

## Homework 1

Here are a few problems to help us gain some quantitative intuition. The problems are intended to be simple to solve, but to provide insight into the physical quantities.

### 1 Photon Momentum

A photon has a momentum  $h/\lambda$  where  $\lambda$  is the wavelength, and  $h$  is Planck's constant. When a photon impinges on a particle, it produces an impulse,  $\int f dt$ , where  $f$  is the force. Thus, for  $N_t$  photons per unit time, the average force is  $f = \frac{h}{\lambda} N_t$ . How much optical power is needed to levitate a glass bead  $50\mu\text{m}$  in diameter (density 2.5grams/cc)?

### 2 Fields

Consider a 1-Watt laser beam focused to an area with radius of 5 microns. What are the magnitudes of the fields,  $E$  in Volts per meter,  $B$ , in Teslas, and  $H$ , in Amperes/meter?

### 3 Raman Spectroscopy

Carbon Tetrachloride has three Raman peaks, at 288, 314, and 459 inverse centimeters.

If it is excited at a wavelength of 532nm, what are the three emission wavelengths?

These frequency changes are called Stokes shifts. There may also be Anti-Stokes shifts where the same transitions occur but in opposite directions. Then the emitted photons have more energy than the excitation ones.

Why are these weaker than the Stokes lines?

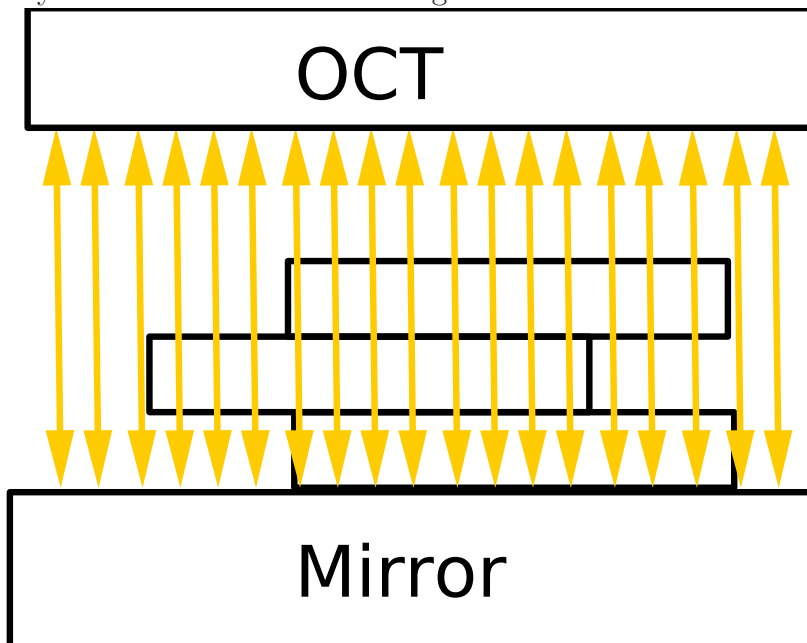
What is the source of the extra energy?

## 4 Laser Radar

What is the distance to a target if light makes the round trip in  $1\mu\text{s}$ ? If it does so in  $1\text{ms}$ ?

## 5 OCT

Optical Coherence Tomography (OCT) can be used to measure the transit time of light like a laser radar, but with much smaller resolution. We will discuss in Chapter 10 how it works. For now, it shows a brightness in a column on the display proportional to the amount of light reflected back at each time interval, and scales the axis assuming the material is vacuum. It moves horizontally to the next position and does this again, making an image. In the figure below, the OCT device is at the top, and a mirror is below it (top is the reflective surface), with three glass cover-slips sitting on it, each having an index of refraction of  $n = 1.5$ . Plot the resulting image. Don't worry for now about how much light is reflected at each interface.



## 6 Energy

Someone suggested using a laser ice scraper to clear a car windshield of ice. Let's take a very quick look at feasibility. Suppose we use a laser with 100 Watts (very high power), and suppose the ice absorbs all the power. How long will it take to melt a layer of ice 2mm thick?

Let's neglect any reflection and cooling effects so that all the energy goes into melting. Let's also assume that we need to melt all the ice. The former is overly optimistic and the latter is overly pessimistic so perhaps our number will be close to reality.

## 7 Snow Globe

Let's consider a snow globe, which is a transparent plastic container full of water with a 3-d scene inside. To make it simple suppose the container is a sphere of radius 3cm. Pick one axis through the sphere as the axis, and let  $s$  vary continuously along the axis inside the sphere. Plot  $s'$ , the image location,  $m$ , the magnification, and  $m_z$  as functions of  $s$ .

## 8 Oil-Immersion Lens

Consider an oil-immersion microscope lens where the object is immersed in oil of index of refraction 1.5. The back focal length is  $f' = 2\text{mm}$ , and the magnification is  $m = 100$ . What is the front focal length,  $f$ ? Where are the object and image,  $s$  and  $s'$ . If  $s$  is changed by  $5\mu\text{m}$ , what is the change in  $s'$ ?

## 9 Thin Lenses

Remember that for short distances between surfaces, refracting powers add. Consider a plano-convex lens with focal length,  $f = 10\text{cm}$  in air. If  $r_1 \rightarrow \infty$ , what is  $r_2$ . If we put two of these lenses close together, what is the focal length of the combination?

## 10 Dogleg

Homework problem 2.1 in the text.