# EE 119 Homework 1

Professor: Jeff Bokor TA: Xi Luo
Due Tuesday, Feb 2nd 2010
(Please submit your answers in EE119 homework box located in 240 Cory Hall)

1. (a) Pat is a happy dolphin who grew up in Sea World. Today Uncle Lee, Pat's trainer, is going to teach him a new trick to jump through a ring from underneath the water. Pat is below the water surface by a distance d2 and away from Uncle Lee horizontally by a distance L, and he sees Uncle Lee holding the ring above the water surface by a distance d1. Where should Pat aim? (Express your answer in terms of d1, d2, and L. Ignore the effect of gravity and assume Pat goes along a straight line. Small angle approximation can be used.)

   (b) After taking your advice and successfully demonstrating the new trick, Pat won applause from all the kids watching the show. After the show, he takes a break at the bottom of the pool. Looking straight up toward the smooth surface, Pat receives a cone of rays and sees a circle of light filled with the images of sky and birds and whatever else is up there. Can you explain what is happening and compute the cone-angle?
   (Take refractive index air=1, water=4/3)

2. (a) A student is studying a material with a work function of 2.4eV, and someone accidentally turns on a nearby 610nm, 1mW laser that hits the material. The student has a detector nearby that is very sensitive in detecting electrons. Does the detector detect any ejected electrons? What if the laser power was doubled to 2mW?

   (b) What is the maximum wavelength required of the laser, so that the detector can detect ejected electrons from the material?

   (c) Using the laser from (b) with an intensity of $1\text{nW/m}^2$ and a spot diameter of 1mm, how many electrons are ejected per second from the material?

3. (a) Superman has been told that he is faster than a speeding bullet, but he has never checked whether this is actually true. He does an experiment and finds he is indeed faster than a speeding bullet! In fact, his friend Spiderman found that it only took Superman 2 seconds to fly around the earth (40,000km). Superman decides to try and impress Miss Lois Lane by showing her that he is faster than light! He is looking for a material to build a 1km tube in which he can pipe light into, and race it for 1km. What is the index of refraction he needs the tube to be made out of if he is to tie the 1km race?

(b) Superman is happy with his win at the race and decides to make a cup of tea. He uses his heat vision to send infrared radiation ($\lambda$ = 1000nm) at angle of 75° from the normal towards a cup of water to heat it up. The index of refraction of water is 1.33. Assuming his eyes are unpolarized (equal s-polarization and p-polarization), what is the ratio of the energies of p-polarized to s-polarized light transmitted into the water? If his eyes were only p-polarized, what is the optical angle to heat the water at, such that the infrared radiation is fully transmitted?

4. Rainbow was described as "one of the most spectacular light shows observed on earth" by Authur Donald Ahrens in his text *Meteorology Today*. Rosie still remembers the excitement she had on one evening in July 2009, when she was just driving off the Freeway I80 and turning onto University Blvd towards the East. She saw **two** rainbows (**primary and secondary rainbows**) elegantly hanging over Berkeley hills and hence could not help text- messaging all her friends to come out and see. Obviously this was not her first time to see a rainbow, but **two!?** - definitely something worth cheering for, as the secondary rainbow is one-tenth the intensity of that of the primary bow and is not normally seen. Now Rosie needs you to help her appreciate this natural phenomenon better in answering the following questions.

(a) Rainbow is sunlight spread out into its spectrum of colors and diverted to the eye of the observer by water droplets. In formation of the **primary rainbow**, the light path involves refraction and a single reflection inside the water droplet (in the shape of a sphere), as shown in Fig. 1(on the next page). Please indicate in Fig. 1, the color (violet or red) of each refracted ray coming towards the observer in the corresponding brackets (1-4). And from there, what is the sequence of the color spectrum observed in the primary rainbow? The top color red or violet?

(b) The primary rainbow is observed to form between about 40° and 42° from the anti-solar point (Fig. 2). If one depicts, in Fig.3, the path of a monochromatic light ray through a single spherical raindrop which contributes to the primary rainbow, the deviation angle $\delta$ of the emergent ray from its original direction is then 42°(for red). This ray drawn here is called the ***Descarte* or *rainbow ray***; and it has the **smallest angle of deviation** of all the rays incident upon the raindrop. Much of the sunlight is focused along this ray path of the minimum deviation, which gives rise to the arch of the rainbow.

Please show that for red light ($n_{water}$ = 1.33), the minimum deviation angle $\delta$ is indeed 42°.

