures, type the Pset, and submit a printed copy.

Recommended tools for typesetting your problem set are either LibreOffice or the LaTeX typesetting system available either by download at <https://www.latex-project.org/get/> or in online-only mode via, e.g., <https://www.overleaf.com/>.

1. How Do You Say “Absorption” in Astrophysics? [12 pts]

- (a) Define α_λ , extinction coefficient (in words, not just an equation!), and give its typical units. [3 pts]
- (b) Define σ_λ , cross-section (in words, not just an equation!), and give its typical units. [3 pts]
- (c) Define κ_λ , opacity (in words, not just an equation!), and give its typical units. [3 pts]
- (d) Define τ_λ , the optical depth (in words, not just an equation!), and give its typical units. [3 pts]

2. A Hazy Morning [15 pts] On a given day the weather report mentions that visibility is about one km. Take that as the distance at which $\tau_\lambda \approx 1$:

- (a) Estimate the atmosphere’s extinction coefficient α_λ that morning. [3 pts]
- (b) If the visibility is mainly limited by smoke from nearby fires, find a way to estimate the number density n of these particles in the atmosphere. [4 pts]
- (c) Given the typical density ρ of air at sea level, estimate the opacity κ_λ of the smoky air (in SI units). [4 pts]
- (d) Now assume that this same smoke layer is confined to a thin layer near the ground with a thickness of just 100 m (due to some unknown atmospheric phenomenon; the reason isn’t important here). What is the optical depth at visible wavelengths when looking straight overhead? and when looking up at a 45° angle (halfway between straight up and parallel to the ground)? [4 pts]

3. Radiation Quantities [15 pts] Consider two astronomical objects: an Earth-size planet with $T \approx 300$ K and a Sun-like star $T \approx 5800$ K. Assume that both objects radiate as blackbodies. Recalling that $F_\lambda = \pi I_\lambda \left(\frac{R}{d}\right)^2$ (Rybicki, Eq. 1.13; where R is the object’s radius and d is the distance from the object’s center):

- (a) Plot the flux density, F_λ , at the *surface* of each of these objects. [4 pts]
- (b) Plot the flux density, F_λ , at a distance of 10 parsecs (pc) from each of these objects. [4 pts]
- (c) Plot the wavelength-dependent planet-star flux ratio, $F_{\lambda,p}/F_{\lambda,*}$, of these two blackbody spectra. What does this plot suggest about the best wavelengths to look for radiation emitted by Earth-like planets in other Solar systems? [4 pts]
- (d) Calculate the bolometric (wavelength-integrated) planet-star flux ratio, F_p/F_* . [3 pts]

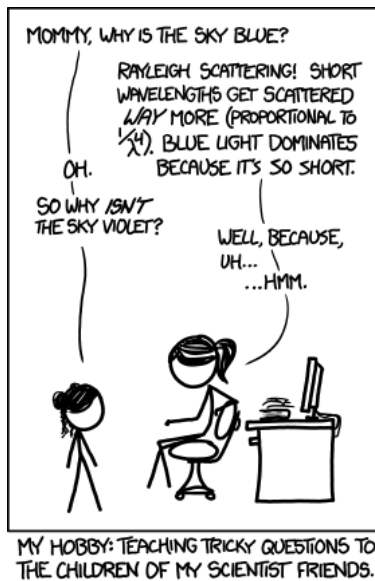


Figure 1: A cruel trick involving Rayleigh scattering, from <https://xkcd.com/1145/>. Bonus points if you answer this child's second question.