Tutorial Name ____________________________

Finding mechanism: Pulses

I. One traveling pulse: The effect of flicking the spring faster

When you throw a ball, increasing the speed of your hand increases the speed of the ball. Does the same apply to a wave pulse?

A. A TA and a student stretch out a slinky along the floor. The TA creates a wave pulse by flicking his or her hand side-to-side along the floor as shown in this top-view drawing. The TA then creates a second pulse, moving her hand side-to-side the same amount as before, but more quickly.

TOP VIEW

1. *Prediction:* Does that second pulse take more time, less time, or the same time to reach the other end, as compared to the first pulse? Explain your reasoning.

2. *Experiment:* What do you observe? Which pulse is faster, or are they about the same?

B. The experiment is repeated, but this time the TA flicks her hand forward and back rather than side-to-side – that is, she quickly pushes the spring toward the person at the other end, then pulls it back.

1. *Prediction:* For this kind of flicking, when the TA flicks her hand faster, does the wave pulse take more time, less time, or the same time to reach other end, as compared to the pulse produced by the less quick flick? Explain.

2. *Experiment:* What do you observe? Which pulse is faster, or are they about the same?

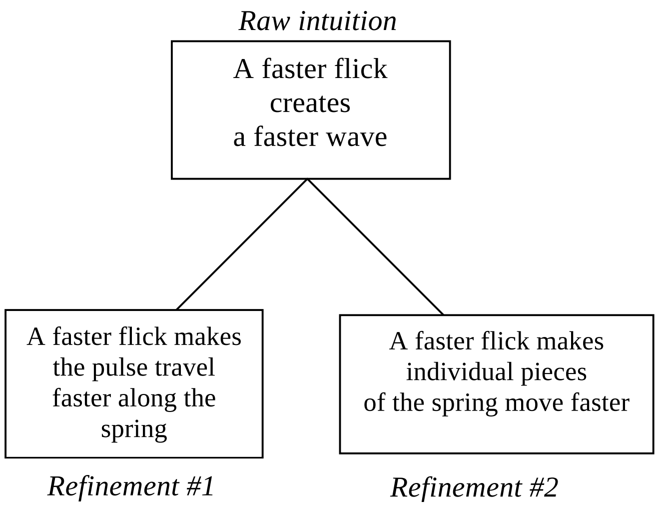
C. A student, discussing what to make of the experiment she just observed, says:

> I think the point here is to show us where our common sense is wrong so that we know not to rely on that part of our common sense.

In what ways do you agree and/or disagree? Explain.

D. Let's see if we can *refine* the common-sense idea that a faster flick produces a faster wave. One of the coils on the spring is marked with tape. That coil moves side-to-side or forward and backward as a wave pulse passes by. In which case do you think the marked coil will move faster: when the flicker moves her hand slower, or when the flicker moves her hand faster? If you want, go ahead and run the experiment.

E. Look at the *intuition refinement diagram* shown here. Many students share the raw intuition that a faster flick creates a faster wave. The bottom row shows two possible ways to *refine* that raw intuition into something more precise.



1. Which refinement corresponds to your prediction in question A.1 and B.1?

2. Which refinement corresponds to your observations?

II. So, what *does* affect the speed of a wave pulse?

Later, we'll return to the issue of why the flick speed doesn't control the pulse speed. But first, let's find what *does* control the pulse speed.

A. Suppose you want to increase the *tension* in the spring.

1. How could you do it?

2. How do you think increasing the tension affects the pulse speed, if at all? Explain your reasoning.

B. Now imagine thickly painting the spring with heavy paint, thereby increasing its mass per length. Do you expect this paint job to increase or decrease the pulse speed, other things being equal, or do you expect the pulse speed would be unchanged? Explain your reasoning.

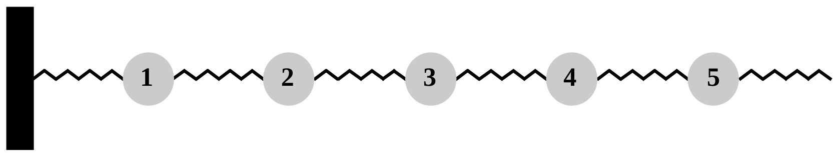
☆ *Consult an instructor before you proceed.*

C. A careful derivation shows that the pulse speed is $v = \sqrt{\dfrac{Tension}{linear\ mass\ density}}$, where linear mass density is mass per length. Does this equation agree with your answers to parts A and B?

