Physics 346 – Spring 2021
Worksheet # 1: Common astronomical quantities

1. Astronomers working at far-infrared through radio wavelengths often express intensities in flux density (f_ν) units of $\mathrm{erg\,cm^{-2}\,s^{-1}\,Hz^{-1}}$ ($1\,\mathrm{Jy} = 10^{-23}\,\mathrm{erg\,cm^{-1}\,s^{-1}\,Hz^{-1}}$). Astronomers working at optical and near-infrared wavelengths, however, often express intensities in flux per unit wavelength (f_λ) units, i.e., $\mathrm{erg\,cm^{-2}\,s^{-1}\,\AA^{-1}}$ or $\mathrm{erg\,cm^{-2}\,s^{-1}\,\mu m^{-1}}$. Suppose that a given source has a power-law spectrum that can be equally well described as either $f_\nu \propto \nu^\alpha$ or $f_\lambda \propto \lambda^\beta$. What is the relationship between the power law indices α and β in this case? *Hint: the definition* $f_\lambda d\lambda = -f_\nu d\nu$ *may be helpful.*

2. Redshift is defined by the relations

$$1 + z = \frac{\nu_0}{\nu} = \frac{\lambda}{\lambda_0} \tag{1}$$

where a 0 subscript indicates rest (emitted) frequency or wavelength. Radio and optical astronomers have defined different approximate "velocities" (call them v_{rad} and v_{opt}) according to the conventions

$$\nu = \nu_0 \left(1 - (v_{\mathrm{rad}}/c)\right) \tag{2}$$

$$\lambda = \lambda_0 \left(1 + (v_{\mathrm{opt}}/c)\right) \tag{3}$$

What are v_{rad} and v_{opt} in terms of z? If an observer were given a source to observe at a radio velocity that was actually an optical velocity, could a problem result, and if so, how severe would the problem be?

3. The brightness of an astronomical object at optical/near-IR wavelengths is often expressed in terms of a *magnitude*

$$\mathrm{mag} = -2.5 \log\left(f_\nu / f_{\nu,0}\right) \tag{4}$$

where f_ν is the flux density of an object of interest and $f_{\nu,0}$ is the flux density of Vega (the fifth brightest star in the sky in the visual) in the same units. This convention requires that observers keep track of how bright Vega is (i.e., what value $f_{\nu,0}$ has) over many different wavelengths, which can be a headache. An alternative "AB" magnitude system was proposed by Oke & Gunn (1983, ApJ, 266, 713) to address this problem: in all bands, the zero magnitude by an absolute calibration

$$\mathrm{mag_{AB}} \equiv -2.5 \log\left(\frac{f_\nu}{\mathrm{erg\,cm^{-2}\,s^{-1}\,Hz^{-1}}}\right) - 48.60 \tag{5}$$

rather than by the flux density of Vega. What do you see as the advantages and disadvantages of using the Vega-based and AB magnitude systems?