

# Tutorial Instructor's Guide

## Two-source interference

### Equipment:

- An enlargement of the double-concentric-circles diagram on the first page of the tutorial. One per group per hour, plus plenty of extras (these are “used up” by each group).
- Colored pencils, pens, or crayons, at least four colors per table.
- Concentric-circles transparency and matching concentric-circles diagram on paper. One per table (these are not “used up”).

This tutorial helps students understand two-source interference in the context of water waves. The analogy to light is made in the subsequent tutorial.

Each tutorial should begin with a fresh double-concentric-circles diagram on each table, along with the colored pencils or crayons. Withhold the transparency and matching concentric-circles diagram until later.

*Note:* Students **and TAs** tend to use sloppy language in this tutorial: for example, they'll refer to “the wavelength of the sources” rather than the wavelength of the waves from the sources. Sometimes this is just because speaking correctly is cumbersome and doesn't really matter in context; other times it is an important clue to incorrect thinking. TAs (and their facilitators...) have to judge which of these is going on when.

I. In this part students briefly practice interpreting the concentric-circles representation of waves in a ripple tank.

The answers we expect are: One-quarter period later, the solid and dashed lines would all have expanded outward into middle of the adjacent blank region. (This is easier to sketch than to say.) One period later, the diagram would look exactly like it does already.

II. In this part students interpret the diagram of waves from a pair of point sources, and do a whole lot of work understanding the interference pattern resulting from their overlap.

A. 1. Everyone gets this right (the frequencies are the same) but not everyone is careful about the basis for this answer. This question is a little tricky in that the frequencies are not represented directly in the diagram. The *wavelengths* of the waves from the two sources are shown to be the same; and because the waves are in the same medium, the speeds of the two waves are the same, so they must have been generated at the same rate in order to wind up the same distance apart. How much of this to hold students responsible for depends on where the lectures are; if they haven't covered the idea that the wave speed is determined by the medium, TAs might let the details of this pass.

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2. Students often don't know what "in phase" means and can benefit from a finger-tapping demonstration: " 'In phase' means like this: [tap fingertips on table together]. 'Out of phase' means this: [tap fingers on table alternately]." With this assistance (which also appears in text in the tutorial), people can usually answer that the two sources shown are in phase, since they are both generating a crest at the moment shown.
  3. Students sometimes do nutty things like measure the source separation with a ruler, measure the wavelength with a ruler, and divide. This is because they don't yet know that it's useful to express source separation in terms of wavelength, and they think the instruction to do so is just an exercise. It's fine to tell them to just count rather than measuring.
- B. Students do fine with this part; the superposition is pretty intuitive. They are totally untroubled by the approximation of equal amplitudes at all distances.
- C, D, & E. Students can usually do these on their own, but often need some time and discussion to create a complete and correct diagram. TAs are often tempted to hurry students into getting it all right off the bat; tell them to hold back at least a little, because students usually can find a lot of the pattern on their own. However, by the time students get to the bottom of page 2, their communal diagram should indicate a complete and correct pattern, with different colors for the different kinds of points, symmetries exploited, etc. **This is an informal checkpoint. TAs can make it formal, if they want to do so with their own students.** If students have incomplete diagrams, a good TA strategy is to point to a particular spot on the diagram and say, for example, "What color should go right here, if any?" Another strategy is to say, for example, "Are those all the crests, or are there more?"

Many students will mark dots for crests, dots for troughs, and dots for equilibrium, marking those last ones only where a crest meets a trough. It can help to ask them what goes *between* the dots for equilibrium; encourage them to think about how the waves are adding at that point, maybe even draw a side view. This can help them recognize that while the crests and troughs come in dots, the equilibrium points are really lines.

Good extension questions **for TAs**, and for students who are doing well:  
*What's going on in the center region of the diagram? What goes through the middle – the line of crests/troughs, or the line of equilibrium?* (Symmetry allows for either.) [Use whatever term the students are using at this time, or talk in terms of the colors – "is the exact center of the diagram blue, or green and red?"]  
*What's going on in between the dots that mean crests and the dots that mean troughs? Should those be colored the same as you're using for equilibrium, or are those different from those places in some way?*

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- F. Students often have trouble following the grammar of these questions, but I don't know of a way to make them clearer. Part of the problem is probably that they don't yet know why the quantity "the difference in the distances to the two sources" would be of any interest.

The answer this is looking for is that if the point of interest were the same distance from the two sources, it would be seeing the same part of the wave from each – two crests, or two troughs, for example – and therefore would not be a place of cancellation. The distances from the point of interest to the two sources must be different by half a wavelength (or three-halves, or five-halves, etc) in order for the two waves to cancel.

- G. Students can do this on their own. They sometimes don't label all the points with the appropriate  $\Delta D$ ; TAs can just tell them to do so. The idea of part 3 is just for the students to articulate that the "nodes" (places where the waves always cancel) form whole lines, not just series of dots.

- H. Students can do this on their own although they sometimes need a little handholding about the phase difference. Sometimes students don't know whether to use phase differences greater than  $180^\circ$ , or greater than  $360^\circ$ ; it's fine for TAs to tell them that the usual thing is to keep phase differences at  $180^\circ$  or less but they should use the convention their professor/textbook prefers.

Some students, once they decide to cap the phase difference at  $180^\circ$ , also cap the  $\Delta D$  at  $\lambda/2$ . This is understandable but it's not conventional, and TAs should just tell students not to do that.

By the time they get to the bottom of this page, students should have a complete diagram in which every line is properly labeled with its  $\Delta\phi$  and  $\Delta D$ . **This is another informal checkpoint** that the TAs are free to formalize with their students if they wish.

- I. Students usually find it easy to state that although the ripples themselves would travel outward, the nodal lines and lines of maximum constructive interference would not move or change.
- J. In this question, students look at ripple tank photos and relate them to the concentric-circles diagram they've been working with so far. They should be able to identify that one of the photos has the same pattern of nodal lines etc. that their concentric-circles diagram has.

Part 3 is more challenging: TAs might ask questions like *What exactly are the differences between the two diagrams?* (One has more nodal lines, and also has the crests closer together. It's hard to tell if the source separation is different or not.)

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*What could make the crests closer together? (Higher-frequency tapping; or a slower medium.)*

*Would that same change also create more nodal lines, or would you have to do something else in order for that to happen?*

*What other way is there to get more nodal lines? (Greater source separation)*

*Would that account for the other differences in the photos, or would you have to make some other change as well?*

- K. Students often explore somewhat independently for this part. They (**and TAs**) may have trouble seeing the nodal lines appear; facilitators should help. You can see them pop out if you sort of fuzz your vision or cross your eyes.

Checkpoint: This checkpoint can cover any and all of the above issues. Many of the extension questions suggested above are also appropriate for the end of the tutorial.

Students who have time might investigate questions such as

*What would the pattern look like if one set of circles had half the wavelength of the other set of circles? How could that happen physically?*

*Can you figure out a formula relating the number of nodal lines to the source separation?*