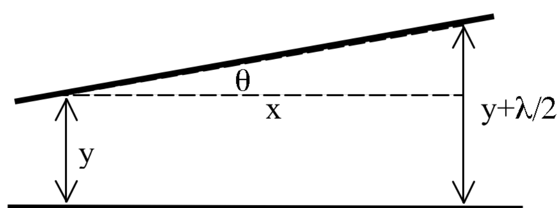
HW#14 Solutions

1) a) Blue light is not reflected, but red and green are. Red and green produce yellow.
   b) The wavelength of blue light in air is 450 nm. In water its wavelength is $\lambda' = \lambda/n = 450$ nm$/1.33 = 338$ nm.
   c) Thickness = 338 nm/4 = 84.5 nm. 1 mm = 1,000,000 nm, so the thickness is 0.0000845 mm.
   d) Magenta is red plus blue, so green must not be reflected. The wavelength of green in the film is 550 nm/1.33 = 414 nm. One fourth of this is 104 nm or 0.000104 mm.

   As per a recent e-mail, I realized the statement that the thickness of the film is ¼ λ was incorrect. The film thickness should have been ½ λ which means that the thickness of the film is actually 0.000208 mm, which is still incredibly thin.

2) a) $\tan\theta \approx \sin\theta = 0.001$ cm$/15$ cm $\approx \theta$ Thus $\theta = 0.0000667$ radians $= 0.0038°$.
   b) The light travels an extra wavelength. Since the light travels down through the air gap and then back up, the extra thickness must be half of a wavelength = 294.5 nm.
   c) The figure below shows the air gap between the two plates with an exaggerated angle. On the left is one dark band, where the thickness of the air is y. On the right is the adjacent dark band where the thickness is $y + \lambda/2$. As you can see, $\tan\theta = (\lambda/2)/x$. Solving for x gives $x = 294.5\text{nm}/\tan(0.0038°) = 4400000$ nm $= 4.4$ mm.



3) Ch.24 Q29 Lots of ways.
   1) Look at some glare coming off the floor through the glasses and rotate the glasses. If the brightness of the glare changes then they are polarized.
   2) Take two pairs and look at a light through both of them. Rotate one and if the brightness changes they are polarized.
   3) Look at a calculator or computer screen while wearing the glasses. Rotate your head and if the display gets hard at certain angles the glasses are polarized. We didn't talk about this in class but it is discussed in your textbook.
   4) Look at the part of the sky 90º from the sun and rotate your head. If the sky gets darker and lighter then the glasses are polarized. This is also discussed in your textbook.

4) Polarized sunglasses block light that is polarized in the horizontal direction, because most glare is naturally polarized in the horizontal direction. The light getting through

the upper pair of sunglasses is polarized in the vertical direction (with respect to the picture). The sunglasses on the left only allow light through that is polarized in the horizontal direction (with respect to the picture), so no light gets through.

5) λ_{green} = 550 nm. E = hf = hc/λ = 3.6 × 10^{-19} J. From our earlier studies of an electron gun we know that qV = ½ mv^2 = KE. Thus KE = 1.6 × 10^{-19} C × 150 J/C = 2.4 × 10^{-17} J. The Kinetic energy of the electron is 67 times the energy of the photon, so there is more than enough energy to create a 550 nm photon when the electron collides with a helium atom.

6) $E_{x\text{-}ray}$ = hf = hc/λ = 2.0 × 10^{-15} J. This is 5500 times more energy than a green photon. This explains why x-rays can go through skin and muscle while green light cannot. It also explains why x-rays can cause genetic damage while green light cannot. X-rays can penetrate deeply enough that they can get to the DNA located in germ cells, and then disrupt the bonding in the DNA, resulting in a mutation.

7) 1 mW = 0.001 J/s. The energy of a 633 nm photon is hc/λ = 3.14 × 10^{-19} J. Thus the number of photons emitted in 1 second is (0.001J)/(3.14 × 10^{-19} J) = 3.2 × 10^{15} . That is quite a few photons.

8) a) 5 km = 5000 m. Intensity = power/area. Assuming the candle light spreads out evenly in all directions we have I = 0.003 W/[4π$(5000)^2$] = 9.55 × 10^{-12} W/m^2.

b) The area of the pupil is A = πr^2 = π $(0.005\text{m})^2$ = 0.000079 m^2.

c) Power = Intensity × area = 9.55 × 10^{-12} W/m^2 x 0.000079 m^2 = 7.5 × 10^{-16} W. Thus, 7.5 × 10^{-16} J enter the eye every second.

d) The energy of a 590 nm photon is 3.37 × 10^{-19} J, so the number entering per second is 7.5 × 10^{-16} J/3.37 × 10^{-19} J = 2200 photons. If the eye is really well dark adapted it can do a little better than this. It is estimated that about 500 photons per second is enough to register a response.

9) Ch. 27 P21 The maximum kinetic energy will occur with violet light at 400 nm. The energy of these photons is 4.97 × 10^{-19} J. The work function is 2.48 eV = 2.48 × (1.6 × 10^{-19} J/eV) = 3.97 × 10^{-19} J. Thus the maximum KE is 4.97 - 3.97 = 1.0 × 10^{-19} J.

10) Ch.27P24

a) Since the cut-off wavelength is 350 nm, the work function is the energy of a 350 nm photon = 5.7×10^{-19} J. The energy of a 280 nm photon is 7.1×10^{-19} J. Thus the maximum kinetic energy of an electron is $7.1 - 5.7 = 1.4 \times 10^{-19}$ J.

b) 360 nm is a longer wavelength than the cut-off, so no electrons are ejected.

11) a) 656 nm. You saw this in lab this week. It is the red line of hydrogen.

b) 397 nm. This is just beyond the visible so we did not see this line in lab. It is in the UV.

c) 365 nm. This is also in the UV. Notice that this is not very different from the n =7 to n = 2 photon. At higher n the energy levels become very close together, even though the radii get enormous (see next problem).

d) 122 nm. This is pretty far into the UV. We do not see any lines for transitions to the n = 1 level.

e) 823 nm. This is in the infrared. We do not see any transitions to the n = 3 level either. It is rather a nice coincidence of nature that the four visible lines we see in the hydrogen spectrum all involve transitions to the n = 2 level. It could easily have worked out that the spectrum of hydrogen was much more complicated, for example involving transitions to the n = 1 and n = 3 levels in addition to transitions to the n = 2 level. In that case, it would have made it much harder for Balmer and Bohr to come up with a nice explanation for the spectrum. An an example, think of the helium spectrum or worse, the neon spectrum. A formula like Balmer's does not work for explaining either of these spectra.

12) From your textbook or lecture notes we have $r_n = n^2h^2/(4\pi^2mke^2)$. For n = 1 the radius is 5.3×10^{-11} m. For n = 2 it is 4 times as big, namely 2.12×10^{-10} m. For n = 3 the radius is 9 times as big as the n = 1 orbit. It is interesting that the orbit increases as n^2 not as n as is commonly thought by many students making planetary models of atoms.