Physics 109: Homework #5 Solutions

5.1 In the US, AM radio stations cover the frequency band 530 kHz to 1710 kHz, while FM stations cover 87.9 MHz to 107.9 MHz. The wavelengths at the center of each band (AM: 1120 kHz; FM: 97.9 MHz) are 268 m and 3 m. The second part of the question asks how fast you would need to be traveling so that the AM band is shifted in wavelength into the FM band by the Doppler effect. First, in order for the wavelength to decrease, your motion must toward the transmitter. The fractional amount of the decrease in wavelength $\Delta\lambda/\lambda = (268 - 3)/268 = 0.9888$ is equal to the fraction of the speed of light that you must be traveling. You would need to be traveling within about 1% of the speed of light (or roughly 185,000 miles/second!).

5.2 Flux depends on distance as an inverse square. Mars' orbit has a semimajor axis of 1.523 AU (appendix 4), so the flux of solar radiation at Mars is only $(1/1.523)^2 = 0.43$ times the flux at Earth.

5.3 Reflection is the bouncing of a wave from a surface, refraction is the bending of light when it passes from one material to another, and dispersion is the separation of light according to wavelength. Examples include: mirrors, eyeglass lenses, rainbows, respectively.

5.4 Optical observatories in space avoid the effects of atmospheric "seeing," so they can make sharper images. They are also not subject to light pollution from nearby cities or the vagaries of weather. Some parts of the electromagnetic spectrum are entirely blocked by the Earth's atmosphere so astronomical observations in these bands (e.g., X-ray, ultraviolet, parts of the infrared band) can only be done in space. A radio telescope in orbit provides a very long baseline that can be combined with ground-based telescopes for high resolution VLBI measurements.

5.5 The Keck telescope has a diameter of 10 m, while the pupil of your eye has a diameter of 0.8 cm. The light gathering power of the Keck telescope is $(10\text{ m} / 0.8\text{ cm})^2 = (10\text{ m} / 0.8 \times 10^{-2}\text{ m})^2 = 1.56 \times 10^6$ times greater than that of the human eye. The ideal angular resolution of the Keck telescope (at 550 nm $= 550 \times 10^{-9}$ m) is $\theta = 250,000 \times 550 \times 10^{-9}/10 = 0.014$ arcsec, while that of the human eye is $\theta = 250,000 \times 550 \times 10^{-9}/0.8 \times 10^{-2} = 17$ arcsec. However, atmospheric blurring limits the actual angular resolution of the Keck telescope to something between 0.5 arcsec and 1 arcsec, generally.