College Physics II
Lab 3: Microwave Optics

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We will be dealing with microwaves, a kind of electromagnetic radiation with wavelengths around a few centimeters. We have a source of microwaves, and a detector that shows the presence of microwaves by the deflection of a needle. The sensitivity of the detector is adjustable. We can use this set-up to explore wave interference.

In this lab you will set up , and take and interpret data for, three different phenomena, each involving interference in some way.

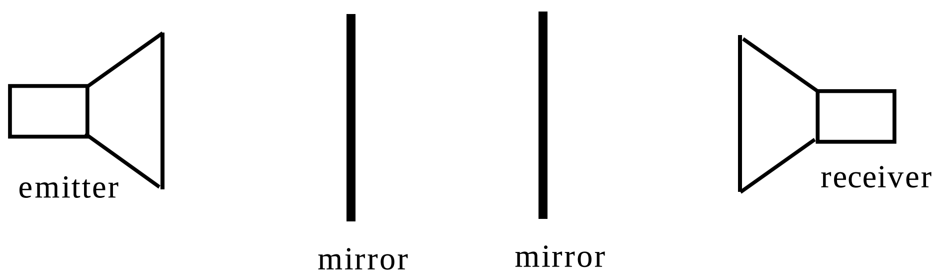
Activity 1: Resonant cavity

Recall how, in a previous lab, we found the wavelength of a sound wave by finding the difference in length between neighboring resonances in a column of air. Now you will do a similar thing with electromagnetic waves.

You will set up two microwave equivalents of half-silvered mirrors facing each other. (A half-silvered mirror reflects part of the light incident on it but lets part of it through.) These microwave mirrors are metallic grids. You will then shine some microwaves into that cavity. Quite a bit will be reflected away, but some will get into the cavity.

On the other side of the cavity some of the energy from the cavity will leak out and be detected by the detector: If twice the distance between the mirrors is equal to an integer number of wavelengths, then the waves formed as the microwaves bounce back and forth between the mirrors will reinforce each other, and you will have a *standing wave*. The energy density in the cavity is especially high when there is a standing wave, and thus the intensity of microwave energy leaked out to the receiver will be particularly high.

We can make an analogy between this experiment and the experiment in Lab 1: emitter $\Leftrightarrow$ tuning fork, receiver $\Leftrightarrow$ your ear, resonant cavity $\Leftrightarrow$ glass tube, microwaves $\Leftrightarrow$ sound waves. If you adjust the mirrors so that there is a standing wave, and then you move one mirror until you get another standing wave, then the distance the mirror moved must be half of a wavelength.



Using the set-up shown above, carefully measure the distance d you need to move one mirror for there to be 11 successive maxima (that is, 11 successive positions in which there is a strong standing wave). The distance between the first and eleventh maxima must correspond to 5 wavelengths.

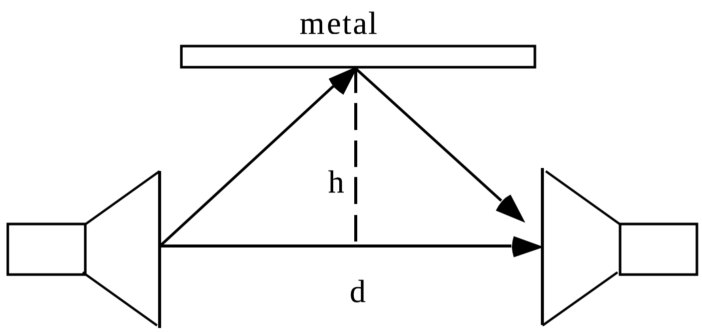
To hand in for Activity 1

- Distances corresponding to the 11 maxima.
- d, the distance between maximum 1 and maximum 11.
- Expression used to find wavelength λ from d.
- Result for wavelength λ of the microwaves.

Activity 2: A model for radio signals

The ionosphere acts as a mirror for AM radio waves, and the ionosphere moves up and down. Sometimes a radio signal that bounces off the ionosphere interferes destructively with the original signal, and the result is that the radio station you are listening to fades out. We can make a model of this process by letting the emitter be the radio transmitter, letting the receiver be your radio, and letting the ionosphere be a metallic oven liner. Study the diagram.