(Hint: first obtain the expression of $\delta$ in terms of incident angle $\theta$; solve for the value of $\theta$ that makes $d\delta/d\theta = 0$; note that $\frac{d(\arcsin(x))}{dx} = \frac{1}{\sqrt{1-x^2}}$)

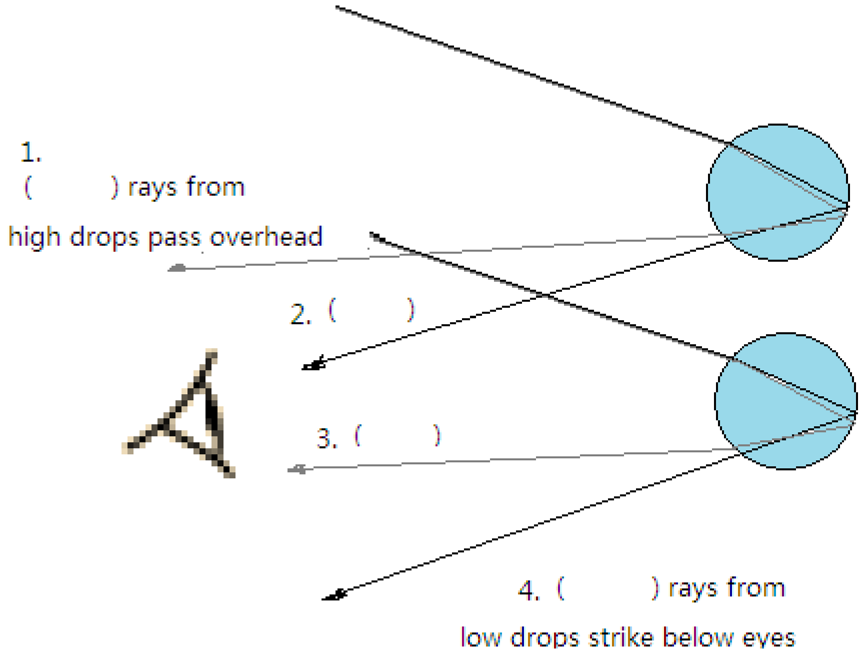


Fig. 1

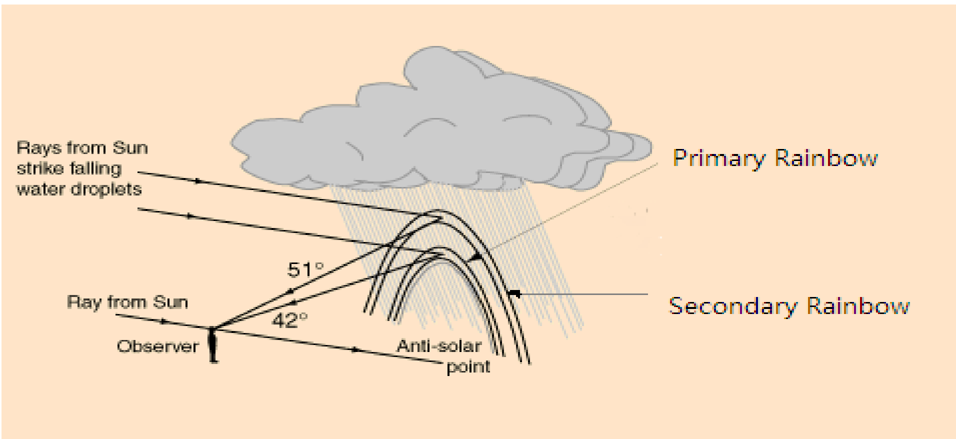


Fig. 2

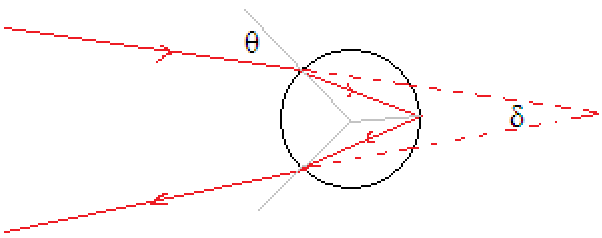


Fig. 3

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* some pictures and infos for this problem are referenced from online resource which will be specified in the solution part.

(c) Using value of the incident angle θ solved from (b), show that the violet ray from the primary rainbow makes an angle of approximately 40° (<42°) from the anti-solar point, given that the refractive index of water for violet is 1.34.

(d) **The secondary rainbow involves two reflections inside the rain droplets.** Please draw a sketch similar to Fig. 1 for the case of secondary rainbow, in which the ray paths of red and violet light refracted and reflected into/inside both a high and a low water drops are shown, and please indicate in the sketch, the rays that miss the eye of the observer and those that can be seen. From there, please tell Rosie the sequence of the color spectrum observed in the secondary rainbow (the top color red or violet?)

5. **Hecht 8.1** Describe completely the state of polarization of each of the following waves:

(a) $\vec{E} = \hat{i} E_0 \cos(kz - \omega t) - \hat{j} E_0 \cos(kz - \omega t)$

(b) $\vec{E} = \hat{i} E_0 \sin 2\pi(z/\lambda - \upsilon t) - \hat{j} E_0 \sin 2\pi(z/\lambda - \upsilon t)$

(c) $\vec{E} = \hat{i} E_0 \sin(\omega t - kz) + \hat{j} E_0 \sin(\omega t - kz - \pi/4)$

(d) $\vec{E} = \hat{i} E_0 \cos(\omega t - kz) + \hat{j} E_0 \cos(\omega t - kz + \pi/2)$.