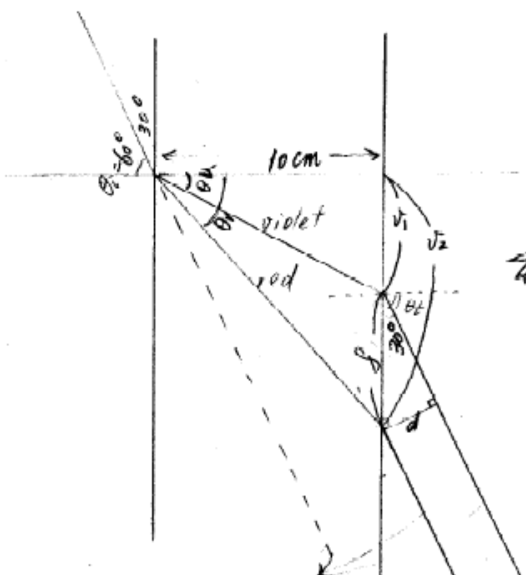
PHY 431 Homework Set #1

Due 2014-09-11 at the start of class

1. ***Wavelength, Energy, Photon Flux, Intensity*** (40%)
Example 1-1 and Example 1-2 in Pedrotti[3] (Due 2014-09-04)

See textbook.

2. Refraction/Color (10%) An exceeding narrow beam of white light is incident at 60.0° on a sheet of glass 10.0 cm thick in air. The index of refraction for red light is 1.505 and for violet light it's 1.545. Determine the approximate diameter of the emerging beam.



- parallel to each other
- $\theta_t = \theta_i = 60°$
refer to problem (3)

Snell's law

$\sin\theta_r = \dfrac{\sin\theta_i}{1.505}$ red

$\sin\theta_v = \dfrac{\sin\theta_i}{1.545}$ violet

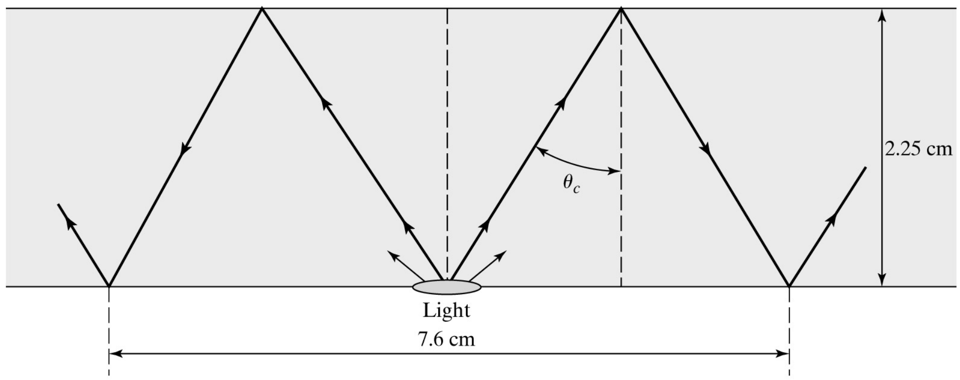
$\delta = v_2 - v_1 = 10\tan\theta_v - 10\tan\theta_r$

$d = \delta \cdot \sin 30° = \dfrac{\delta}{2}$

$= \dfrac{10\,cm}{2} \times (\tan\theta_v - \tan\theta_r))$

$= 0.134$ cm

3. **Total internal reflection** (20%). [Problem 2-7 in Pedrotti[3]] A small source of light at the bottom face of a rectangular glass slab 2.25 cm thick is viewed from above. Rays of light totally internally reflected at the top surface outline a circle of 7.60 cm in diameter on the bottom surface. Determine the refractive index of the glass.

