PHYS 171: Planetary & Stellar Astronomy
Due: Friday, September 27, 2019

Problem Set #4

1. Blackbody physics

a) What is the peak emission wavelength of a stove burner at 500° C ?
b) What is the luminosity of the stove burner?
c) The stove burner has a total area of 100 cm^2. What is the total power radiated by the burner?

1. Brightness of the Sun

a) The Sun is a good blackbody radiator and has a surface temperature of 5800 K. What is its peak emission wavelength?
b) What is the luminosity of the Sun's surface? (answer in W/m^2)
c) The Sun has a radius of 696.3×10^3 km. What is the total radiated power of the Sun?
d) The Earth is located at 149.6×10^6 km from the Sun. What is the intensity of sunlight at the Earth? (answer in W/m^2)

3. Solar sail

a) Calculate the light pressure of the Sun in the vicinity of the Earth, given a solar intensity of 1000 W/m^2. You can assume that solar photon are absorbed (not reflected).
b) Calculate the force on a solar sail that is 1 km × 1 km. The solar sail is perfectly reflective.
c) If the solar sail in b) has a density 10 g/m^2, then calculate the acceleration of the solar sail. What is its velocity after 1 month of acceleration? (at constant solar intensity and zero gravity)

4. Radiation pressure on a gas

Background: Consider a gas of hydrogen in its ground state (n=1), subject to ultraviolet radiation from the Sun. This ultraviolet light drives the n=1 to n=2 transition in H at 121.57 nm. Each time the H atom absorbs one of these photons from the Sun it gets a momentum recoil. Shortly thereafter, the excited H atom re-emits a 121.567 nm photon in a random direction, and gets another recoil in the opposite direction (random direction). If this process is repeated many times, then H atom always absorbs a photon from the Sun in the same direction. However, since the re-emission is always in random direction, all of the re-emission recoils average to zero.

Task: If the H atom absorbs photons are a rate of 10^6 photons/second, then calculate the acceleration of the H atom from this process. The mass of an H atom is $m_H = 1.67 \times 10^{-27}$ kg.

5. Doppler shift

Using a telescope and spectrometer on Earth, you measure the 121.567 nm transition line of hydrogen gas on either side of the equator of Jupiter, which has a diameter of 143×10^3 km. On the left edge, you measure 121.558 nm, while on the right edge you measure 121.568 nm.
a) Is Jupiter approaching or receding from the Earth? At what speed (line-of-sight speed)?
b) What is the rotation speed at Jupiter's equator? What is the rotation period of Jupiter in days?