World of Light - Problem Set #3

Assigned April 8, due at start of class on ***Wed. April 22***.

Reading

Light Science chapters 1 and 2. Also section 6.5.
Use Wikipedia, too.

Topics and Equations

This problem set reviews the following topics: pinhole cameras, the wave nature of light, the photon nature of light, experiment calibration, colors, and the hydrogen atom.

surface area of a sphere: $A = 4\pi R^2$
area of a circle: $A = \pi R^2$
power and energy: $P = E/t$
energy of a photon: $E = hf$
frequency and wavelengths: $v = \lambda f$

speed of light: $c = 3\times10^8$ m/s
Planck's constant: $h = 6.62\times10^{-34}$ J·s
Rydberg constant: $R = 1.097\times10^7$ m^{-1}

Problems

Grading scale: basically right = 1 point, basically wrong = 0 points, some right and some wrong = 0.5 points.

1. Describe the colors of the following fruits and vegetables when illuminated with red light: (a) a yellow banana, (b) a red apple, (c) a green pepper, (d) a white onion. (From *Light Science* p. 18.)

2. Draw a diagram of an electromagnetic wave, which shows: (a) electric field vectors, (b) magnetic field vectors, (c) an arrow that shows the direction of travel, and (d) the wavelength.

3. Suppose you have a pinhole camera which is 5 cm long between the hole and the film (this is typically called the focal length, but this term is misleading). You photograph a 1 cm long bug that is 10 cm in front of the pinhole. (a) Draw a diagram of this. b) How long will the image of the bug be on the film? (c) Will the image be rightside up or upside down? *Extra credit*: (d) Will the image on the film be simply rotated from the real bug, or a mirror image?

4. Consider green light with a wavelength of 550 nm. (a) What is the light frequency? (b) What is the energy of a single photon? (c) Does a red photon have a higher or lower frequency? (d) Does a red photon have a higher or lower energy?

5. Using the same pinhole camera as above, you take a picture of candle that is 10 meters from the camera. The candle emits about 18 mW of visible light (12 lumens of light with

about 683 lm/W). (a) What is the light energy per square meter, at 10 meters away from the candle (hint: divide 18 mW by the surface area of a 10 m radius sphere)? (b) The pinhole is 0.12 mm in radius; how much light goes through the pinhole (in watts)? (c) You take a 1 second exposure. How much energy goes through the pinhole (in joules)? (d) Assuming that all the light has a wavelength of 600 nm, what is the energy of one photon? (e) How many photons is this (hint: energy/(energy per photon))?

6. Give examples of (a) a scalar quantity, (b) a vector quantity, (c) a scalar field, (d) a vector field.

7. From the atomic spectra lab, we met the Rydberg formula for the emission wavelengths of hydrogen atoms. It is

$$\frac{1}{\lambda} = R\left(\frac{1}{n^2} - \frac{1}{m^2}\right)$$

where R is the Rydberg constant, which is equal to 1.097×10^7 m^{-1}. Also, m is the energy level where the electron starts and n is the energy level where the electron ends. Both m and n are positive integers. (a) Compute the wavelength for the case where $n = 2$ and $m = 3$ (you did this in your spectrum lab). (b) What color is this? (c) Compute the wavelength for the case where $n = 1$ and $m = 2$. (d) Compute the wavelength for the case where $n = 1$ and $m = \infty$. (e) What color is this? (f) Are there any m and n combinations that can give a shorter wavelength? (g) What is the energy of one photon of this wavelength? This energy is called the ionization energy; it is the amount of energy that is required to remove an electron from the atom.

8. Complete the following color "equations". (a) red light + blue light = __ light, (b) yellow light + blue light = ___ light, (c) blue light + ___ light = cyan light, (d) cyan paint + magenta paint = ___ paint, (e) cyan paint + red paint = ___ paint, (f) magenta paint + ___ paint = black paint.

9. (a) What is the photoelectric effect? (b) How did its explanation change the understanding of the physics of light? (c) Give an example of how the photoelectric effect is used in daily life.

10. (a) Why is the sky blue? (b) Why are sunsets red? (c) Why are clouds white?