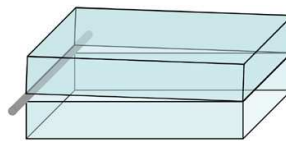
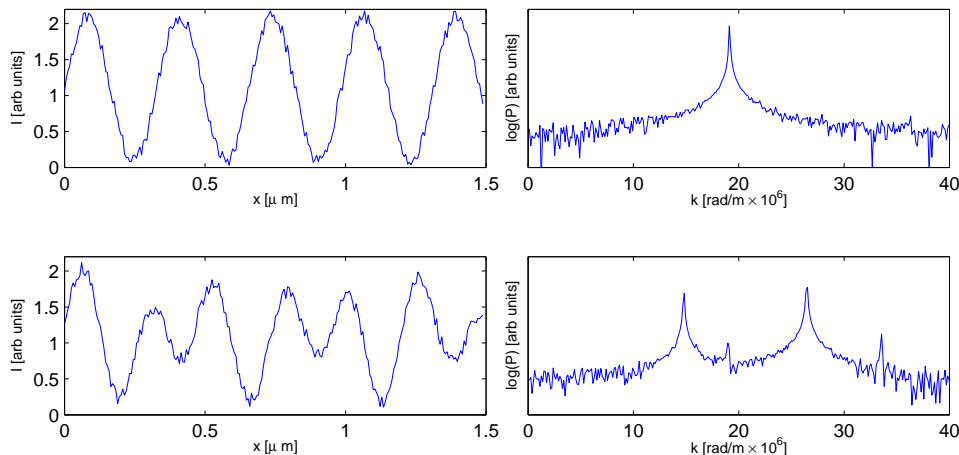


- (7 pts) Remember blowing soap bubbles as a kid? Imagine that you dip your “bubble wand” into a bubble solution. The solution is mostly water, so the index of refraction for the solution is about equal to 1.333. When you pull the wand out it has a thin soap film stretched over it. Due to gravity, the film will be thinner at the top than at the bottom. (a) If the thickness of the soap film at the top is 76 nm, what is the wavelength of visible light that will be most strongly reflected at the top of the film? (Give the “vacuum wavelength” - the wavelength that this light would have in vacuum) (b) What color will the light reflected at the top of the bubble be? (Use figure 35.20 to answer this). (c) At the bottom the film is 128 nm thick. What wavelength of visible light is most strongly reflected at the bottom? (d) What color will the light reflected from the bottom be? Note that visible light has wavelengths from 400 to 700 nm.
- (8 pts) Imagine two rectangular pieces of extremely flat glass which are 10 cm wide and 15 cm long. One piece is set on a table, and the other piece is placed directly on top of the first piece. A thin wire is then placed between the two pieces at the very edge of the glass plates, as shown in the figure below. When a red light with a wavelength of 633 nm illuminates the plates from above you see 300 bright reflection fringes. What is the diameter of the wire?



- (7 pts) I shoot a laser beam into a Michelson interferometer. I put a very tiny photodiode on the output of the interferometer to monitor the intensity of the light coming out at a very particular point. I then move one of the mirrors and monitor the light intensity on the photodiode. When I plot the light intensity as a function of the mirror position I get the upper left graph below. This looks an awful lot like a sine wave (plus some noise): $I(x) = I_0 \sin(kx + \phi) + noise$. If I take the Fourier transform of the data (the log of the amplitude squared is shown in the upper right plot below) I find that $k = 19.1 \times 10^6 \text{ rad/m}$. (a) What is the wavelength of my laser? (b) Now I use a telescope to direct light from a star into my interferometer. As I scan the mirror position I no longer get an intensity on the photodiode which is sinusoidal in the position of the mirror, but I get the lower-left plot below. But I know that $I(x)$ can be written as a sum of sine waves. When I take a Fourier transform of $I(x)$ and plot the Fourier transform (the lower-right plot below — again this is the log of the amplitude squared) I find that the signal is mostly made up of two sine waves which have $k = 14.8 \times 10^6 \text{ rad/m}$ and $k = 26.5 \times 10^6 \text{ rad/m}$. What are the two wavelengths of light that this star is strongly emitting?



4. (8 pts) People who make lenses often put thin-film coatings on them to minimize reflections on the surfaces of the lens. Many of the lenses in my lab are made of BK7, a type of glass with an index of refraction of 1.52 at 589 nm, with a thin film of MgF_2 ($n = 1.38$ at 589 nm) over each surface. (a) What is the thickness of the thinnest possible film of MgF_2 which will produce a reflection minimum for light with a wavelength of 589 nm (in vacuum)? (b) Will a coating of this thickness produce a reflection maximum for any visible wavelengths? If so, which ones? Visible light has wavelengths from 400-700 nm.

Extra problems I recommend you work (not to be turned in)

- A HeNe laser beam at 633 nm is sent through a Michelson interferometer. One mirror in the interferometer is heated up. Due to thermal expansion, the surface of the mirror moves ever so slightly toward the beam splitter. As the mirror is heated, the center of the fringe pattern on the output of the interferometer goes from bright to dark 47 times. How far did the surface of the mirror move?
- One cool spy gadget is known as a “laser microphone.” The basic idea is this — you make a Michelson interferometer and use the window in a house across the street as one of the mirrors. As people talk inside the house, the sound waves cause the window to vibrate, resulting in shifting interferometer fringes. This way you can use the interferometer to eavesdrop. To make this work well, however, you need a laser with a long coherence length. (a) Why? It turns out that you can get around this problem by sending both beams to the window such that they reflect off of different parts of the window — giving you a signal which represents the relative displacement of the two parts of the window. (b) Can you think of another way to make this work using a laser with a short coherence length?
- If a drop of oil is allowed to spread over the surface of a pool of water, the oil film will tend to be thinnest near the edge of the film. If the edges are very thin, as you look from the center of the oil film and then move your gaze toward the edge you will see bands of different colors, then a dark band, then a bright white band at the very edge. From the fact that the last band, where the oil is thinnest, is a reflection maximum, figure out whether the index of refraction of oil is greater than or less than the index of refraction of water. (Assume that the index of refraction is greater than that of air.) You can try this if you want. Fill your sink with water, wait for the water to be calm, and then carefully put a tiny drop of cooking oil on the top of the water and wait for it to spread. It works best if the water is hot (it will cause the oil film to spread faster).
- All of the problems we have done with thin films assumes that the light strikes the surface at normal incidence. Now let's see what happens when it doesn't. Consider a soap film suspended in air with a thickness of 100 nm. The index of refraction for the soap is 1.333. (a) If you look at normal incidence at the film and see the light from a flashlight right in front of your face reflected off of the film, what will be the wavelength of visible light which is most strongly reflected? (b) Now imagine that you shine the flashlight at an angle of 45° from the normal and look at the reflected light. What wavelength of visible light will be most strongly reflected?