Now, destructive interference happens when there is a half-integer wavelength difference between the waves from two different sources. Here, you have one source, but the reflection gives you another path to the detector, so you can have interference. There is one small complication. A reflected wave undergoes a *phase shift* of half a wavelength. Therefore, in *this circumstance*, with reflection involved, the signal at the receiver will be noticeably weak, due to destructive interference, if the path traveled by the reflected beam differs from the straight path by an integer number of wavelengths.



Let m be the number of wavelengths by which the two paths differ at destructive interference ($m = 1, 2, 3, \ldots$). Put your knowledge of geometry to use by *calculating* the height h at which you get destructive interference. That is, find h as a function of d, m and λ for destructive interference.

Now set d to exactly 60 cm, and predict values of h at which you should get a particularly weak signal at the receiver for $m = 1$, 2, and 3. Test your predictions.

To hand in for Activity 2

- Calculation of $h_{\text{destructive}}$,
- Measured value of d,
- Predicted values of $h_{\text{destructive}}$ for $m = 1$, 2 and 3,
- Experimentally determined values of $h_{\text{destructive}}$ for $m = 1$, 2 and 3.

Activity 3: Double-slit interference

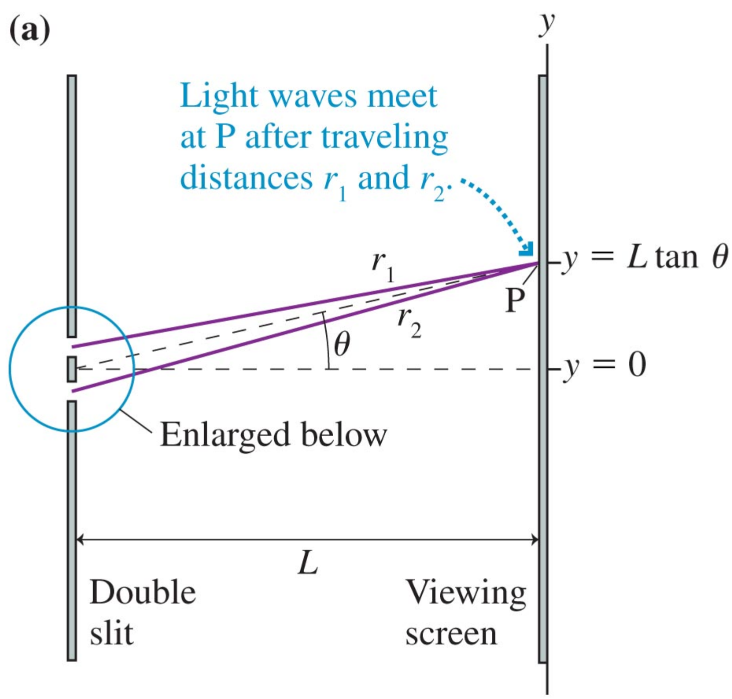
You will design and perform your own version of the double-slit experiment, using the microwave source and detector and the double slit screen in your equipment box.

The bright fringes (constructive interference) will take place when

$$\sin\theta_m = m\,\frac{\lambda}{d} \qquad m = 0, \pm 1, \pm 2, \ldots$$

You will be able to measure the central maximum ($m = 0$), and the first maxima ($m = \pm 1$), but probably no more.

For your experiment, reproduce something like the the classic textbook picture below:



In your case, however, you will find it easier to measure the angle θ directly, with your apparatus, rather than dealing with L and y values. Record the intensity I at various values of θ. Make a graph of how I depends on θ. (Don't worry about units for I, because we only care about relative intensities, not absolute values.)

Note that d in this activity has nothing to do with distances involving the source or detector. Instead, d is the distance between the *centers* of the two slits.

Remember that you have already measured λ before. Therefore check if your experimental location of the $m = \pm 1$ intensity peaks fit your theoretical predictions.

To hand in for Activity 3

- Predictions of your θ values for $m = \pm 1$,
- Graph of I vs θ,
- Experimental values for θ at $m = \pm 1$ (the peak locations in your graph).
- A comparison (percent difference) of your experimental and theoretical results.