Astronomy 1 — fall 2009
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Solutions to Assignment 4

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1 Ch. 5 #3

See solutions to Ch1 #29 on HW1. It's the same problem!

Ch. 3 #5

Just use figure 5-7 in the book:
(a) 2.6μm-Infrared
(b) 34m-Radio
(c) 0.54nm-X-ray
(d) 0.0032-Gamma-ray
(e) 0.62μm-visible
(f) 310nm-Ultra Violet
(g) 0.012m-Microwave

Ch. 3 #6

Frequency is how many times something happens in a fixed amount of time. For light we define frequency to be the number of wavelengths to pass a given point every second. Frequency has units of Herz (Hz=1/s). Frequency and wavelength are related by the following equation:

$$\nu = \frac{c}{\lambda}$$

Ch. 3 #7

Solving the equation above for lambda and plugging in the given frequency in Hz (not GHz!), we find

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8 m/s}{880.65 \times 10^6 Hz} = 0.34m$$

2 Ch. 5 #9

(a) A blackbody is an idealized object that absorbs all incident light. (b) A blackbody is black because it doesn't reflect any light. Therefore it won't have any color. (c) A blackbody emits light through thermal radiation. (d) If you shine a flashlight on a perfect blackbody it won't look any different at first. It would emit the same thermal radiation that it was emitting before you turned on the light and no more. Of course, since the blackbody absorbs all incoming light from the flashlight, it will heat up and begin to emit more radiation at a shorter peak wavelentth.

Ch. 5 #10

Scientists use the Kelvin scale because there are no negative numbers. Celsius or Fahrenheit requires negative numbers because they are tuned to our everyday experiences: freezing of water, anal temperature of cows, etc.

Ch. 5 #12

Looking at Wien's Law tells you that the maximum emitted wavelength of light from a blackbody gets smaller as the temperature increases. If the wavelength decreases, the frequency increases. Increasing temperature will move the peak emission to higher wavelengths/shorter frequencies and change the color of the peak emission. In addition, as temperature increases, the flux will increase, due to Stefan-Boltzmann's Law. Thus the intensity of peak emission will be greater for shorter wavelength/higher frequency blackbodies.

3 Ch. 5 #14

Here we can use Wien's Law to find the peak wavelength of emission:

$$\lambda_{max} = \frac{0.0029Km}{T} = \frac{0.0029Km}{21,500K} = 1.35 \times 10^{-9}m = 135nm$$

This wavelength will actually peak in the UV part of the spectrum, but due to the shape of the blackbody curve, there will still be a great deal of blue light reaching our eyes from this star, much more that the intensity of red light, so the star appears blue to us. See Figure 5-11 for the shape of the blackbody curve.

Ch. 5 #16

Answers may vary, but Young's double slit experiment is generally used to display the wave-like nature of light, whereas Einstein's photoelectric effect reveals the particle-like nature of light. If you're interested in either of these experiments do some research or ask us! Generally, we like to say that light travels as a wave and interacts with matter like a particle, but these are really just attempts to give us some intuition about the strange behavior of light.

Ch.5 #22

The Doppler Effect is a shift in the wavelength of light when the source (or the observer) due to the relative motion of the observer (or source). The Doppler Effect is important for astronomers because it allows us to determine the line-of-sight motion of distant objects. Applications include the search for extra-solar planets, the expansion of the universe, the rotation curves of galaxies which provide evidence of dark matter, and many more!

4 Ch. 5 #24

Use Wien's Law to plug in our body temperature (in Kelvin) to see that our bodies emit radiation in the infrared part of the spectrum.

$$\lambda_{max} = \frac{.0029Km}{T} = \frac{0.0029Km}{310K} = 9.4 \times 10^{-6}m = 9400nm$$

Ch. 5 #40

We'll invoke the Doppler Effect to solve this problem. The difference between the two wavelengths is 0.021 nm or 2.1x10^-11 m. The change in wavelength is generally the absolute value of the difference to avoid negative numbers, so it won't matter which you subtract from the other. The stationary laboratory measurement of this spectral line is 486.133nm. So the Doppler can be solved for v to give us the relative motion:

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

$$v = c\frac{\Delta\lambda}{\lambda_0}$$

$$v = c\frac{\Delta\lambda}{\lambda_0} = 3 \times 10^8 m/s \frac{2.1 \times 10^{-11}m}{4.86133 \times 10^{-7}m} = 1.3 \times 10^4 m/s = 13km/s$$

Since the observed wavelength is smaller than the stationary wavelength, the source must be coming towards us.

Ch. 5 #41

The speeder must have taken Astro 1 in order to make such a claim, but let's assume that the officer is a learned astronomer as well and tries to make sense of the claim. He scribbles on his notepad the following:

$$v = c\frac{\Delta\lambda}{\lambda_0} = 3 \times 10^8 m/s \frac{2 \times 10^{-7}m}{7 \times 10^{-7}m} = 8.6 \times 10^7 m/s$$

since the difference in wavelengths is 200nm (given in meters above) and the stationary light is disputed by the cop to be red at 700nm. The cop must give in and say that the light could have appeared green due to the Doppler Effect, but in order for that to be the case, the car would have to be traveling at one quarter the speed of light! The officer would then give the option of paying the fine for running a red light or the fine for an astronomical amount for the larger speeding ticket in the history of the world!

5

I'm going to assume that the water buffalo is a sphere with a radius of 1 m. The surface area of the water buffalo would then be

$$A = 4\pi R^2 = 4\pi(1m)^2 = 12.6m^2$$

The flux of the water buffalo can be found using the Stefan-Boltzmann Law, making the further assumption that the water buffalo is a blackbody (not quite true)

$$F = \sigma T^4 = (5.67 \times 10^{-8} W m^{-2} K^{-4})(300K)^4 = 460 W m^{-2}$$

The luminosity, or total power output of the water buffalo is given by the product of flux and the surface area, thus we can compute

$$L = FA = (460 W m^{-2})(12.6 m^2) = 5796W$$

Can you figure out how many calories (unit of energy) that the water buffalo would have to eat over the course of a day in order to radiate at this level? Answers may vary significantly for this problem based on the approximation of the surface area of the buffalo.

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The object is Jupiter!