# PHY 474 Spring 2021

# Homework 1—due by 5:00 PM, Friday, Apr 9

**You may write by hand and scan as a single PDF, or write in latex (using the template file provided) or Word, and generate PDF. Please submit one PDF file only. Only questions and sub-parts that are numbered clearly, with numbers corresponding to those in this document, will be graded. See the syllabus for more detailed rules.**

***Submit late homework into the late D2L dropbox for reduced credit (see syllabus); late submissions will be accepted until 8 AM on Monday (Apr 12). Emailed or paper copies of homework are never accepted; in particular, do not attach homework to email to make an end-run around the D2L deadline or late deadline; such emails are automatically deleted and do not count as submissions.***

**1.** In class, we discussed some relevant timescales. Yet another such quantity is the timescale for photons created in the core of the Sun to reach the surface.

Note that we will work with a single photon in this problem, but in reality the same photon doesn't actually make its way to the surface; instead, photons are absorbed and re-emitted.

(a) Assuming the Sun is completely ionized, the Thomson scattering cross section is relevant in this problem, since photons will scatter off the free electrons, and it is given by

$$\sigma_T = \frac{8\pi}{3}\left(\frac{e^2}{4\pi\epsilon_0\, m_e c^2}\right)^2$$

in SI units, where $e$ is the electron charge, and $m_e$ is the electron mass.

Compute $\sigma_T$. *Show steps clearly if you want full credit.*

(b) The photon scattering timescale is then given by $t_s = \dfrac{l}{c}$, where $l = \dfrac{1}{n_e \sigma_T}$ is the mean free path.

Calculate $t_s$.

**Note:** You'll need to find the electron density $n_e$ (in $\mathrm{cm}^{-3}$), which you can do by using the average (mass) density of the Sun, $\rho = 1.4 \times 10^3$ kg $\mathrm{m}^{-3}$.

**Question 2 begins on the next page.**

**2.** In class, we discussed the $\eta$ Cas binary star system, located at a distance of 6.0 pc from us. The mean separation of the two stars, $\eta$ Cas A and $\eta$ Cas B, is 71 AU.

(a) When separated by 71 AU, what would be the angular separation of the two stars, $\eta$ Cas A and $\eta$ Cas B, as seen from Earth? Express your answer in arcseconds ($''$) if you want full credit.

(b) The system has very high eccentricity, and when it was discovered during the time of William Herschel, the angular separation of the two stars was only about $6.2''$. How far apart in AU were $\eta$ Cas A and $\eta$ Cas B at that time?

**3.** The binary star system Albireo, or $\beta$ Cyg, is sometimes called the "eye of the swan" for its location in the constellation of Cygnus at a distance of about 390 Ly from us. When observed with a V-band filter, the magnitude of the brighter component $\beta$ Cyg A is 3.18, and the fainter component $\beta$ Cyg B is about 5.9 times fainter than $\beta$ Cyg A.

(a) Compute the *absolute* magnitude of the brighter component $\beta$ Cyg A.

(b) Compute the *apparent* magnitude of the fainter component $\beta$ Cyg B.

**4.** In class, we learned about the Lorentzian distribution

$$\phi(\nu) = \frac{\gamma_n/4\pi^2}{(\nu - \nu_0)^2 + (\gamma_n/4\pi)^2}$$

Show that the Lorentzian distribution is normalized to unity, so that

$$\int_0^\infty \phi(\nu)\, d\nu = 1$$