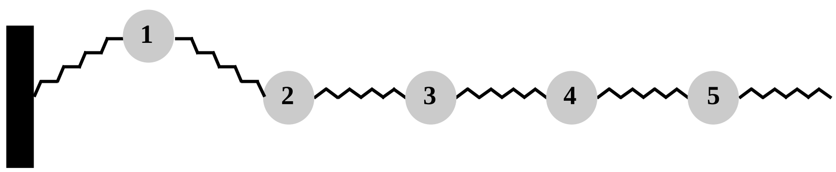
III. The mechanism of wave pulse propagation

Now you'll figure out *how* a wave pulse propagates along a spring.

Let's model a real spring as a series of small masses connected by massless springs. This model separates the *springiness* of a real spring from its *heaviness*, so that we can think about them one at a time. Both ends of the spring are attached to a wall, but the right wall is off the page. The spring is stretched, which means the little massless springs in the model are all stretched. **Neglect gravity** for now (call this a top view, if you like).



To "flick" the spring, a person quickly pushes mass 1 up and then lets go. This figure shows the position of mass 1 when the person stops pushing. It doesn't show how mass 2 "reacts" to mass 1's displacement, because that's what we want you to think about.



A. At the moment pictured here, mass 2 starts (or has started) to move.

   1. Why?

   2. In approximately what direction does mass 2 move?

B. Let's think about what happens to the other masses.

   1. After mass 2 starts to move, what happens to mass 3? In what direction does it move, and why?

   2. After mass 3 starts to move, what happens to mass 4?

   3. Explain in your own words *why* a wave pulse travels rightward along the spring.

IV. Using that mechanism to figure out deeper explanations

Using the mechanism of wave pulse propagation you just spelled out, you can (i) deepen your understanding of why the pulse speed depends on tension and on linear mass density, *and* (ii) explain why a faster flick doesn't produce a faster pulse.

A. To think about the speed of that wave pulse, let's define the *response time* as the time it takes mass 3 to reach its peak (highest point) *after* mass 2 has reached its peak. In other words, it's the time that passes between when mass 2 reaches it peak and when mass 3 reaches its peak.

   1. Is the response time as just defined greater than, less than, or equal to the time that passes between when mass 3 reaches its peak and when mass 4 reaches its peak? Explain.

   2. Based on your answers above, explain how thinking about the response time lets us figure out what controls the pulse speed.

      Specifically, would lowering the response time make the wave pulse travel faster or slower (or would it make no difference)? Explain.

☆ *Consult an instructor before you proceed.*

B. Now let's think about what controls the response time. First, imagine the effect of changing the massless springs.

   1. Suppose each of the massless springs in the model were suddenly made stiffer (harder to stretch). Would the increased stiffness increase or decrease the response time? Why?

   2. So, would stiffening the massless springs increase or decrease the pulse speed?

   3. How does the answer you just gave compare with your reasoning in section II, part A above (back on page 2)? Explain.

C. Now let's think about how the masses in our model affect the response time and pulse speed. Suppose each of the masses were made bigger, but the massless springs were left unchanged.

1. Would this increase or decrease the response time, or would the response time be unaffected? Explain.

2. So, would increasing those masses make the pulse travel faster or slower?

3. Does the answer you just gave mesh with your reasoning in section II (page 2) above?

V. The punch line: Why a faster flick doesn't produce a faster pulse

Now we're finally ready to address the central mystery of this tutorial: Why doesn't a faster flick cause the pulse to travel faster?

A. Suppose mass 1 is flicked to its peak faster than before.

1. Explain why the faster flick does *not* quicken the response time, i.e., does not reduce the time that passes between when mass 2 reaches its peak and when mass 3 reaches its peak.

2. Answering that last question, a student wrote,

   The response time is controlled entirely by how each mass reacts to the one before it. And that reaction is controlled by the tensions and masses; the flicker of mass 1 can't do anything to make mass 3 respond faster to mass 2's motion.

   In what ways do you agree and/or disagree with that reasoning?

B. Time to summarize. In your own words, explain why a faster flick doesn't create a faster pulse.