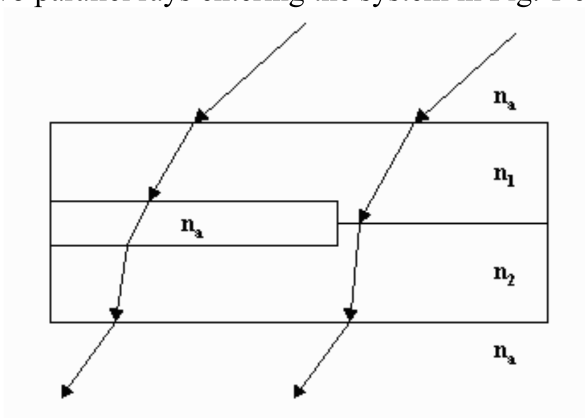


Refer to Figure 2-33 in the text. By geometry, $\tan\theta_c = \dfrac{7.60/4}{2.25}$ so $\theta_c = 40.18°$

Snell's law: $n \sin\theta_c = (1)\sin 90° \Rightarrow n = \dfrac{1}{\sin 40.18°} = 1.55$

4. Ray tracing (30%)

(a) Show that the two parallel rays entering the system in Fig. 1 emerge parallel.



(b) [Problem 2-8 in Pedrotti[3]] Show that the lateral displacement d of a ray of light passing through a rectangular glass slab of thickness t is given by:

$$d = \frac{t\sin(\theta_1 - \theta_2)}{\cos\theta_2}$$

where θ_1 and θ_2 are the angles of incidence and refraction respectively. Find the displacement when t = 3 cm, n = 1.50, and θ_1 = 60 deg. By definition, d is normal to the incident and outgoing rays.

(a) Apply Snell's law sequentially

The left and right beams will be parallel if θt (Left) = θt (Right) in the final medium (a).

Since all interfaces are parallel, the transmitted angle into a medium equals the incident angle at the next medium.

Apply Snell's law at each interface

Left : $n_a \sin\theta_i = n_1 \sin\theta_{t1} = n_a \sin\theta_{ta} = n_2 \sin\theta_{t2} = n_a \sin\theta_{ta}$

Compare 1st and last term

$\Rightarrow \sin\theta_i = \sin\theta_{ta} \Rightarrow \theta_{ta} = \theta_i$

Right : $n_a \sin\theta_i = n_1 \sin\theta_{t1}' = n_2 \sin\theta_{t2}' = n_a \sin\theta_{ta}'$

Compare 1st and last term

$\sin\theta_i = \sin\theta_{ta}' \Rightarrow \theta_{ta}' = \theta_i$

For each beam $\theta_{ta} = \theta_i$. The emerging beams parallel.

(b)

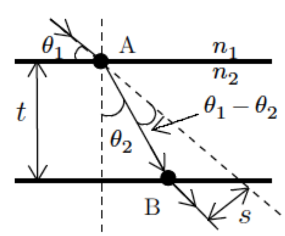
Referring to the figure one can see that,

$s = \mathrm{AB}\sin(\theta_1 - \theta_2)$ and $\mathrm{AB} = \dfrac{t}{\cos\theta_2}$. Therefore,

$s = \dfrac{t\sin(\theta_1-\theta_2)}{\cos\theta_2}$. For $t = 3\,\mathrm{cm}$, $n_2 = 1.50$, $\theta_1 = 50°$,

Snell's law gives, $\sin\theta_2 = \dfrac{n_1}{n_2}\sin\theta_1 = \dfrac{1}{1.5}\sin 50°$.

Then, $\theta_2 = 30.71°$ and $s = \dfrac{3\sin(50° - 30.71°)}{\cos 30.71°} = 1.153\,\mathrm{cm}$.



Extra Credits:

Microwave oven I (0.25 pts). The glass window isn't important to the microwave oven's operation, but the metal grid associated with that window certainly is. The grid forms the sixth side of the metal box that traps the microwaves so they cook food effectively. What is the approximate dimension of the holes of the grid? Explain why the metal grid is critical in preventing microwaves from escaping outside to cook your brain.

Microwave oven II (0.25 pts). Ceramic plates, glass cups, and plastic containers are water-free and usually remain cool while the food is being cooked in a microwave oven. Even ice has trouble absorbing microwave power because of its crystal structure restrict the water molecules' motion. Explain why only foods or objects containing water or other polar molecules cook well in a microwave oven. (Hint: water or polar molecules are electrically polarized and will tend to rotate into alignment with the field.)

1. Watch a video by Bill Hammack (energyguy) https://www.youtube.com/watch?v=kp33ZprO0Ck
2. Read Ch. 13.2 Microwave ovens in "How everything works", by Louis Bloomfield.