

# Tutorial Instructor's Guide

## Finding mechanism: Pulses

### Equipment:

- A long skinny spring which can be extended over ten feet or so and used as a medium for sending single transverse pulses. The one we use is probably ten feet long unstretched, about an inch in diameter, and is tightly coiled. One for the whole room.

I. This part elicits the common student intuition that the speed of a pulse traveling along a spring is influenced by the conditions under which the pulse was created – specifically, that flicking the spring faster creates a faster pulse.

A. and B. Once all students have made the predictions (only a minute or two is needed), a TA should do the demos for the whole class.

### Demo for part A:

A TA holds one end of the spring down on the floor and a student (or the second TA) holds the other end, also on the floor, as far away from the first TA as can be reasonably accomplished given the spring and the room layout. The TA shows the students a sample side-to-side flick and asks them to observe the pulse only as it travels away from him – to ignore the reflections that bounce off the other end. The TA might also point out that they can kind of hear how fast the pulse is going (as it scrapes on the floor), in addition to being able to see it (it goes by pretty fast). The TA asks students what their prediction is about a faster side-to-side flick; many predict that the faster flick will create a faster pulse. The TA demonstrates, alternating a fast flick with a slow flick, trying to maintain the same amplitude for each just in case. Students may have trouble telling whether one is faster. The TA can try to do a flick that is twice as fast, and ask whether the resulting pulse travels twice as fast. It clearly doesn't.

### Demo for part B:

The TA asks students what their prediction is about a faster forward-and-back flick. Some students **and TAs** think that a longitudinal flick *would* create a faster pulse even though a side-to-side flick doesn't. These people think that the reason the faster flick doesn't move the pulse faster is that the flick is perpendicular to the motion. The TA demonstrates, using the same techniques as above.

TAs can then send students back to their tables.

C. This is something we hear commonly from students. It's not terrible, but it is a little sad, imagining students trying to "rope off" parts of their intuition as inherently wrong and to be avoided. The next few exercises in the tutorial try to illustrate that an intuition that appears at first to be incorrect can often be reconciled with correct physics. For now, TAs can just inquire curiously about students' answers.

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- D. Usually students answer this question easily, but if they have trouble, or are curious, they can try it with the demo spring.
  - E. Here's where students reconcile their perhaps-incorrect intuition in part C.
- II. In this part students think about some properties of the spring that *do* affect the pulse speed.
- A. There are at least two ways to increase the tension. One is to stretch the spring more, either by having the two holders move farther apart, or having them stay the same places but “reel in” the ends of the spring so that something less than the whole spring is between them. Another is to replace the spring with a stiffer spring (one that's harder to stretch), and stretch it the same amount as the original.

Students may as yet have no reason to know how the tension affects the pulse speed, and that's all right for now (they'll do more in the next section).

- B. Again, students may not know how this will affect the pulse spring, and it's no big deal if they don't.

Checkpoint: The point of this checkpoint is mostly for the TAs to just hear what the students are thinking so far. What did they think would happen with the faster flick? Where are they on the “intuition refinement diagram”? How do they think the tension, or painting the spring with heavy paint, influences the pulse speed? Wrong or muddled answers are fine for now, but student should explain how they are thinking about it. TAs should, however, help the students think of both ways of increasing the spring tension – it'll help with a later question.

- C. The point of this question is to have students interpret the quantities in the equation (tension and linear mass density) in terms of the physical changes they've thought about in the last couple of questions. We take this for granted, but for them it's often nontrivial.

III. In this part students think about how a pulse travels along a spring.

Students tend not to neglect gravity. Having them think of the diagram as a top-view diagram sometimes helps.

- A. The intended answers to these questions are pretty straightforward – mass 2 moves roughly “up” (toward the top of the page), because the spring from mass 1 pulls it that way.

An interesting supplemental question to ask at this point is whether any of the masses ever pass below the equilibrium position. Many students **and TAs** have trouble with this one at first, partly because they are not being mechanistic about

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wave propagation – not thinking about the forces that each mass and spring exerts on the objects touching it.

- B. The intended answers to these questions are even easier: each mass moves up or down because it's tugged upward or downward by the spring/mass next to it. The resulting series of displacements is the pulse traveling rightward. Analogies to “doing the wave” in a sports stadium are welcome.

IV. In this part students think about why the pulse speed depends on the tension and mass density.

- A. Part 2 can be tricky but it's good for students to have to think about it. Lowering the response time would create a faster-traveling wave.

*Checkpoint:* TAs should check in with the students about their thinking regarding the response time and the wave speed. This time, they should make sure the students have it right before letting them move on. TAs might also want to check students' interpretation of the equation at the bottom of page 1, which was just after the last checkpoint.

These questions involve doing some for-real mechanistic thinking about the physics, mentally applying Newton's laws to the springs as well as understanding the effect of making changes to the springs.

- B. The right answer is that making the spring harder to stretch would make each mass pull harder on the mass next to it (i.e. increasing  $k$  increases  $F$ , for the same  $\Delta x$ ). Pulling harder on the mass decreases the response time, which increases the pulse speed. This is consistent with what they did on page 2, where they said that increasing the tension would increase the pulse speed.

Students may not recognize the relationship between spring stiffness and tension. Asking them to think about the force that the spring exerts for a given amount of stretch should help.

- C. The right answer is that making the masses heavier increases the response time, which makes the pulse go slower. Students are usually comfortable with this, and able to relate it to the linear mass density in the equation on page 2.

V. In this part students think about why the pulse speed does not depend on the speed of the flicking.

This is honestly a question I haven't watched students answer before, so I don't know how well they do with it! I'll be curious to find out.